Mechanical engineering

stolen from the catagory

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Mechanical engineering

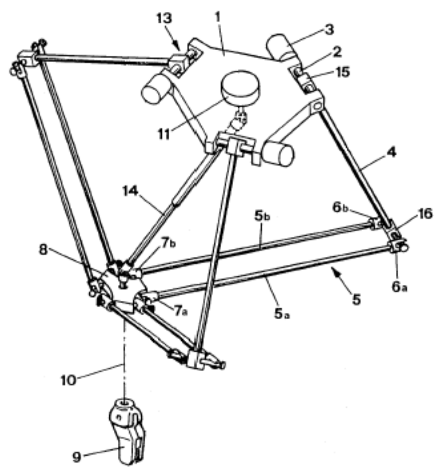
Mechanical Engineering is an engineering discipline that was developed from the application of principles from physics and materials science. Mechanical engineering involves the analysis, design, manufacturing, and maintenance of various systems. It is one of the oldest and broadest engineering disciplines.


Mechanical engineers design and build engines and power plants...


...structures and vehicles of all sizes...

The field requires a solid understanding of core concepts including mechanics, kinematics, thermodynamics, fluid mechanics, materials science, and energy. Mechanical engineers use the core principles as well as other knowledge in the field to design and analyze manufacturing plants, industrial equipment and machinery, heating and cooling systems, motor vehicles, aircraft, watercraft, robotics, medical devices and more.

Development


...and mechanisms, machines, and robots.

Applications of mechanical engineering are found in the records of many ancient and medieval societies throughout the globe. In ancient Greece, the works of Archimedes (287 BC–212 BC) and Heron of Alexandria (c. 10–70 AD) deeply influenced mechanics in the Western tradition. In China, Zhang Heng (78–139 AD) improved a water clock and invented a seismometer, and Ma Jun (200–265 AD) invented a chariot with differential gears. The medieval Chinese horologist and engineer Su Song (1020–1101 AD) incorporated an escapement mechanism into his astronomical clock tower two centuries before any escapement could be found in clocks of medieval Europe, as well as the world's first known endless power-transmitting chain drive.[1]

During the years from 7th to 15th century, the era called the Islamic golden age, there have been remarkable contributions from Muslims in the field of mechanical technology, Al Jaziri, who was one of them wrote his famous "Book of Knowledge of Ingenious Mechanical

Devices" in 1206 presented many mechanical designs. He is also considered to be the inventor of such mechanical devices which now form the very basic of mechanisms, such as crank and cam shafts.

During the early 19th century in England and Scotland, the development of machine tools led mechanical engineering to develop as a separate field within engineering, providing manufacturing machines and the engines to power them.[2] The first British professional society of mechanical engineers was formed in 1847, thirty years after civil engineers formed the first such professional society.[3] In the United States, the American Society of Mechanical Engineers (ASME) was formed in 1880, becoming the third such professional engineering society, after the American Society of Civil Engineers (1852) and the American Institute of Mining Engineers (1871).[4] The first schools in the United States to offer an engineering education were the United States Military Academy in 1817, an institution now known as Norwich University in 1819, and Rensselaer Polytechnic Institute in 1825. Education in mechanical engineering has historically been based on a strong foundation in mathematics and science.[5]

The field of mechanical engineering is considered among the broadest of engineering disciplines. The work of mechanical engineering ranges from the depths of the ocean to outer space.

Education

Degrees in mechanical engineering are offered at universities worldwide. In Bangladesh, China, India, Nepal and North America, mechanical engineering programs typically take four to five years and result in a Bachelor of Science (B.Sc), Bachelor of Technology (B.Tech), Bachelor of Engineering (B.Eng), or Bachelor of Applied Science (B.A.Sc) degree, in or with emphasis in mechanical engineering. In Spain, Portugal and most of South America, where neither BSc nor BTech programs have been adopted, the formal name for the degree is "Mechanical Engineer", and the course work is based on five or six years of training.

In the U.S., most undergraduate mechanical engineering programs are accredited by the Accreditation Board for Engineering and Technology (ABET) to ensure similar course requirements and standards among universities. The ABET web site lists 276 accredited mechanical engineering programs as of June 19, 2006.[6] Mechanical engineering programs in Canada are accredited by the Canadian Engineering Accreditation Board (CEAB),[7] and most other countries offering engineering degrees have similar accreditation societies.

Some mechanical engineers go on to pursue a postgraduate degree such as a Master of Engineering, Master of Science, Master of Engineering Management (MEng.Mgt or MEM), a Doctor of Philosophy in engineering (EngD, PhD) or an engineer's degree. The master's and engineer's degrees may or may not include research. The Doctor of Philosophy includes a significant research component and is often viewed as the entry point to academia.[8]

Coursework

Standards set by each country's accreditation society are intended to provide for uniformity in fundamental subject material, promote competence among graduating engineers, and to maintain confidence in the engineering profession as a whole. Engineering programs in the U.S., for instance, are required by ABET to show that their students can "work professionally in both thermal and mechanical systems areas."[9] The specific courses required to graduate, however, may differ from program to program. Universities will often combine multiple subjects into a single class or split a subject into multiple classes, depending on the faculty available and the university's major area(s) of research. Fundamental subjects of mechanical engineering usually include:

- Statics and dynamics
- Strength of materials and solid mechanics
- Instrumentation and measurement
- Thermodynamics, → heat transfer, energy conversion, and HVAC
- Fluid mechanics and fluid dynamics
- Mechanism design (including kinematics and dynamics)
- Manufacturing technology or processes
- → Hydraulics and pneumatics
- Engineering design
- Mechatronics and control theory
- Material Engineering
- Drafting, CAD (including solid modeling), and CAM[10] [11]

Mechanical engineers are also expected to understand and be able to apply basic concepts from chemistry, chemical engineering, electrical engineering, civil engineering, and physics. Most mechanical engineering programs include several semesters of calculus, as well as advanced mathematical concepts which may include differential equations and partial differential equations, linear and modern algebra, and differential geometry, among others.

In addition to the core mechanical engineering curriculum, many mechanical engineering programs offer more specialized programs and classes, such as robotics, transport and logistics, cryogenics, fuel technology, automotive engineering, biomechanics, vibration, optics and others, if a separate department does not exist for these subjects.[12]

Most mechanical engineering programs also require varying amounts of research or community projects to gain practical problem-solving experience. Mechanical engineering students usually hold one or more internships while studying, though this is not typically mandated by the university.

License

Engineers may seek license by a state, provincial, or national government. The purpose of this process is to ensure that engineers possess the necessary technical knowledge, real-world experience, and knowledge of the local legal system to practice engineering at a professional level. Once certified, the engineer is given the title of *Professional Engineer* (in the United States, Canada, Japan, South Korea, Bangladesh and South Africa), *Chartered Engineer* (in the UK, Ireland, India and Zimbabwe), *Chartered Professional Engineer* (in Australia and New Zealand) or *European Engineer* (much of the European Union). Not all mechanical engineers choose to become licensed; those that do can be distinguished as

Chartered or Professional Engineers by the post-nominal title P.E., P. Eng., or C.Eng., as in: John Doe, P.Eng.

In the U.S., to become a licensed Professional Engineer, an engineer must pass the comprehensive FE (Fundamentals of Engineering) exam, work a given number of years as an *Engineering Intern (EI)* or *Engineer-in-Training (EIT)*, and finally pass the "Principles and Practice" or PE (Practicing Engineer or Professional Engineer) exams.

In the United States, the requirements and steps of this process are set forth by the National Council of Examiners for Engineering and Surveying (NCEES), a national non-profit representing all states. In the UK, current graduates require a BEng plus an appropriate masters degree or an integrated MEng degree plus a minimum of 4 years post graduate on the job competency development in order to become chartered through the → Institution of Mechanical Engineers.

In most modern countries, certain engineering tasks, such as the design of bridges, electric power plants, and chemical plants, must be approved by a Professional Engineer or a Chartered Engineer. "Only a licensed engineer, for instance, may prepare, sign, seal and submit engineering plans and drawings to a public authority for approval, or to seal engineering work for public and private clients."[13] This requirement can be written into state and provincial legislation, such as Quebec's Engineer Act.[14] In other countries, such as Australia, no such legislation exists; however, practically all certifying bodies maintain a code of ethics independent of legislation that they expect all members to abide by or risk expulsion.[15]

Salaries and workforce statistics

The total number of engineers employed in the U.S. in 2004 was roughly 1.4 million. Of these, 226,000 were mechanical engineers (15.6%), second only to civil engineers in size at 237,000 (16.4%). The total number of mechanical engineering jobs in 2004 was projected to grow 9% to 17%, with average starting salaries being $50,236 with a bachelor's degree, $59,880 with a master's degree, and $68,299 with a doctorate degree. This places mechanical engineering at 8th of 14 among engineering bachelors degrees, 4th of 11 among masters degrees, and 6th of 7 among doctorate degrees in average annual salary.[16] The median annual income of mechanical engineers in the U.S. workforce is roughly $63,000. This number is highest when working for the government ($72,500), and lowest when doing general purpose machinery manufacturing in the private sector ($55,850).[17]

Canadian engineers make an average of $29.83 per hour with 4% unemployed. The average for all occupations is $18.07 per hour with 7% unemployed. Twelve percent of these engineers are self-employed, and since 1997 the proportion of female engineers has risen to 6%.[18]

Mechanical Engineering is the second highest paid profession in the UK behind medicine. A Mechanical Engineer with a CEng Status earns an average of £55,000 a year. It is also recognized that Mechanical Engineers are happy workers according to national statistics in 2006.

Modern tools

Many mechanical engineering companies, especially those in industrialized nations, have begun to incorporate computer-aided engineering (CAE) programs into their existing design and analysis processes, including 2D and 3D solid modeling computer-aided design (CAD). This method has many benefits, including easier and more exhaustive visualization of products, the ability to create virtual assemblies of parts, and the ease of use in designing mating interfaces and tolerances.

Other CAE programs commonly used by mechanical engineers include product lifecycle management (PLM) tools and analysis tools used to perform complex simulations. Analysis tools may be used to predict product response to expected loads, including fatigue life and manufacturability. These tools include finite element analysis (FEA), computational fluid dynamics (CFD), and computer-aided manufacturing (CAM).

Using CAE programs, a mechanical design team can quickly and cheaply iterate the design process to develop a product that better meets cost, performance, and other constraints. No physical prototype need be created until the design nears completion, allowing hundreds or thousands of designs to be evaluated, instead of a relative few. In addition, CAE analysis programs can model complicated physical phenomena which cannot be solved by hand, such as viscoelasticity, complex contact between mating parts, or non-Newtonian flows

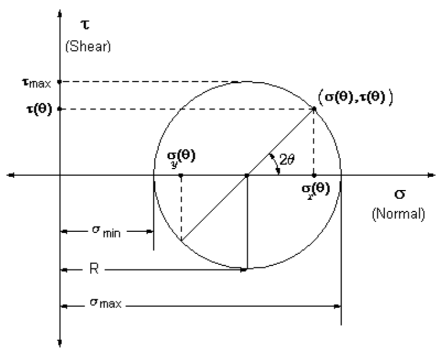
As mechanical engineering begins to merge with other disciplines, as seen in mechatronics, multidisciplinary design optimization (MDO) is being used with other CAE programs to automate and improve the iterative design process. MDO tools wrap around existing CAE processes, allowing product evaluation to continue even after the analyst goes home for the day. They also utilize sophisticated optimization algorithms to more intelligently explore possible designs, often finding better, innovative solutions to difficult multidisciplinary design problems.

Subdisciplines

The field of mechanical engineering can be thought of as a collection of many mechanical disciplines. Several of these subdisciplines which are typically taught at the undergraduate level are listed below, with a brief explanation and the most common application of each. Some of these subdisciplines are unique to mechanical engineering, while others are a combination of mechanical engineering and one or more other disciplines. Most work that a mechanical engineer does uses skills and techniques from several of these subdisciplines, as well as specialized subdisciplines. Specialized subdisciplines, as used in this article, are more likely to be the subject of graduate studies or on-the-job training than undergraduate research. Several specialized subdisciplines are discussed at the end of this section.

Mechanics

Mechanics is, in the most general sense, the study of forces and their effect upon matter. Typically, engineering mechanics is used to analyze and predict the acceleration and deformation (both elastic and plastic) of objects under known forces (also called loads) or stresses. Subdisciplines of mechanics include



Mohr's circle, a common tool to study stresses in a mechanical element

- Statics, the study of non-moving bodies under known loads
- Dynamics (or kinetics), the study of how forces affect moving bodies
- Mechanics of materials, the study of how different materials deform under various types of stress
- Fluid mechanics, the study of how fluids react to forces[19]
- Continuum mechanics, a method of applying mechanics that assumes that objects are continuous (rather than discrete)

Mechanical engineers typically use mechanics in the design or analysis phases of engineering. If the engineering project were the design of a vehicle, statics might be employed to design the frame of the vehicle, in order to evaluate where the stresses will be most intense. Dynamics might be used when designing the car's engine, to evaluate the forces in the pistons and → cams as the engine cycles. Mechanics of materials might be used to choose appropriate materials for the frame and engine. Fluid mechanics might be used to design a ventilation system for the vehicle (see HVAC), or to design the intake system for the engine.

Kinematics

Kinematics is the study of the motion of bodies (objects) and systems (groups of objects), while ignoring the forces that cause the motion. The movement of a crane and the oscillations of a piston in an engine are both simple kinematic systems. The crane is a type of open kinematic chain, while the piston is part of a closed four bar linkage.

Mechanical engineers typically use kinematics in the design and analysis of mechanisms. Kinematics can be used to find the possible range of motion for a given mechanism, or, working in reverse, can be used to design a mechanism that has a desired range of motion.

Mechatronics and robotics

Training FMS with learning robot SCORBOT-ER 4u, workbench CNC Mill and CNC Lathe

Mechatronics is an interdisciplinary branch of mechanical engineering, electrical engineering and software engineering that is concerned with integrating electrical and mechanical engineering to create hybrid systems. In this way, machines can be automated through the use of electric motors, servo-mechanisms, and other electrical systems in conjunction with special software. A common example of a mechatronics system is a CD-ROM drive. Mechanical systems open and close the drive, spin the CD and move the laser, while an optical system reads the data on the CD and converts it to bits. Integrated software controls the process and communicates the contents of the CD to the computer.

Robotics is the application of mechatronics to create robots, which are often used in industry to perform tasks that are dangerous, unpleasant, or repetitive. These robots may be of any shape and size, but all are preprogrammed and interact physically with the world. To create a robot, an engineer typically employs kinematics (to determine the robot's range of motion) and mechanics (to determine the stresses within the robot).

Robots are used extensively in industrial engineering. They allow businesses to save money on labor, perform tasks that are either too dangerous or too precise for humans to perform them economically, and to insure better quality. Many companies employ assembly lines of robots, and some factories are so robotized that they can run by themselves. Outside the factory, robots have been employed in bomb disposal, space exploration, and many other fields. Robots are also sold for various residential applications.

Structural analysis

Structural analysis is the branch of mechanical engineering (and also civil engineering) devoted to examining why and how objects fail. Structural failures occur in two general modes: static failure, and fatigue failure. *Static structural failure* occurs when, upon being loaded (having a force applied) the object being analyzed either breaks or is deformed plastically, depending on the criterion for failure. *Fatigue failure* occurs when an object fails after a number of repeated loading and unloading cycles. Fatigue failure occurs because of imperfections in the object: a microscopic crack on the surface of the object, for instance, will grow slightly with each cycle (propagation) until the crack is large enough to cause ultimate failure.

Failure is not simply defined as when a part breaks, however; it is defined as when a part does not operate as intended. Some systems, such as the perforated top sections of some plastic bags, are designed to break. If these systems do not break, failure analysis might be employed to determine the cause.

Structural analysis is often used by mechanical engineers after a failure has occurred, or when designing to prevent failure. Engineers often use online documents and books such as those published by ASM[20] to aid them in determining the type of failure and possible causes.

Structural analysis may be used in the office when designing parts, in the field to analyze failed parts, or in laboratories where parts might undergo controlled failure tests.

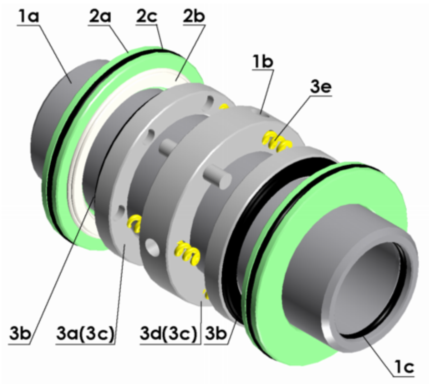
Thermodynamics and thermo-science

Thermodynamics is an applied science used in several branches of engineering, including mechanical and chemical engineering. At its simplest, thermodynamics is the study of energy, its use and transformation through a system. Typically, engineering thermodynamics is concerned with changing energy from one form to another. As an example, automotive engines convert chemical energy (enthalpy) from the fuel into heat, and then into mechanical work that eventually turns the wheels.

Thermodynamics principles are used by mechanical engineers in the fields of → heat transfer, thermofluids, and energy conversion. Mechanical engineers use thermo-science to design engines and power plants, heating, ventilation, and air-conditioning (HVAC) systems, heat exchangers, heat sinks, radiators, refrigeration, insulation, and others.

Drafting

Drafting or technical drawing is the means by which mechanical engineers create instructions for manufacturing parts. A technical drawing can be a computer model or hand-drawn schematic showing all the dimensions necessary to manufacture a part, as well as assembly notes, a list of required materials, and other pertinent information. A U.S. mechanical engineer or skilled worker who creates technical drawings may be referred to as a drafter or draftsman. Drafting has historically been a two-dimensional process, but computer-aided design (CAD) programs now allow the designer to create in three dimensions.



A CAD model of a mechanical double seal

Instructions for manufacturing a part must be fed to the necessary machinery, either manually, through programmed instructions, or through the use of a computer-aided manufacturing (CAM) or combined CAD/CAM program. Optionally, an engineer may also manually manufacture a part using the technical drawings, but this is becoming an increasing rarity, with the advent of computer numerically controlled (CNC) manufacturing. Engineers primarily manually manufacture parts in the areas of applied spray coatings, finishes, and other processes that cannot economically or practically be done by a machine.

Drafting is used in nearly every subdiscipline of mechanical engineering, and by many other branches of engineering and architecture. Three-dimensional models created using CAD software are also commonly used in finite element analysis (FEA) and computational fluid dynamics (CFD).

Frontiers of research

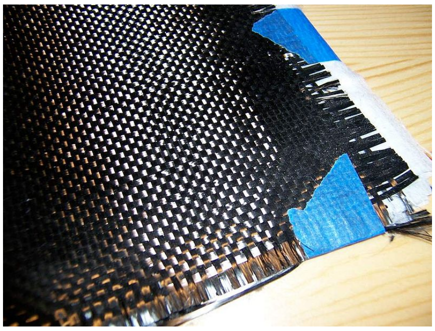
Mechanical engineers are constantly pushing the boundaries of what is physically possible in order to produce safer, cheaper, and more efficient machines and mechanical systems. Some technologies at the cutting edge of mechanical engineering are listed below (see also exploratory engineering).

Micro Electro Mechanical Systems (MEMS)

Micron-scale mechanical components such as springs, gears, fluidic and heat transfer devices are fabricated from a variety of substrate materials such as silicon, glass and polymers like SU8. Examples of MEMS components will be the accelerometers that are used as car airbag sensors, gyroscopes for precise positioning and microfluidic devices used in biomedical applications.

Composites

Composites or composite materials are a combination of materials which provide different physical characteristics than either material separately. Composite material research within mechanical engineering typically focuses on designing (and, subsequently, finding applications for) stronger or more rigid materials while attempting to reduce weight, susceptibility to corrosion, and other undesirable factors. Carbon fiber reinforced composites, for instance, have been used in such diverse applications as spacecraft and fishing rods.


Composite cloth consisting of woven carbon fiber.

Mechatronics

Mechatronics is the synergistic combination of mechanical engineering, electronic engineering, and software engineering. The purpose of this interdisciplinary engineering field is the study of automata from an engineering perspective and serves the purposes of controlling advanced hybrid systems.

Nanotechnology

At the smallest scales, mechanical engineering becomes nanotechnology and molecular engineering—one speculative goal of which is to create a molecular assembler to build molecules and materials via mechanosynthesis. For now that goal remains within exploratory engineering.

Finite Element Analysis

This field is not new, as the basis of Finite Element Analysis (FEA) or Finite Element Method (FEM) dates back to 1941. But evolution of computers has made FEM a viable option for analysis of structural problems. Many commercial codes such as ANSYS, Nastran and ABAQUS are widely used in industry for research and design of components.

Other techniques such as Finite Difference Method (FDM) and Finite Volume Method (FVM) are employed to solve problems relating heat and mass transfer, fluid flows, fluid surface interaction etc.

Related Fields

Manufacturing Engineering and Aerospace Engineering are typically grouped with Mechanical Engineering. A bachelor's degree in these areas will typically have a difference of only a few specialized classes

See also

- Building officials
- Building services engineering
- List of historic mechanical engineering landmarks
- List of mechanical engineering topics
- Related journals
- → Mechanical engineering technology
- Fields of engineering
- → Simple machine
- List of mechanical engineers
- List of inventors
- Patent

Associations

- ASHRAE (American Society of Heating, Refrigerating and Air-Conditioning Engineers)
- ASME (American Society of Mechanical Engineers)
- Pi Tau Sigma (Mechanical Engineering Honor Society)
- SAE (Society of Automotive Engineers)
- SWE (The Society of Women Engineers)
- → IMechE (Institution of Mechanical Engineers) (British)
- Chartered Institution of Building Services Engineers (CIBSE) (British)

Wikibooks

- Aeronautical Engineering
- Astronautical Engineering
- Automotive Engineering
- Elasticity
- Engineering Mechanics
- Solid Mechanics
- Engineering Acoustics
- Engineering Thermodynamics
- Heat Transfer
- Introduction to elasticity
- Microtechnology
- Nanotechnology

- Engineering Thermodynamics
- Fluid Mechanics
- Pro Engineer
- Strength of Materials

Further reading

- Burstall, Aubrey F. (1965). *A History of Mechanical Engineering*. The MIT Press. ISBN 0-262-52001-X.

External links

- Kinematic Models for Design Digital Library (KMODDL) [21] - Movies and photos of hundreds of working mechanical-systems models at Cornell University. Also includes an e-book library [22] of classic texts on mechanical design and engineering.
- Mechanical dictionary.in [23], features many definitions and descriptive information regarding many terms used in the field of mechanical engineering.

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[18] Mechanical Engineers (http://www.jobfutures.ca/noc/2132p4.shtml). jobfutures.ca, Accessed: June 30 2007.
[19] Note: fluid mechanics can be further split into fluid statics and fluid dynamics, and is itself a subdiscipline of continuum mechanics. The application of fluid mechanics in engineering is called hydraulics and pneumatics.
[20] ASM International's site containing more than 20,000 searchable documents, including articles from the *ASM Handbook* series and *Advanced Materials & Processes* (http://asmcommunity.asminternational.org/portal/site/asm/)
[21] http://kmoddl.library.cornell.edu/index.php

[22] http://kmoddl.library.cornell.edu/e-books.php
[23] http://www.mechanicaldictionary.in

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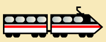
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EED article in progess

Entertainment Engineering is an engineering discipline that involves the application of traditional engineering programs such as → mechanical engineering, electrical engineering and structural engineering to create the highly technical designs that the entertainment industry has come to demand.

It involves the use of equipment from many industries to create highly specialized devices for the entertainment industry.

Education

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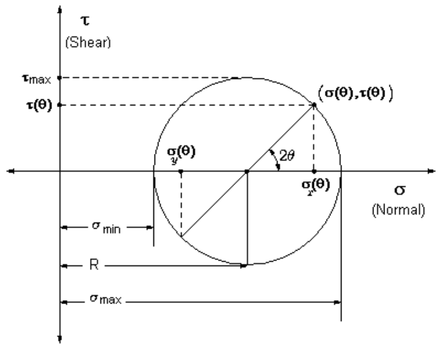

Mohr's circle, a common tool to study stresses in a mechanical element

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- Fluid mechanics, the study of how fluids react to forces[4]
- Continuum mechanics, a method of applying mechanics that assumes that objects are continuous (rather than discrete)

Mechanical engineers typically use mechanics in the design or analysis phases of engineering. If the engineering project were the design of a vehicle, statics might be employed to design the frame of the vehicle, in order to evaluate where the stresses will be most intense. Dynamics might be used when designing the car's engine, to evaluate the forces in the pistons and → cams as the engine cycles. Mechanics of materials might be used to choose appropriate materials for the frame and engine. Fluid mechanics might be used to design a ventilation system for the vehicle (see HVAC), or to design the intake system for the engine.

Kinematics

Kinematics is the study of the motion of bodies (objects) and systems (groups of objects), while ignoring the forces that cause the motion. The movement of a crane and the oscillations of a piston in an engine are both simple kinematic systems. The crane is a type of open kinematic chain, while the piston is part of a closed four bar linkage.

Mechanical engineers typically use kinematics in the design and analysis of mechanisms. Kinematics can be used to find the possible range of motion for a given mechanism, or, working in reverse, can be used to design a mechanism that has a desired range of motion.

Mechatronics and robotics

Training FMS with learning robot SCORBOT-ER 4u, workbench CNC Mill and CNC Lathe

Mechatronics is an interdisciplinary branch of mechanical engineering, electrical engineering and software engineering that is concerned with integrating electrical and mechanical engineering to create hybrid systems. In this way, machines can be automated through the use of electric motors, servo-mechanisms, and other electrical systems in conjunction with special software. A common example of a mechatronics system is a CD-ROM drive. Mechanical systems open and close the drive, spin the CD and move the laser, while an optical system reads the data on the CD and converts it to bits. Integrated software controls the process and communicates the contents of the CD to the computer.

Robotics is the application of mechatronics to create robots, which are often used in industry to perform tasks that are dangerous, unpleasant, or repetitive. These robots may be of any shape and size, but all are preprogrammed and interact physically with the world. To create a robot, an engineer typically employs kinematics (to determine the robot's range of motion) and mechanics (to determine the stresses within the robot).

Robots are used extensively in industrial engineering. They allow businesses to save money on labor, perform tasks that are either too dangerous or too precise for humans to perform them economically, and to insure better quality. Many companies employ assembly lines of robots, and some factories are so robotized that they can run by themselves. Outside the factory, robots have been employed in bomb disposal, space exploration, and many other fields. Robots are also sold for various residential applications.

Structural analysis

Structural analysis is the branch of mechanical engineering (and also civil engineering) devoted to examining why and how objects fail. Structural failures occur in two general modes: static failure, and fatigue failure. *Static structural failure* occurs when, upon being loaded (having a force applied) the object being analyzed either breaks or is deformed plastically, depending on the criterion for failure. *Fatigue failure* occurs when an object fails after a number of repeated loading and unloading cycles. Fatigue failure occurs because of imperfections in the object: a microscopic crack on the surface of the object, for instance, will grow slightly with each cycle (propagation) until the crack is large enough to cause ultimate failure.

Failure is not simply defined as when a part breaks, however; it is defined as when a part does not operate as intended. Some systems, such as the perforated top sections of some plastic bags, are designed to break. If these systems do not break, failure analysis might be employed to determine the cause.

Structural analysis is often used by mechanical engineers after a failure has occurred, or when designing to prevent failure. Engineers often use online documents and books such as those published by ASM[5] to aid them in determining the type of failure and possible causes.

Structural analysis may be used in the office when designing parts, in the field to analyze failed parts, or in laboratories where parts might undergo controlled failure tests.

Related Fields

Like Manufacturing Engineering and Aerospace Engineering, Entertainment Engineering and Design are typically grouped with Mechanical Engineering. A bachelor's degree in these areas will typically have a difference of only a few specialized classes

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[4] Note: fluid mechanics can be further split into fluid statics and fluid dynamics, and is itself a subdiscipline of continuum mechanics. The application of fluid mechanics in engineering is called hydraulics and pneumatics.
[5] ASM International's site containing more than 20,000 searchable documents, including articles from the *ASM Handbook* series and *Advanced Materials & Processes* (http://asmcommunity.asminternational.org/portal/site/asm/)

AFGROW

AFGROW is the Air Force Growth (AFGROW) crack life prediction software tool that allows users to analyze crack initiation, fatigue crack growth, fracture, and assess the life of metallic structures. AFGROW is one of the fastest, most efficient, and user-friendly crack life prediction tools available today. AFGROW is mainly used for aerospace applications; however it can be applied to any type of metallic structure that experiences fatigue cracking.

Software Architecture

The stress intensity factor library provides models for over 30 different crack geometries (including tension, bending and bearing loading for many cases). In addition, an advanced, multiple crack capability allows AFGROW to analyze two independent cracks in a plate (including hole effects), non-symmetric corner cracked. Finite Element (FE) based solutions are available for two, non-symmetric through cracks at holes as well as cracks growing toward holes. This capability allows AFGROW to handle cases with more than one crack growing from a row of fastener holes.

AFGROW implements five different material models (Forman Equation, Walker Equation, Tabular lookup, Harter-T Method and NASGRO Equation) to determine crack growth per applied cyclic loading. Other AFGROW user options include five load interaction (retardation) models (Closure, FASTRAN, Hsu, Wheeler, and Generalized Willenborg), a strain-life based fatigue crack initiation model, and the ability to perform a crack growth analysis with the effect of the bonded repair. AFGROW also includes useful tools such as: user-defined stress intensity solutions, user-defined beta modification factors (ability to estimate stress intensity factors for cases, which may not be an exact match for one of the stress intensity solutions in the AFGROW library), a residual stress analysis capability, cycle

counting, and the ability to automatically transfer output data to Microsoft Excel.

AFGROW provides COM (Component Object Model) Automation interfaces that allow users to build scripts in other Windows applications to perform repetitive tasks or control AFGROW from their applications.

AFGROW also has new plug-in crack geometry interface that allows AFGROW to interface with any structural analysis program capable of calculating stress intensity factors (K) in the Windows environment. Users may create their own stress intensity solutions by writing and compiling dynamic link libraries (DLLs) using relatively simple codes. This includes the ability to animate the crack growth as is done in all other native AFGROW solutions. This interface also makes it possible for FE analysis software to feed AFGROW three-dimensional based stress intensity information throughout the crack life prediction process, allowing for a tremendous amount of analytical flexibility.

History

AFGROW's history traces back to a crack growth life prediction program (ASDGRO) which was written in BASIC for IBM-PCs by Mr. Ed Davidson at ASD/ENSF in the early-mid 1980's. In 1985, ASDGRO was used as the basis for crack growth analysis for the Sikorsky H-53 Helicopter under contract to Warner-Robins ALC. The program was modified to utilize very large load spectra, approximate stress intensity solutions for cracks in arbitrary stress fields, and use a tabular crack growth rate relationship based on the Walker equation on a point-by-point basis (Harter T-Method). The point loaded crack solution from the Tada, Paris, and Irwin Stress Intensity Factor Handbook was originally used to determine K (for arbitrary stress fields) by integration over the crack length using the unflawed stress distribution independently for each crack dimension. After discussions with Dr. Jack Lincoln (ASD/ENSF), a new method was developed by Mr. Frank Grimsley (AFWAL/FIBEC) to determine stress intensity, which used a 2-D Gaussian integration scheme with Richardson Extrapolation which was optimized by Dr. George Sendeckyj (AFWAL/FIBEC). The resulting program was named MODGRO since it was a modified version of ASDGRO.

Early years

Many upgrades were made during the late 1980’s and early 1990’s. The primary improvement was modifying the coding language from BASIC to Turbo Pascal and C. Numerous small changes/repairs were made based on errors that were discovered. During this time period, NASA/Dryden implemented MODGRO in the analysis for the flight test program for the X-29.

Recent Times

In 1993, the Navy was interested in using MODGRO to assist in a program to assess the effect of certain (classified) environments on the damage tolerance of aircraft. Work began at that time to convert the MODGRO, Version 3.X to the C language for UNIX to provide performance and portability to several UNIX Workstations.

In 1994, the results of the Navy project were presented to the Navy sponsor and MODGRO was renamed AFGROW, Version 3.X.

Since 1996, the Windows based version of AFGROW has replaced the UNIX version since the demand for the UNIX version did not justify the cost to maintain it. There was also an

experiment to port AFGROW to the Mac OS. The Mac version had the same problem (lack of demand) as the UNIX version. An automated capability was added to AFGROW in the form of a Microsoft Component Object Model (COM) interface. The AFGROW COM interface allows users to use AFGROW as the crack growth analysis engine for any Windows based software.

Present Day

An advanced model feature has been added to allow users to select cases with two, independent cracks (with and without holes). This feature continues to be improved and expanded to cover more combinations of corner and through-the-thickness cracks. A user-defined plug-in stress intensity model capability has also been added to AFGROW. This allows users to create their own stress intensity solutions in the form of a Windows DLL (dynamic link library). Drawing tools have been included in AFGROW to allow the user-defined solution to be animated during the analysis. Interactive stress intensity solutions have been demonstrated using AFGROW to perform life predictions while sending geometric data to an external FEM code, which returns updated stress intensity solutions back to AFGROW.

Verification testing is a continuing process to improve AFGROW and expand the available database. There are plans to continue to add new technology and improvements to AFGROW. A Consortium has been started with users in Government and Industry to combine the best fracture mechanics methods available.

External links

- AFGROW Homepage [1]
- AFGROW Version Information [2]

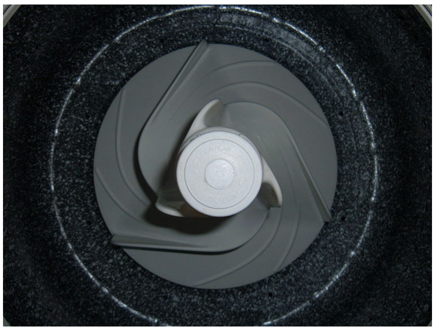
References

[1] http://www.afgrow.net
[2] http://www.afgrow.net/about/currentver.aspx

Agitator (device)

An **agitator** is a mechanism to put something into motion by shaking or stirring.

Washing machine agitator



Agitator for a laundromat washing machine.

In a top load washing machine the agitator projects from the bottom of the wash basket and creates the wash action by rotating back and forth, rolling garments from the top of the load, down to the bottom, then back up again.

There are several types of agitators with the most common are the "straight-vane" and "dual-action." The "straight-vane" is a one-part agitator with bottom and side fins that usually turns back and forth. The Dual-action is a two-part agitator that has bottom washer fins that moves back and forth and a spiral top that rotates clockwise to help guide the clothes to the bottom washer fins.

The modern agitator, which is the dual action, was first made in Kenmore washing machines in the 1980s to present. These agitators are known by Kenmore as dual-rollover and triple-rollover action agitators.

Magnetic Agitator

This is a device formed by a little metallic bar (called the agitation bar) which is normally covered by a plastic layer, and by a sheet that has underneath it a rotatory magnet or a series of electromagnets arranged in a circular form to create a magnetic rotatory field. It is very common that the sheet has an arrangement of electric resistances that can heat some chemical solutions.

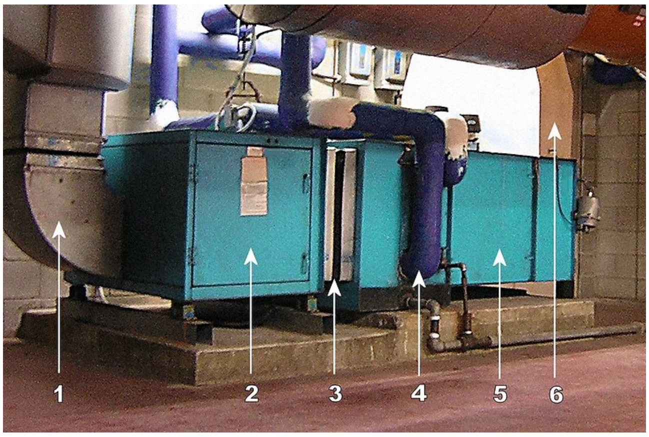
Thus, during the operation of a typical magnetic agitator, the magnetic agitator bar is moved inside a container that can be a flask or a glass with some liquid inside that can be agitated. The container must be placed on the sheet, so that the magnetic field influences the agitation bar and makes it rotate. This allows it to mix different substances at high speeds.

See also

- Impeller

Air handler

An **air handler**, or **air handling unit** (often abbreviated to **AHU**), is a device used to condition and circulate air as part of a heating, ventilating, and air-conditioning (**HVAC**) system. Usually, an air handler is a large metal box containing a blower, heating and/or cooling elements, filter racks or chambers, sound attenuators, and dampers. Air handlers usually connect to ductwork that distributes the conditioned air through the building, and returns it to the AHU. Sometimes AHUs discharge (*supply*) and admit (*return*) air directly to and from the space served, without ductwork.



An air handling unit; air flow is from the right to left in this case. Some AHU components shown are:
1 - Supply duct
2 - Fan compartment
3 - Vibration isolator ('flex joint')
4 - Heating and/or cooling coil
5 - Filter compartment
6 - Mixed (recirculated + outside) air duct

Small air handlers, for local use, are called **terminal units**, and may only include an air filter, coil, and blower; these simple terminal units are called blower coils or → fan coil units. A larger air handler that conditions 100% outside air, and no recirculated air, is known as a **makeup air unit** (**MAU**). An air handler designed for outdoor use, typically on roofs, is known as a **packaged unit** (**PU**) or **rooftop unit** (**RTU**).

Air handler components

Blower/fan

Air handlers typically employ a large → squirrel cage blower driven by an AC induction electric motor to move the air. The blower may operate at a single speed, offer a variety of pre-set speeds, or be driven by a Variable Frequency Drive so as to allow a wide range of air flow rates. Flow rate may also be controlled by inlet vanes or outlet dampers on the fan. Some residential air handlers (central 'furnaces' or 'air conditioners') use a brushless DC electric motor that has variable speed capabilities.

In large commercial air handling units, multiple blowers may be present, typically placed at the end of the AHU and the beginning of the supply ductwork (therefore also called "supply fans"). They are often augmented by fans in the return air duct ("return fans"), pushing the air into the AHU.

Heating and/or cooling elements

Depending on the location and the application, air handlers may need to provide heating, or cooling, or both to change the supply air temperature.

Smaller air handlers may contain a fuel-burning heater or a refrigeration evaporator, placed directly in the air stream. Electric resistance and heat pumps are used too. Evaporative cooling is possible in dry climates too.

Large commercial air handling units contain coils that circulate hot water or steam for heating, and chilled water for cooling. The hot water or steam is provided by a central boiler, and the chilled water is provided by a central → chiller.

Filters

Air filtration is almost always present in order to provide clean dust-free air to the building occupants. It may be via simple low-MERV pleated media, HEPA, electrostatic, or a combination of techniques. Gas-phase and ultraviolet air treatments may be employed as well.

It is typically placed first in the AHU in order to keep all its components clean.

Humidifier

Humidification is often necessary in colder climates where continuous heating will make the air drier, resulting in uncomfortable air quality and increased static electricity. Various types of humidification may be used:

- Evaporative: dry air blown over a reservoir will evaporate some of the water. The rate of evaporation can be increased by spraying the water onto baffles in the air stream.
- Vaporizer: steam or vapour from a boiler is blown directly into the air stream.
- Spray mist: water is diffused either by a nozzle or other mechanical means into fine droplets and carried by the air.

Mixing chamber

In order to maintain indoor air quality, air handlers commonly have provisions to allow the introduction of outside air into, and the exhausting of air from the building. In temperate climates, mixing the right amount of cooler outside air with warmer return air can be used to approach the desired supply air temperature. A mixing chamber is therefore used which has dampers controlling the ratio between the return, outside, and exhaust air.

A heat recovery heat exchanger, of many types, may be fitted to the air handler for energy savings and increasing capacity.

Controls

Controls are necessary to regulate every aspect of an air handler, such as: flow rate of air, supply air temperature, mixed air temperature, humidity, air quality. They may be as simple as an off/on thermostat or as complex as a building automation system using BACnet or LonWorks, for example.

Common control components include temperature sensors, humidity sensors, sail switches, actuators, motors, and controllers.

Vibration isolators

The blowers in an air handler can create substantial vibration and the large area of the duct system would transmit this noise and vibration to the occupants of the building. To avoid this, vibration isolators (flexible sections) are normally inserted into the duct immediately before and after the air handler and often also between the fan compartment and the rest of the AHU. The rubberized canvas-like material of these sections allow the air handler to vibrate without transmitting much vibration to the attached ducts.

The fan compartment can be further isolated by placing it on a spring suspension, which will mitigate the transfer of vibration through the floor.

Major manufacturers

- FlaktWoods
- Manufacturer: Citizen Industries [1]
- Zamil Air Conditioners
- Carrier Corporation (also makes Bryant and Payne brands)
- Engineered Air
- McQuay International, A member of Daikin Group
- Weger Air Solutions
- Johnson Controls (also makes York International brand)
- TANGRA - Bulgaria(one of the biggest producucer on the Balkan peninsula)
- Lennox International
- Rheem (Ruud)
- Trane
- Flow Master, SHAG Corp.

See also

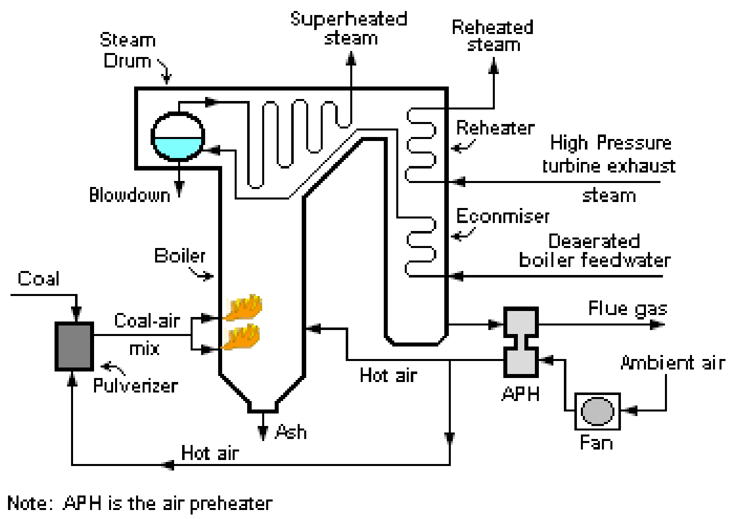
- HVAC
- Thermal comfort
- Indoor air quality

References

[1] http://www.citizenindustries.co.in

Air preheater

An **air preheater** (APH) is a general term to describe any device designed to heat air before another process (for example, combustion in a boiler) with the primary objective of increasing the thermal efficiency of the process. They may be used alone or to replace a → recuperative heat system or to replace a steam coil.



Schematic diagram of typical coal-fired power plant steam generator highlighting the air preheater (APH) location. (For simplicity, any radiant section tubing is not shown.)

In particular, this article describes the combustion air preheaters used in large boilers found in thermal power stations producing electric power from e.g. fossil fuels, biomasses or waste.[1] [2] [3] [4] [5]

The purpose of the air preheater is to recover the heat from the boiler flue gas which increases the thermal efficiency of the boiler by reducing the useful heat lost in the flue gas. As a consequence, the flue gases are also sent to the flue gas stack (or chimney) at a lower temperature, allowing simplified design of the ducting and the flue gas stack. It also allows control over the temperature of gases leaving the stack (to meet emissions regulations, for example).

Types

There are two types of air preheaters for use in steam generators in thermal power stations: One is a tubular type built into the boiler flue gas ducting, and the other is a regenerative air preheater.[1] [2] [6] These may be arranged so the gas flows horizontally or vertically across the axis of rotation.

Another type of air preheater is the *regenerator* used in iron or glass manufacture.

Tubular type

Construction features

Tubular preheaters consist of straight tube bundles which pass through the outlet ducting of the boiler and open at each end outside of the ducting. Inside the ducting, the hot furnace gases pass around the preheater tubes, transferring heat from the exhaust gas to the air inside the preheater. Ambient air is forced by a fan through ducting at one end of the preheater tubes and at other end the heated air from inside of the tubes emerges into another set of ducting, which carries it to the boiler furnace for combustion.

Problems

The tubular preheater ductings for cold and hot air require more space and structural supports than a rotating preheater design. Further, due to dust-laden abrasive flue gases, the tubes outside the ducting wear out faster on the side facing the gas current. Many advances have been made to eliminate this problem such as the use of ceramic and hardened steel.

Many new circulating fluidized bed (CFB) and bubbling fluidized bed (BFB) steam generators are currently incorporating tubular air heaters offering an advantage with regards to the moving parts of a rotary type.

Dew point corrosion

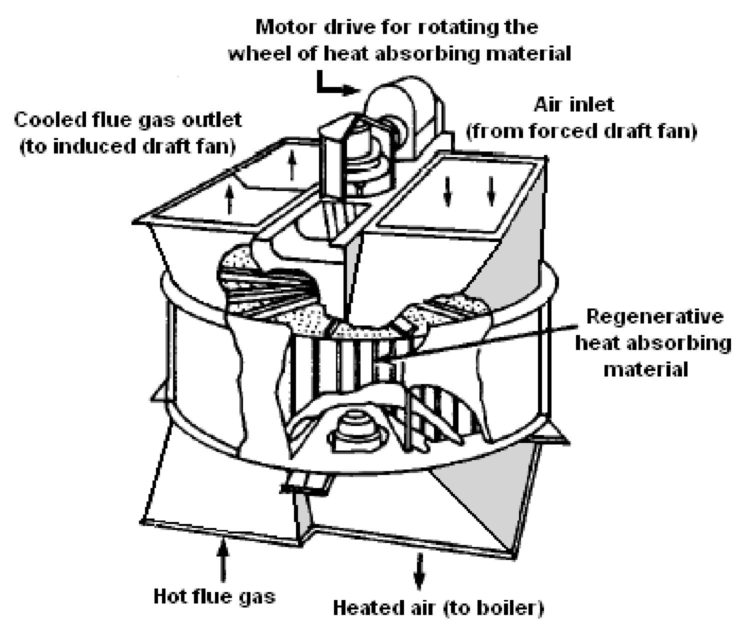
Dew point corrosion occurs for a variety of reasons.[7] [8] The type of fuel used, its sulfur content and moisture content are contributing factors. However, by far the most significant cause of dew point corrosion is the metal temperature of the tubes. If the metal temperature within the tubes drops below the acid saturation temperature, usually at between 190°F (88°C)and 230°F (110°C), but sometimes at temperatures as high as 260°F (127°C), then the risk of dew point corrosion damage becomes considerable.

Regenerative air preheaters

There are two types of regenerative air preheaters: the rotating-plate regenerative air preheaters (RAPH) and the stationary-plate regenerative air preheaters (Rothemuhle).[1] [2] [3] [9]

Rotating-plate regenerative air preheater

The rotating-plate design (RAPH)[2] consists of a central rotating-plate element installed within a casing that is divided into two (*bi-sector* type), three (*tri-sector* type) or four (*quad-sector* type) sectors containing seals around the element. The seals allow the element to rotate through all the sectors, but keep gas leakage between sectors to a minimum while providing separate gas air and flue gas paths through each sector.



Typical Rotating-plate Regenerative Air Preheater (Bi-sector type)[10]

Tri-sector types are the most common in modern power generation facilities.[11] In the tri-sector design, the largest sector (usually spanning about half the cross-section of the casing) is connected to the boiler hot gas outlet. The hot exhaust gas flows over the central element, transferring some of its heat to the element, and is then ducted away for further treatment in dust collectors

and other equipment before being expelled from the flue gas stack. The second, smaller sector, is fed with ambient air by a → fan, which passes over the heated element as it rotates into the sector, and is heated before being carried to the boiler furnace for combustion. The third sector is the smallest one and it heats air which is routed into the → pulverizers and used to carry the coal-air mixture to coal boiler burners. Thus, the total air heated in the RAPH provides: heating air to remove the moisture from the pulverised coal dust, carrier air for transporting the pulverised coal to the boiler burners and the primary air for combustion.

The rotor itself is the medium of → heat transfer in this system, and is usually composed of some form of steel and/or ceramic structure. It rotates quite slowly (around 3-5 RPM) to allow optimum heat transfer first from the hot exhaust gases to the element, then as it rotates, from the element to the cooler air in the other sectors.

Construction features

In this design the whole air preheater casing is supported on the boiler supporting structure itself with necessary expansion joints in the ducting.

The vertical rotor is supported on thrust bearings at the lower end and has an oil bath lubrication, cooled by water circulating in coils inside the oil bath. This arrangement is for cooling the lower end of the shaft, as this end of the vertical rotor is on the hot end of the ducting. The top end of the rotor has a simple roller bearing to hold the shaft in a vertical position.

The rotor is built up on the vertical shaft with radial supports and cages for holding the baskets in position. Radial and circumferential seal plates are also provided to avoid leakages of gases or air between the sectors or between the duct and the casing while in rotation.

For on line cleaning of the deposits from the baskets steam jets are provided such that the blown out dust and ash are collected at the bottom ash hopper of the air preheater. This dust hopper is connected for emptying along with the main dust hoppers of the dust collectors.

The rotor is turned by an air driven motor and gearing, and is required to be started before starting the boiler and also to be kept in rotation for some time after the boiler is stopped, to avoid uneven expansion and contraction resulting in warping or cracking of the rotor. The station air is generally totally dry (dry air is required for the instrumentation), so the air used to drive the rotor is injected with oil to lubricate the air motor.

Safety protected inspection windows are provided for viewing the preheater's internal operation under all operating conditions.

The baskets are in the sector housings provided on the rotor and are renewable. The life of the baskets depend on the ash abrasiveness and corrosiveness of the boiler outlet gases.

Problems

The boiler flue gas contains many dust particles (due to high ash content) not contributing towards combustion, such as silica, which cause abrasive wear of the baskets, and may also contain corrosive gases depending on the composition of the fuel. For example, Indian coals generally result in high levels of ash, sulfur and silica in the flue gas. The wear of the baskets therefore is generally more than other, cleaner-burning fuels.

In this RAPH, the dust laden, corrosive boiler gases have to pass between the elements of air preheater baskets. The elements are made up of zig zag corrugated plates pressed into a steel basket giving sufficient annular space in between for the gas to pass through. These plates are corrugated to give more surface area for the heat to be absorbed and also to give it the rigidity for stacking them into the baskets. Hence frequent replacements are called for and new baskets are always kept ready. In the early days, Cor-ten steel was being used for the elements. Today due to technological advance many manufacturers may use their own patents. Some manufacturers supply different materials for the use of the elements to lengthen the life of the baskets.

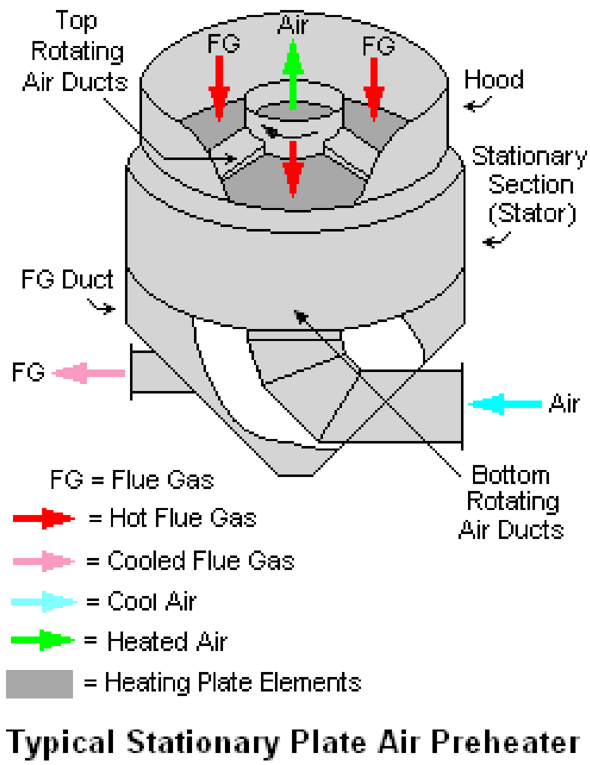
In certain cases the unburnt deposits may occur on the air preheater elements causing it to catch fire during normal operations of the boiler, giving rise to explosions inside the air preheater. Sometimes mild explosions may be detected in the control room by variations in the inlet and outlet temperatures of the combustion air.

Stationary-plate regenerative air preheater

The heating plate elements in this type of regenerative air preheater are also installed in a casing, but the heating plate elements are stationary rather than rotating. Instead the air ducts in the preheater are rotated so as to alternatively expose sections of the heating plate elements to the upflowing cool air.[1] [2] [3]

As indicated in the adjacent drawing, there are rotating inlet air ducts at the bottom of the stationary plates similar to the rotating outlet air ducts at the top of the stationary plates.

Stationary-plate regenerative air preheaters are also known as Rothemuhle preheaters, manufactured for over 25 years by Balke-Dürr GmbH of Ratingen, Germany.



Schematic of typical stationary-plate regenerative air preheater

Regenerator

A regenerator consists of a brick checkerwork: bricks laid with spaces equivalent to a brick's width between them, so that air can flow relatively easily through the checkerwork. The idea is that as hot exhaust gases flow through the checkerwork, they give up heat to the bricks. The airflow is then reversed, so that the hot bricks heat up the incoming combustion air and fuel. For a glass-melting furnace, a regenerator sits on either side of the furnace, often forming an integral whole. For a blast furnace, the regenerators - commonly called **Cowper stoves** - sit separate to the furnace; a furnace needs no less than two stoves,

but may have three. One of the stoves is 'on gas', receiving hot gases from the furnace top and heating the checkerwork inside, whilst the other is 'on blast', receiving cold air from the blowers, heating it and passing it to the blast furnace.

See also

- → Recuperator
- Economiser
- Regenerator

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[10] Course SI:428A (http://yosemite.epa.gov/oaqps/EOGtrain.nsf/fabbfcfe2fc93dac85256afe00483cc4/0747540cee26044285256db900597c4c/$FILE/SI 428A_1.pdf) Online publication of the U.S. Environmental Protection Agency's Air Pollution Training Institute, known as APTI (Scroll down to page 23 of 28)
[11] Air preheaters: Rotating regenerative heat exchangers (http://www.bwe.dk/pdf/brochure-01 APH.pdf)

Airshaft

In manufacturing, an **air shaft** is a device used for handling winding reels in the processing of web-fed materials, such as continuous-process printing presses.

Airshafts are used in the manufacturing processes for fitting into a core onto which materials such as paper, card and plastic film are wound. An Airshaft is designed so that, on fitting into a core, it can be readily expanded, thereby achieving a quick and firm attachment, it may also be easily deflated to facilitate easy withdrawal of the shaft after winding of product is complete. Their efficient design makes them ideal for mounting onto bearing housings to enable the winding or unwinding of rolls of stock material with the minimum of equipment down time. The advantage of using an Airshaft is its ability to grip the core, without damage, whilst providing a positive interface to control the web via motors & brakes. Airshafts are available as either Lug Type (with bladder down the centre) or Strip Type (bladders on the periphery of the shaft)

Manufacturers of Airshafts include Convertech, Inc [1], Rimor [2], Tidland [3], and Nimcor [4].

References

[1] http://www.convertech.com
[2] http://www.rimorconverting.co.uk
[3] http://www.tiland.com
[4] http://www.nimcor.com

American Machinists' Handbook

American Machinists' Handbook was a McGraw-Hill reference book similar to Industrial Press's → *Machinery's Handbook*. (The latter title, still in print and regularly revised, is the one that machinists today are usually referring to when they speak imprecisely of "the machinist's handbook" or "the machinists' handbook".)

The somewhat generic sound of the title *American Machinists' Handbook*, and the ambiguity of its apostrophe usage, no doubt contributed to the confounding of the two books' titles and identities. It capitalized on readers' familiarity with *American Machinist*, McGraw-Hill's popular trade journal. But the usage could have benefited from some branding discipline, because the confusion over whether the title was properly "American Machinist's Handbook" or "American Machinists' Handbook" or "*American Machinist* 's Handbook" was (and is) considerable. ("*American Machinist* 's Handbook" would be parallel to the construction of the title "*Machinery's* Handbook"; perhaps McGraw-Hill's handbook's title was originally conceived as that and later was muddied into "American Machinists' Handbook".)

Although McGraw-Hill's *American Machinists' Handbook* appeared first (1908), it is doubtful that Industrial Press's *Machinery's Handbook* (1914) was a mere me-too conceived afterwards in response. The eager market for such a reference work had probably been obvious for at least a decade before either work was compiled, and presumably the appearance of the McGraw-Hill title merely prodded Industrial Press to finally get moving on a handbook of its own.

American Machinists' Handbook, coedited by Fred H. Colvin and Frank A. Stanley, went through eight editions between 1908 and 1945. In 1955, McGraw-Hill published *The new American machinist's handbook. Based upon earlier editions of American machinists' handbook* (sic; note the apostrophe usage difference within that title), but presumably the book did not compete well enough with *Machinery's Handbook*, because no subsequent editions were produced. Meanwhile, → *Machinery's Handbook* has continued to be regularly revised and updated, right up to today, and it is still a "bible of the metalworking industries."

List of the editions of *American Machinists' Handbook*

Year	Coeditors	Title ± subtitle	Edition number	City, Publisher	Notes
1908	Fred H. Colvin, Frank A. Stanley	American machinists' handbook and dictionary of shop terms: a reference book of machine shop and drawing room data, methods, and definitions	1st ed	New York and London, Hill	*This edition is public-domain (copyright expired) and can be read for free in digitized form* [1] *via Google Book Search.*
1914	Fred H. Colvin, Frank A. Stanley	American machinists' handbook and dictionary of shop terms: a reference book of machine shop and drawing room data, methods and definitions	2nd ed	New York and London, McGraw-Hill	*This edition is public-domain (copyright expired) and can be read for free in digitized form* [2] *via Google Book Search.*
1920	Fred H. Colvin, Frank A. Stanley	American machinists' handbook and dictionary of shop terms: a reference book of machine shop and drawing room data, methods and definitions	3rd ed	New York and London, McGraw-Hill	*This edition is public-domain (copyright expired). No digitized book link is yet available via Google Book Search (as of 2007*[3]*).*
1926	Fred H. Colvin, Frank A. Stanley	American machinists' handbook and dictionary of shop terms: a reference book of machine-shop and drawing-room data, methods and definitions	4th ed	New York and London, McGraw-Hill	*Copyright renewed 1954-01-18*
1932	Fred H. Colvin, Frank A. Stanley	American machinists' handbook and dictionary of shop terms: a reference book of machine shop and drawing room data, methods and definitions	5th ed	New York and London, McGraw-Hill	*Copyright renewed 1959-12-07*
1935	Fred H. Colvin, Frank A. Stanley	American machinists' handbook and dictionary of shop terms, a reference book of machine shop and drawing room data, methods and definitions	6th ed	New York and London, McGraw-Hill	*Copyright renewed 1963-05-06*

1940	Fred H. Colvin, Frank A. Stanley	American machinists' handbook and dictionary of shop terms	7th ed	New York and London, McGraw-Hill	*Copyright renewed 1967-11-03*
1945	Fred H. Colvin, Frank A. Stanley	American machinists' handbook and dictionary of shop terms: a reference book of machine-shop and drawing-room data, methods, and definitions	8th ed	New York and London, McGraw-Hill	*Copyright renewed 1963-05-06*
1955	Fred H. Colvin, Frank A. Stanley	The new American machinist's handbook. Based upon earlier editions of American machinists' handbook	1st ed	New York and London, McGraw-Hill	*(1) Note the apostrophe usage in the title.* *(2) Copyright renewed 1955-07-26*

Renewal data from Rutgers [4]. All works after 1923 with renewed copyright are presumably still protected.

References

[1] http://books.google.com/books?id=o9ANAAAAYAAJ&printsec=titlepage#v=onepage&q=&f=false
[2] http://books.google.com/books?id=4Q8LAAAAIAAJ&pg=PA1&dq=Colvin+%22American+machinists%27+handbook%22#PPR3,M1
[3] http://en.wikipedia.org/wiki/American_machinists%27_handbook
[4] http://www.scils.rutgers.edu/~lesk/copyrenew.html

American Society of Mechanical Engineers

The **American Society of Mechanical Engineers** (**ASME**) is a professional body, specifically an engineering society, focused on → mechanical engineering. The ASME was founded in 1880 by Alexander Lyman Holley, Henry Rossiter Worthington, John Edison Sweet and Matthias N. Forney in response to numerous steam boiler pressure vessel failures. The organization is known for setting codes and standards for mechanical devices. The ASME conducts one of the world's largest technical publishing operations through its ASME Press, holds numerous technical conferences and hundreds of professional development courses each year, and sponsors numerous outreach and educational programs.

The organization's stated vision is to be the premier organization for promoting the art, science and practice of mechanical and multidisciplinary engineering and allied sciences to the diverse communities throughout the world. Its stated mission is to promote and enhance the technical competency and professional well-being of its members, and through quality programs and activities in mechanical engineering, better enable its practitioners to contribute to the well-being of humankind. As of 2006, the ASME has 120,000 members.

Core values include:

- Embrace integrity and ethical conduct
- Embrace diversity and respect the dignity and culture of all people
- Nurture and treasure the environment and our natural and man-made resources

- Facilitate the development, dissemination and application of engineering knowledge
- Promote the benefits of continuing education and of engineering education
- Respect and document engineering history while continually embracing change
- Promote the technical and societal contribution of engineers

ASME Codes and Standards

ASME is one of the oldest standards-developing organizations in the world. It produces approximately 600 codes and standards, covering many technical areas, such as boiler components, elevators, measurement of fluid flow in closed conduits, cranes, hand tools, fasteners, and machine tools.

Note that:

- A **Standard** can be defined as a set of technical definitions and guidelines that function as instructions for designers, manufacturers, operators, or users of equipment.
- A standard becomes a **Code** when it has been adopted by one or more governmental bodies and is enforceable by law, or when it has been incorporated into a business contract.

The ASME Boiler and Pressure Vessel Code (BPVC)

The largest ASME standard, both in size and in the number of volunteers involved in its preparation, is the ASME Boiler and Pressure Vessel Code (BPVC). BPVC is a standard that provides rules for the design, fabrication, and inspection of boilers and pressure vessels. It is reviewed every three years. The BPVC consists of twelve volumes.

Notable members

- Abdul Rahman Al-Athel
- Nancy D. Fitzroy.[1]
- Alexander C. Monteith
- Hugh Pembroke Vowles
- John I. Yellott

ASME Student Professional Development Conference (SPDC)

The Student Professional Development Conference or SPDC is a conference that is run and maintained by ASME. The purpose for the conference is to allow students to network with other students from different colleges and engineers that are out in the work field, host competitive student contests, and gives them the opportunity to see what ASME can do for them professionally. Conferences are held in ten different districts with each district representing a certain section. Districts A-F are held in North America, District G is in Asia and Australia, District H includes most of Europe, District I is in Central and South America, and District J covers the MIddle East and parts of Africa. The location for each district changes every year and colleges attend the conference that is closest to them.[2]

ASME Student Competitions

There are four competitions held at each conference and they are:

- Old Guard Oral Presentation Competition
- Old Guard Technical Poster Competition
- Technical Web Page Competition
- Student Design Competition

Each competition has its own set of rules and prizes. The most prestigious out of the four is the Student Design Competition as it allows engineering students to showcase their abilities, engineering knowledge, and creativity. Every year a problem statement is put up on the ASME SDC website which states the problem that must be solved and the various constraints that go along with it. The first-place team at each district is then invited to compete in an international competition held at ASME's International Mechanical Engineering Congress and Exposition (IMECE).[3]

Organization

Following the reorganization of the ASME during the Continuity and Change process, volunteer activity was organized into five sectors. Each sector is led by a volunteer Senior Vice President who reports directly to the Board of Governors.

1) **Centers**
Senior Vice President: Robert Luna
Mission: Support the growth, vitality and diversity of mechanical and multi-disciplinary engineering, to cultivate future leaders, and to celebrate the contribution of engineers to the well-being of humankind.
Groups (Centers) within Centers are led by Vice Presidents:

- a) Education: Robert Warrington
- b) Leadership and Diversity: May Lynn Realff
- c) Professional Development: Betty Bowersox
- d) Public Awareness: Vincent Wilczynski

2) **Codes & Standards**
Senior Vice President: Bernard E. Hrubala
Mission: The Codes and Standards Board of Directors under the direction of the Board of Governors, will supervise the activities of the Society relating to Codes and Standards.
Groups (Boards) within Codes & Standards are led by Vice Presidents:
a) Codes & Standards Operations: Kenneth R. Balkey, PE
b) Conformity Assessment (BCA): Paul D. Edwards
c) Hearings and Appeals: Bradley D. Closson
d) Nuclear Codes and Standards: Bryan A. Erler, PE
e) New Development: Anthony P. Cirillo
f) Pressure Technology Codes and Standards: Louis E. Hayden Jr , PE
g) Safety Codes and Standards: Robert E. Albert
h) Standardization and Testing: Joseph W. Milton, PE
i) Committee on Strategic Planning and Performance: Bernard E. Hrubala

3) **Institutes**
Senior Vice President: David Wisler
Mission: Providing a focused arena for business activities relevant to identified technical,

educational or technological endeavors is the underlying purpose of ASME's Institutes area.
Groups (Institutes) within Institutes are led by Vice Presidents:
a) International Gas Turbine: Dilip Ballal
b) International Petroleum Technology: Terry Lechinger
c) Continuing Education
d) Engineering Management Certification International
e) Emerging Technologies

4) **Knowledge & Community**
Senior Vice President: Richard Laudenat
Mission: The K&C Sector is designed to provide an organizational and management structure for over 800 member units. The entire K & C structure serves as a resource and platform for enabling the member units
Groups (Communities) within Knowledge & Community are lead by Vice Presidents:
a) Affinity: Justin Young
b) Financial Operations: Lawrence A. Kielasa
c) Global: Thomas Libertiny
d) Programs & Activities: John W. Wesner, PE
e) Technical: Dan Segalman

5) **Strategic Management**
Senior Vice President: Robert Pangborn
Mission: The Strategic Management Sector Board of Directors (SMBOD) under the direction of the Board of Governors, is responsible for the activities of the Society relating to identification, capture and transfer of knowledge that will support ASME's strategies for the technical innovation and advocacy of public policies that are important to advancement of industry and the profession. The units of the Sector include the Board on Government Relations, the Industry Advisory Board, the Strategic Initiatives and Innovation Committee and the Strategic Issues Committee. The operation guide defines the voting members, election of sector leadership, committee duties, meetings and records.

Groups (Boards) within Knowledge & Community are led by a Vice President, Members-at-Large, and Committee Chairs:

- a) Member-at-Large: Susan Ipri-Brown
- b) Member-at-Large: Elizabeth Kisenwether
- c) Vice President, Government Relations: Michael Reischman
- d) Chair, Strategic Issues: Win Phillips
- e) Chair, Strategic Initiatives and Innovation: Chris Przirembel
- f) Chair, Industry Advisory Board: Charla Wise

See also

- ASME Y14.41-2003 Digital Product Definition Data Practices
- List of ASME Presidents
- List of historic mechanical engineering landmarks

References

[1] " Fitzroy, Nancy Deloye ASME President, 1986-1987 (http://www.asme.org/Communities/History/Resources/Fitzroy_Nancy_Deloye.cfm)" (cfm). ASME. . Retrieved 2008-02-18.
[2] " Student Professional Development Conference (http://districts.asme.org/SPDC/)". ASME. . Retrieved 2008-03-27.
[3] " Student Design Competition (http://www.asme.org/Events/Contests/DesignContest/Student_Design_Competition.cfm)". ASME. . Retrieved 2008-03-27.

- White, John H., Jr. (1968). *A history of the American locomotive; its development: 1830-1880*. Dover Publications, New York, NY. ISBN 0-486-23818-0.
- Frederick Remson Hutton (1915) *A History of the American Society of Mechanical Engineers*. ASME. (http://www.archive.org/details/historyoftheamer014404mbp)

External links

- ASME.org (http://www.asme.org)
  - ASME Peerlink Website (http://peerlink.asme.org)
  - 3rd Annual Bioprocess Technology Seminars & Exhibition - Europe (http://www.asmeconferences.org/bioprocesseurope09)
- Outline of ASME Boiler and Pressure Vessel Code
  - by EngineeringToolBox.com (http://www.engineeringtoolbox.com/asme-boiler-vessel-code-d_8.html)
  - by IHS Inc. (http://www.asme2004.com/about_asme.html)
- An ASME Code discussion forum (http://www.onetb.com/forum.htm) for all Code related questions
- Click here (http://www.asme.org/Codes/About/Links/Links_Codes_Standards.cfm) to download the following introductory PDFs on ASME codes:
  - An Introduction to Codes & Standards for Students
  - ASME Codes & Standards - Examples of Code Use for Mechanical Engineering Students
- A Brief History of ASME (http://www.asme.org/Communities/History/ASMEHistory/Brief_History.cfm)
- A Sense of the Past (http://www.asme.org/Communities/History/ASMEHistory/Sense_Past_Historical.cfm) by Eugene Ferguson (1974)
- Writing ASME's History (http://www.asme.org/Communities/History/ASMEHistory/Writing_History_Postscript_by.cfm) by Bruce Sinclair (1980)
- Old Guard Oral Presentation Information (http://www.asme.org/Events/Contests/Old_Guard_Prize_Oral.cfm)
- Old Guard Technical Poster Information (http://www.asme.org/Events/Contests/Old_Guard_Technical_Poster.cfm)
- Technical Web Page Information (http://www.asme.org/Events/Contests/Old_Guard_Technical_Web_Page.cfm)

- Boiler and Pressure Vessel Code - 2007 Edition (http://www.asme.org/Codes/International_Boiler_Pressure.cfm)
- ASME Mechanical Engineering Technology Department Heads Committee records 1980-1994 (http://www.lib.neu.edu/archives/collect/findaids/m108find.htm) - Northeastern University Libraries

American Society for Precision Engineering

The **American Society for Precision Engineering** is a non-profit member association, founded in 1986, dedicated to advancing the arts, sciences, and technology of precision engineering, to promote its dissemination through education and training, and its use by science and industry.

Overview

The American Society for Precision Engineering (ASPE) focuses on many areas that are important in the research, design, development, manufacture and measurement of high accuracy components and systems. This collective discipline is known as → Precision engineering, and includes precision controls, metrology, interferometry, materials, materials processing, nanotechnology, optical fabrication, precision optics, precision replication, scanning microscopes, semiconductor processing, standards and ultra-precision machining.

History

There has long been a "community" of precision engineers within the United States but a formal structure and common focus for the activities was lacking. This was not the case in Japan, as evidenced by the large and active Japanese Society of Precision Engineers. In November 1985, a joint US-Japanese meeting on precision engineering included a special session to discuss the possibility of forming an American Society. The enthusiasm of the participants and the overwhelming response to a subsequent questionnaire provided momentum. By November 1986, the American Society for Precision Engineering was incorporated and held its first Annual Meeting in Dallas, Texas. The theme of the well-attended meeting, "Thresholds in Precision Engineering," was reflected in 28 papers covering a broad spectrum of applications. At this meeting, a Board of Directors was elected with members drawn from industry, private laboratories, government and academia.

ASPE emphasizes the foundations necessary to achieve precision in any application and seeks to bring together practitioners from all of the related fields. The Annual Meeting, held each fall, presents topics spanning the field of precision engineering.

Conferences and Exhibitions

- 24th Annual Meeting, Monterey, California, October 2009
- 25th Annual Meeting, Atlanta, Georgia, October/November 2009

Publications

The Society jointly publishes a peer-reviewed technical journal, *Precision Engineering*, in cooperation with its European and Japanese counterparts.

Past conference proceedings have been made freely available, and may be downloaded directly from the Society website.

External links

- American Society for Precision Engineering [1]
- ASPE Meeting Information [2]
- Precision Engineering: Journal of the International Societies for Precision Engineering and Nanotechnology [3]
- Searchable collection of past ASPE conference proceedings [4]

References

[1] http://www.aspe.net
[2] http://www.aspe.net/meetings/index.html
[3] http://www.elsevier.com/wps/find/journaldescription.cws_home/525017/description#description
[4] http://www.aspe.net/publications/Proceedings_Papers_guests.php

Atmosphere (unit)

The **standard atmosphere** is an international reference pressure defined as 101,325 Pa and formerly used as unit of pressure (symbol: atm).[1] For practical purposes it has been replaced by the bar which is 100,000 Pa.[1] The difference of about 1% is not significant for many applications, and is within the error range of common pressure gauges.

History

In 1954 the 10th Conférence Générale des Poids et Mesures (CGPM) adopted *standard atmosphere* for general use and affirmed its definition of being precisely equal to 1,013,250 dynes per square centimeter (101,325 Pa).[2] This value was intended to represent the mean atmospheric pressure at mean sea level at the latitude of Paris, France, and as a practical matter, truly reflects the mean sea level pressure for many of the industrialized nations (those with latitudes similar to Paris).

In chemistry, the original definition of "Standard Temperature and Pressure" (→ STP) was a reference temperature of 0 °C (273.15 K) and pressure of 101.325 kPa (1 atm). However, in 1982, the International Union of Pure and Applied Chemistry (IUPAC) recommended that for the purposes of specifying the physical properties of substances, "*the standard pressure*" should be defined as precisely 100 kPa (exactly 1 bar).[3]

Pressure units and equivalencies

Pressure Units

	pascal (Pa)	**bar (bar)**	**technical atmosphere (at)**	**→ atmosphere (atm)**	**torr (Torr)**	**pound-force per square inch (psi)**
1 Pa	≡ 1 N/m^2	10^{-5}	1.0197×10^{-5}	9.8692×10^{-6}	7.5006×10^{-3}	145.04×10^{-6}
1 bar	100,000	≡ 10^6 dyn/cm^2	1.0197	0.98692	750.06	14.5037744
1 at	98,066.5	0.980665	≡ 1 kgf/cm^2	0.96784	735.56	14.223
1 atm	101,325	1.01325	1.0332	≡ 1 → atm	760	14.696
1 torr	133.322	1.3332×10^{-3}	1.3595×10^{-3}	1.3158×10^{-3}	≡ 1 Torr; ≈ 1 mmHg	19.337×10^{-3}
1 psi	6.894×10^3	68.948×10^{-3}	70.307×10^{-3}	68.046×10^{-3}	51.715	≡ 1 lbf/in^2

Example reading: 1 Pa = 1 N/m^2 = 10^{-5} bar = 10.197×10^{-6} at = 9.8692×10^{-6} atm, etc.

A pressure of 1 atm can also be stated as:

≡ 1.013 25 bar

≡ 1013.25 hectopascal (hPa)

≡ 1013.25 millibars (mbar, also mb)

≡ 760 torr [B]

≈ 760.001 mm-Hg, 0 °C, subject to revision as more precise measurements of mercury’s density become available [B, C]

≈ 29.9213 in-Hg, 0 °C, subject to revision as more precise measurements of mercury’s density become available [C]

≈ 1.033 227 452 799 886 kgf/cm^2

≈ 1.033 227 452 799 886 technical atmosphere

≈ 1033.227 452 799 886 cm–H_2O, 4 °C [A]

≈ 406.782 461 732 2385 in–H_2O, 4 °C [A]

≈ 14.695 948 775 5134 pounds-force per square inch (psi)

≈ 2116.216 623 673 94 pounds-force per square foot (psf)

Notes:

[A] This is the customarily-accepted value for cm–H_2O, 4 °C. It is precisely the product of 1 kg-force per square centimeter (one technical atmosphere) times 1.013 25 (bar/atmosphere) divided by 0.980 665 (one gram-force). It is not accepted practice to define the value for water column based on a true physical realization of water (which would be 99.997 495% of this value because the true maximum density of Vienna Standard Mean Ocean Water is 0.999 974 95 kg/l at 3.984 °C). Also, this “physical realization” would *still* ignore the 8.285 cm–H_2O reduction that would actually occur in a true physical realization due to the vapor pressure over water at 3.984 °C.

[B] Torr and mm-Hg, 0°C are often taken to be identical. For most practical purposes (to 5 significant digits), they are interchangeable.

[C] NIST value of 13.595 078(5) g/ml assumed for the density of Hg at 0 °C

Other applications

In the United Kingdom, scuba divers and others often use the word *atmosphere* loosely (the correct term is "ambient pressure") to mean 1 bar.

The old European unit technical atmosphere (at) is roughly equal to the gauge pressure under 10 m of water; 1 at = 98066.5 Pa.

See also

- → Standard conditions for temperature and pressure
- Atmospheric pressure
- Bar (unit)

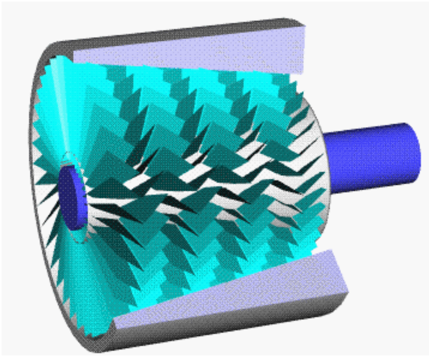
References

[1] British Standard BS 350:2004 *Conversion Factors for Units*
[2] BIPM Definition of the standard atmosphere (http://www.bipm.org/jsp/en/ViewCGPMResolution.jsp?CGPM=10&RES=4)
[3] IUPAC.org, Gold Book, *Standard Pressure* (http://goldbook.iupac.org/S05921.html)

Automaton clock

An **automaton clock** is a type of striking clock featuring automatons. Clocks like these were often built during the Middle Ages in Europe. A Cuckoo clock is a simple form of this type of clock. Often, the automatons come out on the hour to strike the bells, with Death often being one of the figures, to symbolize human mortality.

Axial compressor



An animation of an axial compressor. The static blades are the stators.

Axial compressors are rotating, airfoil based compressors in which the working fluid principally flows parallel to the axis of rotation. This is in contrast with other rotating compressors such as centrifugal, axi-centrifugal and mixed-flow compressors where the air may enter axially but will have a significant radial component on exit.

Axial flow compressors produce a continuous flow of compressed gas, and have the benefits of high efficiencies and large mass flow capacity, particularly in relation to their cross-section. They do, however, require several rows of airfoils to achieve large pressure rises making them complex and expensive relative to other designs (e.g. centrifugal compressor).

Axial compressors are widely used in gas turbines, such as jet engines, high speed ship engines, and small scale power stations. They are also used in industrial applications such as large volume air separation plants, blast furnace air, fluid catalytic cracking air, and propane dehydrogenation. Axial compressors, known as superchargers, have also been used to boost the power of automotive reciprocating engines by compressing the intake air, though these are very rare. A good example of an axial supercharger is the aftermarket Latham type built between 1955-65 which were used on hot rods and aircooled Volkswagens at that time, but these didn't catch on.

Description

Axial compressors consist of rotating and stationary components. A shaft drives a central drum, retained by bearings, which has a number of annular airfoil rows attached. These rotate between a similar number of stationary airfoil rows attached to a stationary tubular casing. The rows alternate between the rotating airfoils (rotors) and stationary airfoils (stators), with the rotors imparting energy into the fluid, and the stators converting the increased rotational kinetic energy into static pressure through diffusion. A pair of rotating and stationary airfoils is called a stage. The cross-sectional area between rotor drum and casing is reduced in the flow direction to maintain axial velocity as the fluid is compressed.

Design

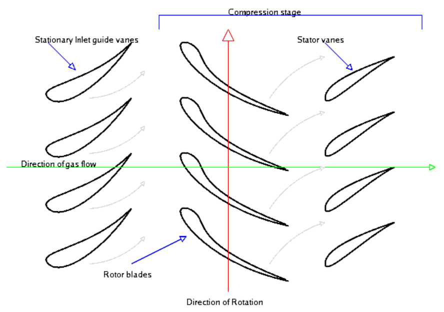


Diagram of an axial flow compressor

The increase in pressure produced by a single stage is limited by the relative velocity between the rotor and the fluid, and the turning and diffusion capabilities of the airfoils. A typical stage in a commercial compressor will produce a pressure increase of between 15% and 60% (pressure ratios of 1.15-1.6) at design conditions with a polytropic efficiency in the region of 90-95%. To achieve different pressure ratios, axial compressors are designed with different numbers of stages and rotational speeds.

Higher stage pressure ratios are also possible if the relative velocity between fluid and rotors is supersonic, however this is achieved at the expense of efficiency and operability. Such compressors, with stage pressure ratios of over 2, are only used where minimising the compressor size, weight or complexity is critical, such as in military jets.

The airfoil profiles are optimised and matched for specific velocities and turning. Although compressors can be run at other conditions with different flows, speeds, or pressure ratios, this can result in an efficiency penalty or even a partial or complete breakdown in flow (known as compressor stall and pressure surge respectively). Thus, a practical limit on the number of stages, and the overall pressure ratio, comes from the interaction of the different stages when required to work away from the design conditions. These “off-design” conditions can be mitigated to a certain extent by providing some flexibility in the compressor. This is achieved normally through the use of adjustable stators or with valves that can bleed fluid from the main flow between stages (inter-stage bleed).

Modern jet engines use a series of compressors, running at different speeds; to supply air at around 40:1 pressure ratio for combustion with sufficient flexibility for all flight conditions.

Development

Early axial compressors offered poor efficiency, so poor that in the early 1920s a number of papers claimed that a practical jet engine would be impossible to construct. Things changed dramatically after A. A. Griffith published a seminal paper in 1926, noting that the reason for the poor performance was that existing compressors used flat blades and were essentially "flying stalled". He showed that the use of airfoils instead of the flat blades would dramatically increase efficiency, to the point where a practical jet engine was a real possibility. He concluded the paper with a basic diagram of such an engine, which included a second turbine that was used to power a propeller.

Although Griffith was well known due to his earlier work on metal fatigue and stress measurement, little work appears to have started as a direct result of his paper. The only obvious effort was a test-bed compressor built by Griffith's colleague at the Royal Aircraft Establishment, Haine Constant. Other early jet efforts, notably those of Frank Whittle and Hans von Ohain, were based on the more robust and better understood centrifugal compressor which was widely used in superchargers. Griffith had seen Whittle's work in 1929 and dismissed it, noting an error in the math and going on to claim that the frontal

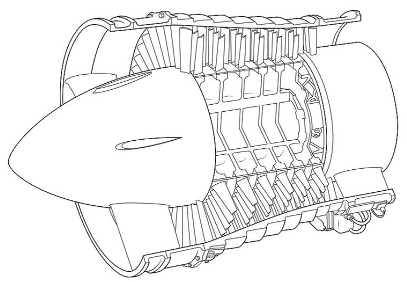
size of the engine would make it useless on a high-speed aircraft.

Real work on axial-flow engines started in the late 1930s, in several efforts that all started at about the same time. In England, Haine Constant reached an agreement with the steam turbine company Metropolitan Vickers (Metrovick) in 1937, starting their turboprop effort based on the Griffith design in 1938. In 1940, after the successful run of Whittle's centrifugal-flow design, their effort was re-designed as a pure jet, the Metrovick F.2. In Germany, von Ohain had produced several working centrifugal engines, some of which had flown including the world's first jet aircraft (He 178), but development efforts had moved on to Junkers (Jumo 004) and BMW (BMW 003), which used axial-flow designs in the world's first jet fighter (Messerschmitt Me 262) and jet bomber (Arado Ar 234). In the United States, both Lockheed and General Electric were awarded contracts in 1941 to develop axial-flow engines, the former a pure jet, the latter a turboprop. Northrop also started their own project to develop a turboprop, which the US Navy eventually contracted in 1943. Westinghouse also entered the race in 1942, their project proving to be the only successful one of the US efforts, later becoming the J30.

By the 1950s every major engine development had moved on to the axial-flow type. As Griffith had originally noted in 1929, the large frontal size of the centrifugal compressor caused it to have higher drag than the narrower axial-flow type. Additionally the axial-flow design could improve its compression ratio simply by adding additional stages and making the engine slightly longer. In the centrifugal-flow design the compressor itself had to be larger in diameter, which was much more difficult to "fit" properly on the aircraft. On the other hand, centrifugal-flow designs remained much less complex (the major reason they "won" in the race to flying examples) and therefore have a role in places where size and streamlining are not so important. For this reason they remain a major solution for helicopter engines, where the compressor lies flat and can be built to any needed size without upsetting the streamlining to any great degree.

Axial-flow jet engines

In the jet engine application, the compressor faces a wide variety of operating conditions. On the ground at takeoff the inlet pressure is high, inlet speed zero, and the compressor spun at a variety of speeds as the power is applied. Once in flight the inlet pressure drops, but the inlet speed increases (due to the forward motion of the aircraft) to recover some of this pressure, and the compressor tends to run at a single speed for long periods of time.



Low pressure axial compressor scheme of the Olympus BOl.1 turbojet.

There is simply no "perfect" compressor for this wide range of operating conditions. Fixed geometry compressors, like those used on early jet engines, are limited to a design pressure ratio of about 4 or 5:1. As with any heat engine, fuel efficiency is strongly related to the compression ratio, so there is very strong financial need to improve the compressor stages beyond these sorts of ratios.

Additionally the compressor may stall if the inlet conditions change abruptly, a common problem on early engines. In some cases, if the stall occurs near the front of the engine, all of the stages from that point on will stop compressing the air. In this situation the energy required to run the compressor drops suddenly, and the remaining hot air in the rear of the

engine allows the turbine to speed up the whole engine dramatically. This condition, known as **surging**, was a major problem on early engines and often led to the turbine or compressor breaking and shedding blades.

For all of these reasons, axial compressors on modern jet engines are considerably more complex than those on earlier designs.

Spools

All compressors have a sweet spot relating rotational speed and pressure, with higher compressions requiring higher speeds. Early engines were designed for simplicity, and used a single large compressor spinning at a single speed. Later designs added a second turbine and divided the compressor into "low pressure" and "high pressure" sections, the latter spinning faster. This **two-spool** design resulted in increased efficiency. Even more can be squeezed out by adding a third spool, but in practice this has proven to be too complex to make it generally worthwhile as there is a trade off between higher fuel efficiency and the higher maintenance involved pushing up total cost of ownership compared to a two spool design. That said, there are several three-spool engines in use, perhaps the most famous being the Rolls-Royce RB.211, used on a wide variety of commercial aircraft.

Bleed air, variable stators

As an aircraft changes speed or altitude, the pressure of the air at the inlet to the compressor will vary. In order to "tune" the compressor for these changing conditions, designs starting in the 1950s would "bleed" air out of the middle of the compressor in order to avoid trying to compress too much air in the final stages. This was also used to help start the engine, allowing it to be spun up without compressing much air by bleeding off as much as possible. Bleed systems were already commonly used anyway, to provide airflow into the turbine stage where it was used to cool the turbine blades, as well as provide pressurized air for the air conditioning systems inside the aircraft.

A more advanced design, the **variable stator**, used blades that can be individually rotated around their axis, as opposed to the power axis of the engine. For startup they are rotated to "open", reducing compression, and then are rotated back into the airflow as the external conditions require. The General Electric J79 was the first major example of a variable stator design, and today it is a common feature of most military engines.

Closing the variable stators progressively, as compressor speed falls, reduces the slope of the surge (or stall) line on the operating characteristic (or map), improving the surge margin of the installed unit. By incorporating variable stators in the first five stages, General Electric Aircraft Engines has developed a ten-stage axial compressor capable of operating at a 23:1 design pressure ratio.

Bypass

For jet engine applications, the "whole idea" of the engine is to move air to provide thrust. In most cases, the engine produces more power to move air than its mechanical design actually allows. Namely, the inlet into the compressor is simply too small to move the amount of air that the engine could, in theory, heat and use. A number of engine designs had experimented with using some of the turbine power to drive a secondary "fan" for added air flow, starting with the Metrovick F.3, which placed a fan at the rear of a late-model F.2 engine. A much more practical solution was created by Rolls-Royce in their early 1950s Conway engine, which enlarged the first compressor stage to be larger than

the engine itself. This allowed the compressor to blow cold air past the interior of the engine, somewhat similar to a propeller. This technique allows the engine to be designed to produce the amount of energy needed, and any air that cannot be blown through the engine due to its size is simply blown around it. Since that air is not compressed to any large degree, it is being moved without using up much energy from the turbine, allowing a smaller core to provide the same mass flow, and thrust, as a much larger "pure jet" engine. This engine is called a "turbofan."

This technique also has the added benefit of mixing the cold bypass air with the hot engine exhaust, greatly lowering the exhaust temperature. Since the sound of a jet engine is strongly related to the exhaust temperature, bypass also dramatically reduces the sound of the engine. Early jetliners from the 1960s were famous for their "screaming" sound, whereas modern engines of greatly higher power generally give off a much less annoying "whoosh" or even buzzing.

Mitigating this savings is the fact that drag increases exponentially at high speeds, so while the engine is able to operate far more efficiently, this typically translates into a smaller real-world effect. For instance, the latest Boeing 737's with high-bypass CFM56 engines operates at an overall efficiency about 30% better than the earlier models. Military turbofans, on the other hand, especially those used on combat aircraft, tend to have so low a bypass-ratio that they are sometimes referred to as "leaky turbojets."

Turbine cooling

The limiting factor in jet engine design is not the compressor, but the temperature at the turbine. It is fairly easy to build an engine that can provide enough compressed air that when burnt will melt the turbine; this was a major cause of failure in early German engines which were hampered by the unavailability of high temperature metals. Improvements in air cooling and materials have dramatically improved the temperature performance of turbines, allowing the compression ratio of jet engines to increase dramatically. Early test engines offered perhaps 3:1 and production engines like the Jumo 004 were about 4:1, about the same as contemporary piston engines. Improvements started immediately and have not stopped; the latest Rolls-Royce Trent operates at about 40:1, far in excess of any piston engine.

Since compression ratio is strongly related to fuel economy, this eightfold increase in compression ratio results in an increase in fuel economy for any given amount of power, which is the reason there is strong pressure in the airline industry to use only the latest designs.

Design notes

Energy exchange between rotor and fluid

The relative motion of the blades relative to the fluid adds velocity or pressure or both to the fluid as it passes through the rotor. The fluid velocity is increased through the rotor, and the stator converts kinetic energy to pressure energy. Some diffusion also occurs in the rotor in most practical designs.

The increase in velocity of the fluid is primarily in the tangential direction (swirl) and the stator removes this angular momentum.

The pressure rise results in a stagnation temperature rise. For a given geometry the temperature rise depends on the square of the tangential Mach number of the rotor row. Current turbofan engines have fans that operate at Mach 1.7 or more, and require significant containment and noise suppression structures to reduce blade loss damage and noise.

Velocity diagrams

The blade rows are designed at the first level using velocity diagrams. A velocity diagram shows the relative velocities of the blade rows and the fluid.

The axial flow through the compressor is kept as close as possible to Mach 1 to maximize the thrust for a given compressor size. The tangential Mach number determines the attainable pressure rise.

The blade rows turn the flow through an angle β; larger turning allows a higher temperature ratio, but requires higher solidity.

Modern blades rows have low aspect ratios and high solidity.

Compressor maps

A map shows the performance of a compressor and allows determination of optimal operating conditions. It shows the mass flow along the horizontal axis, typically as a percentage of the design mass flow rate, or in actual units. The pressure rise is indicated on the vertical axis as a ratio between inlet and exit stagnation pressures.

A surge or stall line identifies the boundary to the left of which the compressor performance rapidly degrades and identifies the maximum pressure ratio that can be achieved for a given mass flow. Contours of efficiency are drawn as well as performance lines for operation at particular rotational speeds.

Compression stability

Operating efficiency is highest close to the stall line. If the downstream pressure is increased beyond the maximum possible the compressor will stall and become unstable.

Typically the instability will be at the Helmholtz frequency of the system, taking the downstream plenum into account.

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- Wilson, David Gordon and Theodosios Korakianitis. 'The Design of High-Efficiency Turbomachinery and Turbines,' 2nd edn, Prentice Hall, 1998. ISBN 0133120007.

External links

- Turbomachinery design and development company [1]
- AxSTREAM turbomachinery design software [2]

References

[1] http://www.conceptsnrec.com
[2] http://www.softinway.com

Ball detent

A **ball detent** is a simple mechanical arrangement used to hold a moving part in a temporarily fixed position relative to another part. Usually the moving parts slide with respect to each other, or one part rotates within the other.

The **ball** is a single, usually metal sphere, sliding within a bored cylinder, against the pressure of a spring, which pushes the ball against the other part of the mechanism, which carries the **detent** - which can be as simple as a hole of smaller diameter than the ball. When the hole is in line with the cylinder, the ball falls partially into the hole under spring pressure, holding the parts at that position. Additional force applied to the moving parts will push the ball back into its cylinder, compressing the spring, and allowing the parts to move to another position.

Ball detents are commonly found in the selector mechanism of a gearbox, holding the selector rods in the correct position to engage the desired gear. Other applications include clutches that slip at a preset torque, and calibrated ball detent mechanisms are typically found in a torque wrench.

dfvd

Band brake

A **band brake** is a primary or secondary braking device, consisting of a band of friction material that tightens concentrically around a piece of equipment to either prevent it from rotating (a static or "holding" brake), or to slow it (a dynamic brake). This application is common on winch drums and chain saws.

Beale number

In → mechanical engineering, the **Beale number** is a parameter that characterizes the performance of **Stirling engines**. It is often used to estimate the power output of a Stirling engine design. For engines operating with a high temperature differential, typical values for the Beale number range from (0.11) to (0.15); where a larger number indicates higher performance.

Definition

The Beale number can be defined in terms of a Stirling engine's operating parameters:

$$B_n = \frac{Wo}{PVF}$$

where:

- **B_n** is the Beale number
- **Wo** is the power output of the engine (watts)
- **P** is the mean average gas pressure (Pa) or (MPa, if volume is in cm^3)
- **V** is swept volume of the expansion space (m^3) or (cm^3, if pressure is in MPa)
- **F** is the engine cycle frequency (Hz)

Estimating Stirling power

To estimate the power output of an engine, nominal values are assumed for the Beale number, pressure, swept volume and frequency, then the power is calculated as the product of these parameters, as follows:

$$Wo = B_n PVF$$

See also

- → West number

External links

- Stirling Engine Performance Calculator [1]

References

[1] http://www.bekkoame.ne.jp/~khirata/academic/simple/simplee.htm

Bearing surface

A **bearing surface** is a → mechanical engineering term that refers to the area of contact between two objects. It usually is used in reference to → bolted joints and bearings, but can be applied to a wide variety of engineering applications.

On a screw the bearing area loosely refers to the underside of the head.[1] Strictly speaking, the bearing area refers to the area of the screw head that directly bears on the part being fastened.[2]

For a cylindrical bearing it is the projected area perpendicular to the applied force.[3]

On a spring the bearing area refers to the amount of area on the top or bottom surface of the spring in contact with the constraining part.[4]

References

[1] Smith 1990, p. 38.
[2] *Fastener terms* (http://www.canadianstainless.ca/page9.html), , retrieved 2009-06-29.
[3] Low & Bevis 1908, p. 115.
[4] *Helical Compression Spring Terminology* (http://www.masterspring.com/technical_resources/helical_compression_spring_terminology/default.html), , retrieved 2009-06-29.

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- Smith, Carroll (1990), *Carroll Smith's Nuts, Bolts, Fasteners, and Plumbing Handbook* (http://books.google.com/books?id=A81HmmRCN7YC), MotorBooks/MBI Publishing Company, ISBN 0879384069, http://books.google.com/books?id=A81HmmRCN7YC.

Bellcrank

A **bell crank** is a type of → crank that changes motion around a 90 degree angle. The name comes from its first use, changing the vertical pull on a rope to a horizontal pull on the striker of a bell, used for calling staff in large houses or commercial establishments.

The bell crank consists of an "L" shaped crank pivoted where the two arms of the L meet. Moving rods (or ropes) are attached to the ends of the L arms. When one is pulled, the L rotates around the pivot point, pulling on the other arm.

Changing the length of the arms changes the → mechanical advantage of the system. Many applications do not change the direction of motion, but instead to amplify a force "in line", which a bell crank can do in a limited space. There is a tradeoff between range of motion, linearity of motion, and size. The greater the angle traversed by the crank, the more non-linear the motion becomes (the more the motion ratio changes).

External links

- Bell Crank [1]

References

[1] http://www.flying-pig.co.uk/mechanisms/pages/bellcrank.html

Bi-metallic strip

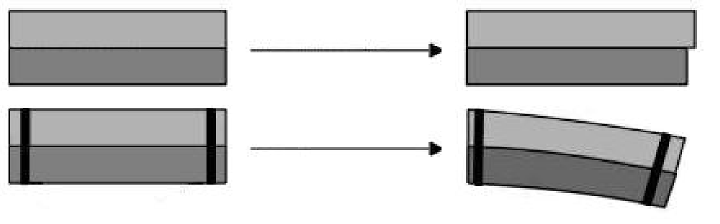
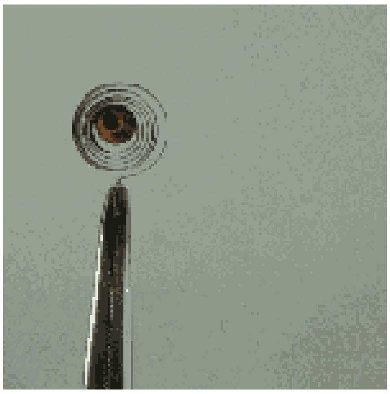


Diagram of a bi-metallic strip showing how the difference in thermal expansion in the two metals leads to a much larger sideways displacement of the strip

A **bi-metallic strip** is used to convert a temperature change into mechanical displacement. The strip consists of two strips of different metals which expand at different rates as they are heated, usually steel and copper, or in some cases brass instead of copper. The strips are joined together throughout their length either riveting, brazing or welding. The different expansions force the flat strip to bend one way if heated, and in the opposite direction if cooled below its normal temperature. The metal with the higher coefficient of thermal expansion is on the outer side of the curve when the strip is heated and on the inner side when cooled.

The sideways displacement of the strip is much larger than the small lengthways expansion in either of the two metals. This effect is used in a range of mechanical and electrical devices. In some applications the bi-metal strip is used in the flat form. In others, it is wrapped into a coil for compactness. The greater length of the coiled version gives improved sensitivity.



A bi-metallic coil from a thermometer reacts to the heat from a lighter, by uncoiling and then coiling back up when the lighter is removed.

History

The bimetallic strip was probably invented by the eighteenth century clockmaker John Harrison for his third marine timekeeper (H3) to compensate for temperature-induced changes in the balance spring.[1] It should not be confused with his bimetallic mechanism for correcting for thermal expansion in the gridiron pendulum. His earliest examples had two individual metal strips joined by rivets but he also invented the later technique of directly fusing molten brass onto a steel substrate. A strip of this type was fitted to his last timekeeper, H5. His invention is recognized in the memorial to him in Westminster Abbey, England.

John Harrison's Memorial in Westminster Abbey, London

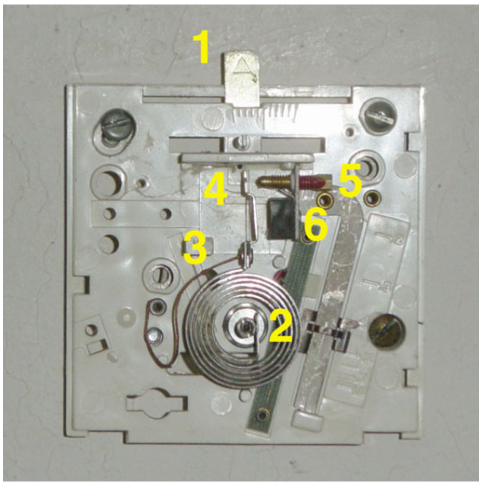
Applications

Clocks

Mechanical clock mechanisms are sensitive to temperature changes which lead to errors in time keeping. A bimetallic strip is used to compensate for this in some mechanisms. The most common method is to use a bimetallic construction for the circular rim of the balance wheel. As the spring controlling the balance becomes weaker with increasing temperature, so the balance becomes smaller in diameter to keep the period of oscillation (and hence timekeeping) constant.

Thermostats

In the regulation of heating and cooling, thermostats that operate over a wide range of temperatures the bi-metal strip is mechanically fixed and attached to an electrical power source while the other (moving) end carries an electrical contact. In adjustable thermostats another contact is positioned with a regulating knob or lever. The position so set controls the regulated temperature, called the **set point**.



Thermostat with bi-metal coil at (2)

Some thermostats use a mercury switch connected to both electrical leads. The angle of the entire mechanism is adjustable to control the set point of the thermostat.

Depending upon the application, a higher temperature may open a contact (as in a heater control) or it may close a contact (as in a refrigerator or air conditioner).

The electrical contacts may control the power directly (as in a household iron) or indirectly, switching electrical power through a relay or the supply of natural gas or fuel oil through an electrically operated valve. In some natural gas heaters the power may be provided with a thermocouple that is heated by a pilot light (a small, continuously burning flame). In devices without pilot lights for ignition (as in most modern gas clothes dryers and some natural gas heaters and decorative fireplaces) the power for the contacts is provided by reduced household electrical power that operates a relay controlling an electronic ignitor, either a resistance heater or an electrically powered spark generating device.

For an illustration of a bi-metal element in a simple thermostat, see the thermostat entry.

Thermometers

A direct indicating dial thermometer (such as a patio thermometer or a meat thermometer) uses a bi-metallic strip wrapped into a coil. One end of the coil is fixed to the housing of the device and the other drives an indicating needle. A bi-metallic strip is also used in a recording thermometer.

Heat engines

Simple toys have been built which demonstrate how the principle can be used to drive a heat engine, ([2] See under Extraordinary Engines, the Seesaw - Candle Bimetal Engine)

Calculations

Curvature of a Bimetallic Beam:

$$\kappa = \frac{6E_1E_2(h_1+h_2)h_1h_2\epsilon}{E_1^2h_1^4+4E_1E_2h_1^3h_2+6E_1E_2h_1^2h_2^2+4E_1E_2h_2^3h_1+E_2^2h_2^4}$$

Where E_1 and h_1 are the Young's Modulus and height of Material One and E_2 and h_2 are the Young's Modulus and height of Material Two. ϵ is the misfit strain, calculated by:

$$\epsilon = (\alpha_1 - \alpha_2)\Delta T$$

Where α_1 is the Coefficient of Thermal Expansion of Material One and α_2 is the Coefficient of Thermal Expansion of Material Two. ΔT is the current temperature minus the reference temperature (the temperature where the beam has no flexure). [3] [4]

External links

- [http://hyperphysics.phy-astr.gsu.edu/hbase/thermo/bimetal.html Bimetallic Strip with liquid nitrogen

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[3] Clyne, TW. "Residual stresses in surface coatings and their effects on interfacial debonding." Key Engineering Materials (Switzerland). Vol. 116-117, pp. 307-330. 1996
[4] Timoshenko, J. Opt. Soc. Am. 11, 233 (1925)

Bimetal

Bi-metal refers to an object that is composed of two separate metals joined together. Instead of being a mixture of two or more metals, like alloys, bimetallic objects consist of layers of different metals. Trimetal and tetrametal refer to objects composed of three and four separate metals respectively.

→ Bi-metallic strips and disks, which convert a temperature change into mechanical displacement, are the most recognized bimetallic objects due to their name. However, there are other common bimetallic objects. For example, tin cans consist of steel covered with tin. The tin prevents the can from rusting. To cut costs and prevent people from melting them down for their metal, coins are often composed of a cheap metal covered with a more expensive metal. For example, the United States penny was changed from 95% copper to 95% zinc, with a thin copper plating to retain its appearance[1]. A common type of trimetallic object (before the all-aluminium can) was a tin-plated steel can with an aluminum lid with a pull tab. Making the lid out of aluminum allowed it to be pulled off by hand instead of using a can opener, but these cans proved difficult to recycle owing to their mix of metals.

Blades for band saws and reciprocating saws are often made with bimetal construction. The teeth, made of high speed steel, are bonded (by various methods, for example, electron beam welding or laser beam welding) to the high-strength carbon steel base.

References

[1] http://en.wikipedia.org/wiki/Cent_%28United_States_coin%29#References

Block and bleed manifold

A **block and bleed manifold** is a → hydraulic manifold that combines one or more block/isolate valves, usually ball valves, and one or more bleed/vent valves, usually ball or needle valves, into one component, for interface with other components (pressure measurement transmitters, gauges, switches, etc.) of a → hydraulic (fluid) system. The purpose of the block and bleed manifold is to isolate or block the flow of fluid in the system, so the fluid from upstream of the manifold does not reach other components of the system that are downstream, then bleed off or vent the remaining fluid from the system on the downstream side of the manifold. For example, a block and bleed manifold would be used to stop the flow of fluids to some component, then vent the fluid from that component's side of the manifold, in order to effect some kind of work (maintenance/repair/replacement) on that component.

A block and bleed manifold with one block valve and one bleed valve is also known as an **isolation valve** or **block and bleed valve**; a block and bleed manifold with multiple valves is also known as an **isolation manifold**.

Also used in combustionable gas trains in many industrial applications.

Double Block and Bleed Valves replace existing traditional techniques employed by pipeline engineers to generate a double block and bleed configuration in the pipeline.

Cartridge Type Standard Length Double Block and Bleed Valves have a patented design which incorporates two ball valves and a bleed valve into one compact cartridge type unit with ANSI B16.5 tapped flanged connections. The major benefit of this design configuration is that the valve has the same face-to-face dimension as a single block ball valve (as specified in API 6D and ANSI B16.10), which means the valve can easily be installed into an existing pipeline without the need for any pipeline re-working.

Three Piece Non Standard Length Double Block and Bleed Valves (DBB Valves) feature the traditional style of flange-by-flange type valve and is available with ANSI B16.5 flanges, hub connections and welded ends to suit the pipeline system it is to be installed in. It features all the benefits of the single unit DBB valve, with the added benefit of a bespoke face-to-face dimension if required.

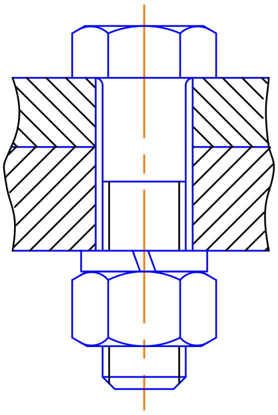
The single unit DBB design also has operational advantages, there are significantly **fewer potential leak paths** within the double block and bleed section of the pipeline. Because the valves are full bore with an uninterrupted flow orifice they have got a negligible pressure drop across the unit. The pipelines where these valves are installed can also be pigged without any problems.

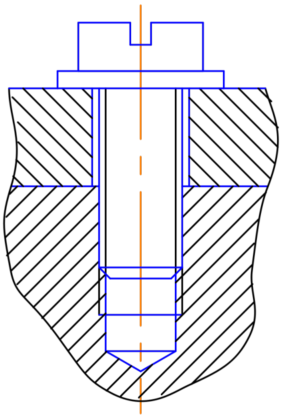
There are several advantages in using a Double Block and Bleed Valve. Significantly, because all the valve components are housed in a single unit, the space required for the installation is dramatically reduced thus freeing up room for other pieces of essential equipment.

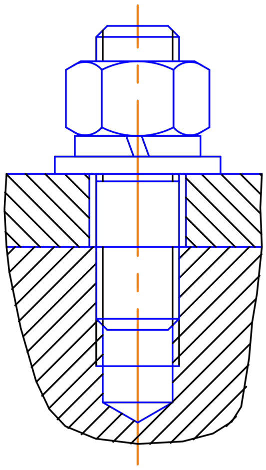
Considering the operations and procedures executed before an operator can intervene, the Double Block and Bleed manifold offers further advantages over the traditional hook up.

Due to the volume of the cavity between the two balls being so small, the operator is afforded the opportunity to evacuate this space efficiently thereby quickly establishing a safe working environment.

Bolted joint


Bolted joint


Screw joint


Stud joint

Bolted joints are one of the most common elements in construction and machine design. They consist of *cap screws* or *studs* that capture and join other parts, and are secured with the mating of screw threads.

There are two main types of bolted joint designs. In one method the bolt is tightened to a calculated clamp load, usually by applying a measured torque load. The joint will be designed such that the clamp load is never overcome by the forces acting on the joint (and therefore the joined parts see no relative motion).

The other type of bolted joint does not have a designed clamp load but relies on the → shear strength of the bolt shaft. This may include clevis linkages, joints that can move, and joints that rely on locking mechanism (like lock washers, thread adhesives, and lock nuts).

Theory

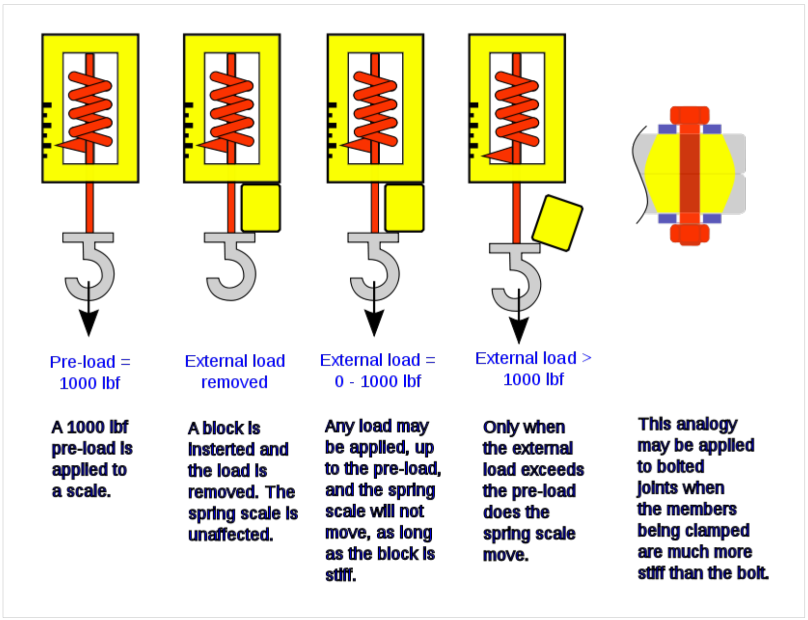
The clamp load, also called preload, of a cap screw is created when a torque is applied, and is generally a percentage of the cap screw's proof strength. Cap screws are manufactured to various standards that define, among other things, their strength and clamp load. *Torque charts* are available that identify the required torque for cap screws based on their *property class* or *grade*.

When a cap screw is tightened it is stretched, and the parts that are captured are compressed. The result is a spring-like assembly. External forces are designed to act on the parts that have been compressed, and not on the cap screw.

The result is a non-intuitive distribution of strain; in this engineering model, as long as the forces acting on the compressed parts do not exceed the clamp load, the cap screw do not *see* any increased load. This model is only valid when the members under compression are

much stiffer than the capscrew.

This is a simplified model. In reality the bolt will see a small fraction of the external load prior to it exceeding the clamp load, depending on the compressed parts' stiffness with respect to the hardware's stiffness.



The results of this type of joint design are:

- *Greater* preloads in bolted joints *reduce* the fatigue loading of the hardware.
- For cyclic loads, the bolt does not see the full amplitude of the load. As a result, fatigue life can be increased or, if the material exhibits an endurance limit, extended indefinitely.[1]
- As long as the external loads on a joint don't exceed the clamp load, the hardware doesn't *see* any motion and will not come loose (no locking mechanisms are required).

In the case of the compressed member being less stiff than the hardware (soft, compressed gaskets for example) this analogy doesn't hold true. The load seen by the hardware is the preload plus the external load.

Thread strength

Nut threads are designed to support the rated clamp load of their respective bolts. If tapped threads are used instead of a nut, then their strength needs to be calculated. Steel hardware into tapped steel threads requires a depth of 1.5× thread diameter to support the full clamp load.

If an appropriate depth of threads is not available, or the threads are in a weaker material than the cap screw, then the clamp load (and torque) needs to be derated appropriately.

Setting the torque

Engineered joints require the torque to be accurately set. Setting the torque for cap screws is commonly achieved using a torque wrench. The required torque value for a particular screw application may be quoted in the published standard document or defined by the manufacturer.

The clamp load produced during tightening is higher than 75% of the fastener's proof load. To achieve the benefits of the pre-loading, the clamping force in the screw must be higher than the joint separation load. For some joints a number of screws are required to secure the joint, these are all hand tightened before the final torque is applied to ensure an even joint seating.

The torque value is dependent on the friction between the threads and beneath the bolt or nut head, this friction can be affected by the application of a lubricant or any plating (e.g.

cadmium or zinc) applied to the screw threads. The screw standard will define whether the torque value is for a dry or lubricated screw thread. If a screw is torqued rather than the nut then the torque value should be increased [2] to compensate for the additional friction - screws should only be torqued if they are fitted in clearance holes.

Lubrication can reduce the torque value by 15 – 25%, so lubricating a screw designed to be torqued dry could over tighten it. Over tightening may cause the bolt to fail, it could damage the screw thread or stretch the bolt. A bolt stretched beyond its elastic limit may no longer adequately clamp the joint.

Torque wrenches do not give a direct measurement of the clamping force in the screw - much of the force applied is lost in overcoming friction. Factors affecting the tightening friction: dirt, surface finish, lubrication, etc. can result in a deviation in the clamping force.

More accurate[3] methods for setting the screw clamping force rely on defining or measuring the bolt extension. The screw extension can be defined by measuring the angular rotation of the screw (turn of the nut method) which gives a screw extension based on thread pitch. Measuring the screw extension directly allows the clamping force to be very accurately calculated. This can be achieved using a dial test indicator, reading deflection at the bolt tail, using a strain gauge or ultrasonic length measurement.

There is no simple method to measure the tension of a bolt already in place other than to tighten it and identify at which point the bolt starts moving. This is known as *re-torqueing*. An electronic torque wrench is used on the bolt under test, and the torque applied is constantly measured. When the bolt starts moving (tightening) the torque briefly drops sharply - this drop-off point is considered the measure of tension.

Recent developments enable bolt tensions to be estimated by using ultrasonic testing. Another way to ensure correct bolt tension (mainly in steel erecting) involves the use of crush-washers. These are washers that have been drilled and filled with orange RTV. When the orange rubber strands appear, the tension is correct.

Large volume users such as auto makers frequently use computer controlled nut drivers. With such machines the computer in effect plots a graph of the torque exerted. Once the torque reaches a set maximum torque chosen by the designer, the machine stops. Such machines are often used to fit wheelnuts and will normally tighten all the wheel nuts simultaneously.

Failure modes

The most common mode of failure is overloading. Operating forces of the application produce loads that exceed the clamp load and the joint works itself loose, or fails catastrophically.

Over *torquing* will cause failure by damaging the threads and deforming the hardware, the failure might not occur until long afterward. Under *torquing* can cause failures by allowing a joint to come loose. It may also allow the joint to flex and thus fail under fatigue.

→ Brinelling may occur with poor quality washers, leading to a loss of clamp load and failure of the joint.

Corrosion, → embedment and exceeding the shear stress limit are other modes of failure.

Locking mechanisms

Locking mechanisms keep bolted joints from coming loose. They are required when vibration or joint movement will cause loss of clamp → load and joint failure, and in equipment where the security of bolted joints is essential.

- two nuts, tightened on each other.
- Locknut (prevailing torque nuts)
  - polymer insert nut
  - oval lock nut
- lock washer
- thread adhesive
- lock wire, castellated nuts/capscrews (common in the aircraft industry)


Bolted joints in an automobile wheel. Here the outer fasteners are 4 studs with 3 of the 4 nuts that secure the wheel. The central nut (with locking cover and cotter pin) secures the wheel bearing to the spindle.

Measurement of frictional torque of threads in bolt

The torque is applied by means of suspending the weights on one end of the rope and other end is wound around the head of the bolt and tied to the projection. The amount of load is increased gradually till the bolt starts rotating. The applied load is then calculated by adding up the weights. This is the load that is required to overcome the friction between the threads. Similarly the net applied torque is calculated by multiplying the resultant load by bolt head radius.

In another method the torque is applied to the nut by an electromagnetic force. A specially designed gripper is used to grip the nut. A bar magnet is mounted on two sides of the gripper. Externally a coil is wound in which AC (alternating current) current is passed. As the magnetic field from the permanent magnet interacts with the field created by the coil, a torque is generated which would try to rotate the magnet, thus rotating the nut. This is quite similar to the construction of the motor, and hence a motor can be directly used to provide the torque. Stepper motor can be used so that the torque is provided in steps, as desired, each time giving a small angular displacement. The torque provided by the motor can be known at each discrete angular displacement of $\Delta\theta$. The process is repeated until the nut has traversed to the desired length of the bolt. The discrete torques can be added to get the net torque consumed in displacing the nut from one end of the bolt to the desirable point. This is the torque that is required to overcome the friction between the threads.

Bolt banging

Bolt banging occurs in buildings where structural members that are bolted together slip.

International standards

- SA-193
- SA-194
- SA-320

See also

- Bolt manufacturing process
- → Embedment
- Quenching and Tempering (Q&T)
- Rivet

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Bibliography

- Collins, Jack A.; Staab, George H.; Busby, Henry R. (2002), *Mechanical Design of Machine Elements and Machines*, Wiley, ISBN 0471033073.

External links

- Information on "bolt banging" (loud bang caused by bolts seating after construction) [4]
- *Threaded Fasteners - Tightening to Proper Tension* [5], US Department of Defense document MIL-HDBK-60, 2.6MB pdf.
- NASA-RP-1228 Fastener Design Manual [6]

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[1] Collins, p. 481.
[2] AIPS 01-02-008: "Bolt Torque"
[3] Machinery's Handbook: "Machinery's Handbook 27th Edition, p 1499"
[4] http://www.aisc.org/MSCTemplate.cfm?Section=Steel_Interchange2&Template=/CustomSource/Faq/SteelInterchange.cfm&FaqID=1957
[5] http://assist.daps.dla.mil/quicksearch/basic_profile.cfm?ident_number=70455
[6] http://hdl.handle.net/2060/19900009424

Brake shoe

A **Brake shoe** is the part of a braking system which carries the brake lining (in the drum brakes used on automobiles) or the brake block in train brakes and bicycle brakes.

Automobile drum brake

The brake shoe carries the brake lining, which is riveted or glued to the shoe. When the brake is applied, the shoe moves and presses the lining against the inside of the drum. The friction between lining and drum provides the braking effort and energy is dissipated as heat.


Drum brake shoes and linings

Modern cars have disc brakes all round, or discs at the front and drums at the rear. An advantage of discs is that they can dissipate heat more quickly than drums so there is less risk of overheating.

The reason for retaining drums at the rear is that a drum is more effective than a disc as a parking brake.

Railway tread brake

The brake shoe carries the brake block. The block was originally made of wood but is now usually cast iron. When the brake is applied, the shoe moves and presses the block against the tread of the wheel. As well as providing braking effort this also "scrubs" the wheel and keeps it clean. Tread brakes on passenger trains have now largely been superseded by disc brakes.

Bicycle rim brake

This comprises a pair of rectangular open boxes which are mounted on the brake calipers of a bicycle and that hold the brake blocks which rub on the rim of a bicycle wheel to slow the bicycle down or stop it.

See also

- Brake pad

Brinelling

Brinelling refers to a material surface failure caused by contact stress that exceeds the material limit. This failure is caused by just one application of a load great enough to exceed the material limit. The result is a permanent dent or "brinell" mark. It is a common cause of roller bearing failures, and loss of preload in → bolted joints when a hardened washer is not used. Engineers can use the Brinell hardness of materials in their calculations to avoid this mode of failure. A rolling element bearing's static load rating is defined to avoid this failure type. A similar-looking kind of damage is called false brinelling. This occurs when contacting bodies vibrate against each other in the presence of very small loads. The results is a finely polished surface that resembles a brinell mark but has not permanently deformed either contacting surface.

See also

- False brinelling

Bullwheel

For the U.S. Navy fuel oil barge, see USNS Bullwheel.

A **bullwheel** is a large wheel on which a rope turns, such as in a chairlift. In that application, the bullwheel that is attached to the prime mover is called the drive bullwheel, with the other known as the return bullwheel.


A chairlift's return bullwheel.

Originally, *bullwheel* was an oil field term applied to the large wheel that turns the drum upon which the drilling line is wound in percussion drilling.

References

- This article contains public domain text from USNS Bullwheel [1] in the Dictionary of American Naval Fighting Ships.

References

[1] http://www.history.navy.mil/danfs/b10/bullwheel-i.htm

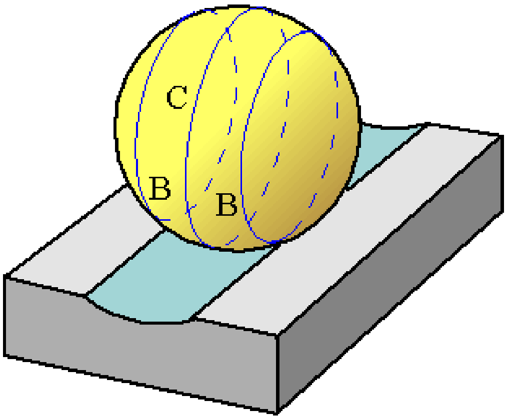
Burnishing (metal)

Burnishing is the plastic deformation of a surface due to sliding contact with another object. Visually, burnishing smears the texture of a rough surface and makes it shinier. Burnishing may occur on any sliding surface if the contact stress locally exceeds the yield strength of the material.

The inner ring of this bearing has been burnished by the bearing's rollers.

Mechanics

To understand burnishing, first look at the simple case of a hardened ball on a flat plate. If the ball is pressed directly into the plate, stresses develop in both objects around the area where they contact. As this normal force increases, both the ball and the plate's surface deform.



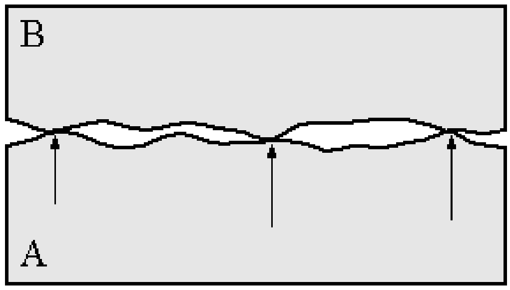
A ball plowing a trough through a flat plate.

The deformation caused by the hardened ball is different depending on the magnitude of the force pressing against it. If the force on it is small, when the force is released both the ball and plate's surface will return to their original, undeformed shape. In this case, the stresses in the plate are always less than the yield strength of the material, so the deformation is purely elastic. Since it was given that the flat plate is softer than the ball, the plate's surface will always deform more. If a larger force is used, there will also be plastic deformation and the plate's surface will be permanently altered. A bowl-shaped indentation will be left behind, surrounded by a ring of raised material that was displaced by the ball. The stresses between the ball and the plate are described in more detail by Hertzian stress theory.

Now consider what happens if the external force on the ball drags it across the plate. In this case, the force on the ball can be decomposed into two component forces: one normal to the plate's surface, pressing it in, and the other tangential, dragging it along. As the tangential component is increased, the ball will start to slide along the plate. At the same time, the normal force will deform both objects, just as with the static situation. If the normal force is low, the ball will rub against the plate but not permanently alter its surface. The rubbing action will create friction and heat, but it will not leave a mark on the plate.

However, as the normal force increases, eventually the stresses in the plate's surface will exceed its yield strength. When this happens the ball will plow through the surface and create a trough behind it. The plowing action of the ball is burnishing.

Burnishing also occurs on surfaces that conform to each other, such as between two flat plate, but it happens on a microscopic scale. Even the smoothest of surfaces will have imperfections if viewed at a high enough magnification. The imperfections that extend above the general form of a surface are called asperities, and they can plow material on another surface just like the ball dragging along the plate. The combined effect of many of these asperities produce the smeared texture that is associated with burnishing.



Upon magnification, two flat plates touch only at a few asperities.

Effects on mechanical components

Burnishing is normally undesirable in mechanical components for a variety of reasons, sometimes simply because its effects are unpredictable. Even light burnishing will significantly alter the surface finish of a part. Initially the finish will be smoother, but with repetitive sliding action, grooves will develop on the surface along the sliding direction. The plastic deformation associated with burnishing will harden the surface and generate compressive residual stresses. Although these properties are usually advantageous, excessive burnishing leads to sub-surface cracks which cause spalling, a phenomenon where the upper layer of a surface flakes off of the bulk material.

Burnishing may also affect the performance of a machine. The plastic deformation associated with burnishing creates greater heat and friction than from rubbing alone. This reduces the efficiency of the machine and limits its speed. Furthermore, plastic deformation alters the form and geometry of the part. This reduces the precision and accuracy of the machine. The combination of higher friction and degraded form often leads to a runaway situation that continually worsens until the component fails.

To prevent burnishing, sliding must be avoided. In the areas of a machine that slide with respect to each other, roller bearings can be inserted so that the components are in rolling contact instead of sliding. If sliding cannot be avoided, then a lubricant should be added between the components. The purpose of the lubricant in this case is to separate the components with a lubricant film so they cannot contact. The lubricant also distributes the load over a larger area, so that the local contact forces are not as high. If there was already a lubricant, its film thickness must be increased; usually this can be accomplished by increasing the viscosity of the lubricant.

Burnishing in manufacturing

Burnishing is not always bad. If it occurs in a controlled manner, it can have desirable effects. Burnishing processes are used in manufacturing to improve the size, shape, surface finish, or surface hardness of a workpiece. It is essentially a forming operation that occurs on a small scale. The benefits of burnishing often include: Combats fatigue failure, prevents corrosion and stress corrosion, textures surfaces to eliminate visual defects, closes porosity, creates surface compressive residual stress.

There are several forms of burnishing processes, the most common are roller burnishing and ball burnishing (ballizing). In both cases, a burnishing tool rubs against the workpiece and plastically deforms its surface. The workpiece may be at ambient temperature, or heated to reduce the forces and wear on the tool. The tool is usually hardened and coated with special materials to increase its life.

Ball burnishing, or ballizing, is a replacement for other bore finishing operations such as grinding, honing, or polishing. A ballizing tool consists of one or more over-sized balls that are pushed through a hole. The tool is similar to a broach, but instead of cutting away material, it plows it out of the way.[1]

Ball burnishing is also used as a deburring operation. It is especially useful for removing the burr in the middle of a through hole that was drilled from both sides.[1]

Roller burnishing, or surface rolling, is used on cylindrical, conical, or disk shaped workpieces. The tool resembles a roller bearing, but the rollers are fixed so they slide against the workpiece surface instead of rolling. It is simultaneously rotated and pressed into the workpiece. Typical applications for roller burnishing include hydraulic system components, shaft fillets, and sealing surfaces.[2]

Burnishing also occurs to some extent in machining processes. In turning, burnishing occurs if the cutting tool is not sharp, if a large negative rake angle is used, if a very small depth of cut is used, or if the workpiece material is gummy. As a cutting tool wears, it becomes more blunt and the burnishing effect becomes more pronounced. In grinding, since the abrasive grains are randomly oriented and some are not sharp, there is always some amount of burnishing. This is one reason the grinding is less efficient and generates more heat than turning.

See also

- Cold working
- Deformation
- Low plasticity burnishing

External links

- Information on Burnishing and Other Surface Enhancement Practices [3]
- Metal Burnishing (Cutlery, Pewter, Silver) [4] Spons' Workshop

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[3] http://www.lambdatechs.com/surface-enhancement/surface-enhancement-methods.html
[4] http://knolik.com/article0004009.html

Cam

A **cam** is a projecting part of a rotating wheel or shaft that strikes a → lever at one or more points on its circular path. The cam can be a simple tooth, as is used to deliver pulses of power to a steam hammer, for example, or an eccentric disc or other shape that produces a smooth reciprocating (back and forth) motion in the *follower* which is a lever making contact with the cam.

Animation showing rotating cams and cam followers producing reciprocating motion.

The reason the cam acts as a lever is because the hole is not directly in the centre, therefore moving the cam rather than just spinning. On the other hand, some cams are made with a hole exactly in the centre and their sides act as cams to move the levers touching them to move up and down or to go back and forth.

Overview

The cam can be seen as a device that translates movement from circular to reciprocating (or sometimes oscillating). A common example is the camshaft of an automobile, which takes the rotary motion of the engine and translates it into the reciprocating motion necessary to operate the intake and exhaust valves of the cylinders.

The opposite operation, translation of reciprocating motion to circular motion, is done by a → crank. An example is the crankshaft of a car, which takes the reciprocating motion of the pistons and translates it into the rotary motion necessary to operate the wheels.

Cams can also be viewed as information-storing and -transmitting devices. Examples are the cam-drums that direct the notes of a music box or the movements of a screw machine's various tools and chucks. The information stored and transmitted by the cam is the answer to the question, "What actions should happen, and when?" (Even an automotive camshaft essentially answers that question, although the music box cam is a still-better example in illustrating this concept.)

Certain cams can be characterized by their displacement diagrams, which reflect the changing position a roller follower would make as the cam rotates about an axis. These diagrams relate angular position to the radial displacement experienced at that position. Several key terms are relevant in such a construction of plate cams: base circle, prime circle (with radius equal to the sum of the follower radius and the base circle radius), pitch curve which is the radial curve traced out by applying the radial displacements away from the prime circle across all angles, and the lobe separation angle (**LSA** - the angle between two adjacent intake and exhaust cam lobes). Displacement diagrams are traditionally presented as graphs with non-negative values.

History

An early cam was built into Hellenistic water-driven automata from the 3rd century BC.[1] The use of cams in a camshaft was first introduced in 1206 by the Arab inventor Al-Jazari born in Al-Jazira, who employed them in his automata, water clocks and water-raising machines.[2] The cam and camshaft later appeared in European mechanisms from the 14th century.[3]

See also

- Binary cam, for compound bows
- → Cam follower
- Dwell cam
- Linkage (mechanical)
- Spring-loaded camming device
- → Swashplate
- Trip hammer
- Piston

External links

- How round is your circle? [4] Contains various cam mechanisms
- Kinematic Models for Design Digital Library (KMODDL) [21] - Movies and photos of hundreds of working mechanical-systems models at Cornell University. Also includes an e-book library [22] of classic texts on mechanical design and engineering.

References

[1] Andrew Wilson: "Machines, Power and the Ancient Economy", *Journal of Roman Studies*, Vol. 92. (2002), pp. 1-32 (16)
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[3] A. Lehr (1981), *De Geschiedenis van het Astronomisch Kunstuurwerk*, p. 227, Den Haag. (See (http://odur.let.rug.nl/~koster/musicbox/musicbox2.htm))
[4] http://www.howround.com/

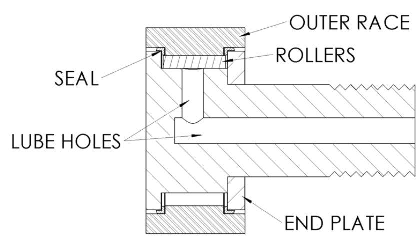
Cam follower

A **cam follower**, also known as a **track follower**,[1] is a specialized type of roller or needle bearing designed to follow → cams. Cam followers come in a vast array of different configurations, however the most defining characteristic is how the cam follower mounts to its mating part; *stud* style cam followers use a stud while the *yoke* style has a hole through the middle.[2]

The first cam follower was invented and patented in 1937 by Thomas L. Robinson of the McGill Manufacturing Company.[3] It replaced using just a standard bearing and bolt. The new cam followers were easier to use because the stud was already included and they could also handle higher loads.[2]

Construction

While cam followers appear to be very similar to roller bearing in construction they have quite a few differences. Standard ball and roller bearings are designed to be pressed into a rigid housing, which provides circumferential support. This keeps the outer race from deforming, so the race cross-section is relatively thin. In the case of cam followers the outer race is loaded at a single point, so the outer race needs a thicker cross-section to reduce deformation. However, in order to facilitate this the roller diameter must be decreased, which also decreases the dynamic bearing capacity.[4]



A cross-sectional view of a stud type cam follower

End plates are used to contain the needles or bearing axially. On stud style followers one of the end plates is integrated into the inner race/stud; the other is pressed onto the stud up to a shoulder on the inner race. The inner race is induction hardened so that the stud remains soft if modifications need to be made. On yoke style followers the end plates are peened or pressed onto the inner race or liquid metal injected onto the inner race. The inner race is either induction hardened or through hardened.[2]

Another difference is that a lubrication hole is provided to relubricate the follower periodically. A hole is provided at both ends of the stud for lubrication. They also usually they have a black oxide finish to help reduce corrosion.[2]

Types

There are many different types of cam followers available.

Anti-friction element

The most common anti-friction element employed is a *full compliment* of needle rollers. This design can withstand high radial loads but no thrust loads. A similar design is the *caged needle roller* design, which also uses needle rollers, but uses a cage to keep them separated. This design allows for higher speeds but decreases the load capacity. The cage also increases internal space so it can hold more lubrication, which increases the time between relubrications. Depending on the exact design sometimes two rollers are put in

each pocket of the cage.[2]

For heavy-duty applications a *roller* design can be used. This employs two rows of larger rollers to increase the dynamic load capacity and provide some thrust capabilities. This design can support higher speeds than the full complement design.[2]

For light-duty applications a *bushing* type follower can be used. Instead of using a type of a roller a plastic bushing is used to reduce friction, which provides a maintenance free follower. The disadvantage is that is can only support light loads, slow speeds, no thrust loads, and the temperature limit is 200 °F (93 °C). A bushing type stud followers can only support approximately 25% of the load of a roller type stud follower, while the heavy and yoke followers can handle 50%.[2]

Shape

The outer diameter (OD) of the cam follower (stud or yoke) can be the standard cylindrical shape or be crowned. Crowned cam followers are used to keep the load evenly distributed if it deflects or if there is any misalignment between the follower and the followed surface. They are also used in turntable type applications to reduce skidding. Crowned followers can compensate for up to 0.5° of misalignment, while a cylindrical OD can only tolerate 0.06°.[5] The only disadvantage is that they cannot bear as much load because of higher stresses.[2]

Stud

Stud style cam followers usually have a *standard* sized stud, but a *heavy* stud is available for increased static load capacity.[2]

Drives

The standard driving system for a stud type cam follower is a slot, for use with a flat head screwdriver. However, hex sockets are available for higher torquing ability, which is especially useful for eccentric cam followers and those used in blind holes. The only problem with hex sockets is that it eliminates relubrication capabilities on that end of the cam follower.[2]

Eccentricity

Stud type cam followers are available with an eccentric stud. The stud has a bushing pushed onto it that has an eccentric outer diameter. This allows for adjustability during installation to eliminate any backlash. The adjustable range for an eccentric bearing is twice that of the eccentricity.[2]

Yoke

Yoke type cam followers are usually used in applications where minimal deflection is required, as they can be support on both sides. They can support the same static load as a heavy stud follower.[2]

Track followers

All cam followers can be track followers, but not all track followers are cam followers. Some track followers have specially shaped outer diameters (OD) to follow tracks. For example, track followers are available with a V-groove for following a V-track, or the OD can have a flange to follow the lip of the track.[6]

Specialized track followers are also designed to withstand thrust loads so the anti-friction elements are usually bearing balls or of a tapered roller bearing construction.[6]

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Cam plastometer

The **cam plastometer** is a mechanical testing machine. It measures the resistance of non-brittle materials to compressive deformation at constant true-strain rates. In this way, it can be compared a bit to the gleeble. In the early days, the machine operates at relatively low strain rates, but over time it has been enhanced and currently it can operate over a wide range of strain rates[1]

The machine is patented under the name of "United States Patent 4109516"[2] .

In the machine, deformation compressive forces are applied to a specimen by two flat, opposing platens which impact a flat, rectangular specimen. The deformation forces can be varied during operation, to simulate actual conditions which occur during industrial pressing and forming operations. The plastometer is also capable of torsional testing of specimens"[2] .

The cam plastometers are expensive and there are only a few of them in the world[3] .

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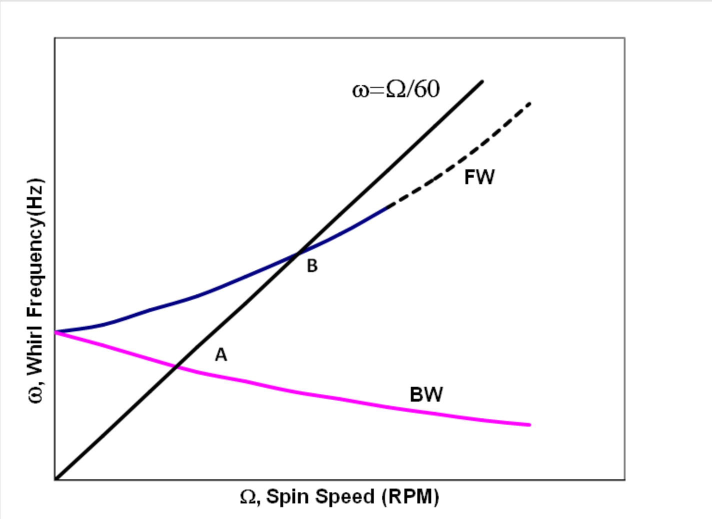
[1] J.E. Hockett and N.A. Lindsay, Journal of Physics E: Scientific Instruments 4 (1971), 520-522.
[2] Cam plastometer (freepatentsonline.com) (http://www.freepatentsonline.com/4109516.html)
[3] G.E. Dieter et al., *Handbook of Workability and Process Design*, ASM International 2003, page 49

Campbell Diagram

Campbell Diagram plot represents system's reponse spectrum as a function of its sollicitation regime.

In rotordynamics



Analytical Campbell Diagram for a Simple Rotor

In rotordynamical systems, the eigenfrequencies often depend on the rotation rates due to the induced gyroscopic effects or variable hydrodynamic conditions in fluid bearings etc. It might represent the following cases:

1. *Analytically* computed values of eigenfrequencies as a function of the shaft's rotation speed.

2. *Experimentally* measured vibration response spectrum as a function of the shaft's rotation speed (waterfall plot), the peak locations for each slice usually corresponding to the eigenfrequencies.

In acoustical engineering

In acoustical engineering, the Campbell diagram would represent the pressure spectrum waterfall plot vs the machine's shaft rotation speed (sometimes also called *3D noise map*).

User:Cedars/Power engineering draft

Power engineering, also called **power systems engineering**, is a subfield of engineering that deals with the generation, transmission and distribution of electric power as well as the electrical devices connected to such systems including generators, motors and transformers. Although much of the field is concerned with the problems of three-phase AC power - the standard for large-scale power transmission and distribution across the modern world - a significant fraction of the field is concerned with the conversion between AC and DC power as well as the development of specialised power systems such as those used in aircraft or for electric railway networks.


A steam turbine used to provide electric power.

History

Electricity became a subject of scientific interest in the late 17th century with the work of William Gilbert.[1] Over the next two centuries a number of important discoveries were made including the incandescent lightbulb and the voltaic pile.[2] [3] Probably the greatest discovery with respect to power engineering came from Michael Faraday who in 1831 discovered that a change in magnetic flux induces an electromotive force in a loop of wire—a principle known as electromagnetic induction that helps explain why generators and transformers work.[4]

In 1881 two electricians built the world's first power station at Godalming in England. The station employed two waterwheels to produce an alternating currrent that was used to supply seven Siemans arc lamps at 250 volts and 34 incandescent lamps at 40 volts.[5] However supply was intermittent and in 1882 Thomas Edison and his company, The Edison Electric Light Company, developed the first steam powered electric power station on Pearl Street in New York City. The Pearl Street Station consisted of several steam-powered generators and initially powered around 3,000 lamps for 59 customers.[6] [7] The power station used direct current and operated at a single voltage. Since the direct current power could not be easily transformed to the higher voltages necessary to minimise power loss, the possible distance between the generators and load was limited to around half-a-mile (800 m).[8]

A sketch of the Pearl Street Station

That same year in London Lucien Gaulard and John Dixon Gibbs demonstrated the first transformer suitable for use in a real power system. The practical value of Gaulard and Gibbs' transformer was demonstrated in 1884 at Turin where the transformer was used to light up forty kilometres (25 miles) of railway from a single alternating current generator.[9] Despite the success of the system, the pair made some fundamental mistakes. Perhaps the most serious was connecting the primaries of the transformers in series so that switching one lamp on or off would affect other lamps further down the line. Following the demonstration George Westinghouse, an American entrepreneur, imported a number of the transformers along with a Siemens generator and set his engineers to experimenting with them in the hopes of improving them for use in a commercial power system.

One of Westinghouse's engineers, William Stanley, recognised the problem with connecting transformers in series as opposed to parallel and also realised that making the iron core of a transformer a fully-enclosed loop would improve the voltage regulation of the secondary winding. Using this knowledge he built a much improved alternating current power system at Great Barrington, Massachusetts in 1886.[10] Then in 1887 and 1888 another engineer called Nikola Tesla filed a range of patents related to power systems including one for a two-phase induction motor. Although Tesla cannot necessarily be attributed with building the first induction motor, his design, unlike others, was practical for industrial use.[11]

By 1890 the power industry had flourished and power companies had built literally thousands of power systems (both direct and alternating current) in the United States and Europe - these networks were effectively dedicated to providing electric lighting. During this time a fierce rivalry known as the "War of Currents" emerged between Edison, Westinghouse and Tesla over which form of transmission (direct or alternating current) was superior. In 1891, Westinghouse installed the first major power system that was designed to drive an electric motor and not just provide electric lighting. The installation powered a 100 horsepower (75 kW) synchronous motor at Telluride, Colorado with the motor being

started by a Tesla induction motor.[12] On the other side of the Atlantic, Oskar von Miller built a 20 kV 176 km three-phase transmission line from Lauffen am Neckar to Frankfurt am Main for the Electrical Engineering Exhibition in Frankfurt.[13] In 1895, after a protracted decision-making process, the Adams No. 1 generating station at Niagara Falls began transferring three-phase alternating current power to Buffalo at 11 kV. Following completion of the Niagara Falls project, new power systems increasingly chose alternating current as opposed to direct current for electrical transmission.[14]

Although the 1880s and 1890s were seminal decades in the field, developments in power engineering continued throughout the 20th and 21st century. In 1936 the first commercial HVDC (high voltage direct current) line using Mercury arc valves was built between Schenectady and Mechanicville, New York. HVDC had previously been achieved by installing direct current generators in series (a system known as the Thury system) although this suffered from serious reliability issues.[15] In 1957 Siemens demonstrated the first solid-state rectifier (solid-state rectifiers are now the standard for HVDC systems) however it was not until the early 1970s that this technology was used in commercial power systems.[16] In 1959 Westinghouse demonstrated the first circuit breaker that used SF_6 as the interrupting medium.[17] SF_6 is a far superior dielectric to air and, in recent times, its use has been extended to produce far more compact switching equipment (known as switchgear) and transformers.[18] [19] Many important developments also came from extending innovations in the information technology and telecommunications field to the power engineering field. For example, the development of computers meant load flow studies could be run more efficiently allowing for much better planning of power systems. Advances in information technology and telecommunication also allowed for much better remote control of the power system's switchgear and generators.

Basics of electric power

Electric power is the mathematical product of two quantities: current and voltage. These two quantities can vary with respect to time (AC power) or can be kept at constant levels (DC power).

An external AC to DC power adapter used for household appliances

Most refridgerators, air conditioners, pumps and industrial machinary use AC power where as most computers and digital equipment use DC power (the digital devices you plug into the mains typically have an internal or external power adapter to convert from AC to DC power). AC power has the advantage of being easy to transform between voltages and is able to be generated and utilised by brushless machinary. DC power remains the only practical choice in digital systems and can be more economical to transmit over long distances at very high voltages (see HVDC).[20] [21]

The ability to easily transform the voltage of AC power is important for two reasons: Firstly, power can be transmitted over long distances with less loss at higher voltages. So in power networks where generation is distant from the load, it is desirable to step-up (increase) the voltage of power at the generation point and then step-down (decrease) the voltage near the load. Secondly, it is often more economical to install turbines that produce higher voltages than would be used by most appliances, so the ability to easily transform voltages

means this mismatch between voltages can be easily managed.[20]

Solid state devices, which are products of the semiconductor revolution, make it possible to transform DC power to different voltages, build brushless DC machines and convert between AC and DC power. Nevertheless devices utilising solid state technology are often more expensive than their traditional counterparts, so AC power remains in widespread use.[22]

Components of power systems

From the power system that supplies your home to the power system found in a hybrid car, there are a wide range of power systems however there are certain components that are common to most systems. This section introduces some of those components.

Generators, batteries and other power supplies

All power systems have one or more sources of power. Direct current power can be supplied by batteries, fuel cells or photovoltaic cells. Alternating current power is typically supplied by a rotor that spins in a magnetic field (a device known as a turbine). Throughout history there have been a wide range of techniques used to spin a turbine's rotor, from water heated to steam using fossil fuels (including coal, gas and oil) to water itself (hydroelectric power) to wind (wind power). Even nuclear power typically depends on water heated to steam using a nuclear reaction.

The speed at which the rotor spins in combination with the number of generator poles determines the frequency of the alternating current produced by the generator. All generators on a single system will target a set frequency. If the load on the system increases, the generators will require more torque to spin at that speed. In addition, depending on how the poles are fed, alternating current generators can produce a variable number of phases of power. A higher number of phases leads to more efficient power system operation but also increases the infrastructure requirements of the system.

If connecting to the grid, frequency and number of phases are usually a given (typically three-phase at 50 or 60 Hz depending upon national standards). However there are a myriad of other considerations too. These range from the obvious: How much power should the generator be able to supply? What is an acceptable length of time for starting the generator (some generators can take hours to start)? Is the availability of the power source acceptable (some renewables are only available when the sun is shining or the wind is blowing)? To the more technical: How should the generator start (some turbines act like a motor to bring themselves up to speed in which case they need an appropriate starting circuit)? What is the mechanical speed of operation for the turbine and consequently what are the number of poles required? What type of generator is suitable (synchronous or asynchronous) and what type of rotor (squirrel-cage rotor, wound rotor, salient pole rotor or cylindrical rotor)?

Loads

In addition to sources of power, all power systems have loads that use the electrical energy to perform a function. These loads range from household appliances to industrial machinary. Most loads expect a certain voltage and, for alternating current devices, a certain frequency and number of phases. The appliances found in your home, for example, will typically be single-phase operating at 50 or 60 Hz with a voltage between 110 and 260 volts (depending on national standards). An exception exists for centralized air conditioning systems as these are now typically three-phase because this allows them to operate more efficiently. All devices in your house will also have a wattage, this specifies the amount of power the device consumes. At any one time, the net amount of power consumed by the loads on a power system must equal the net amount of power produced by the supplies less the power lost in transmission.

Making sure that the voltage, frequency and amount of power supplied to the loads is in line with expectations is one of the great challenges of power system engineering. However it is not the only challenge, in addition to the power used by a load to do useful work (termed real power) many alternating current devices also use an additional amount of power because they cause the alternating voltage and alternating current to become slightly out-of-sync (termed reactive power). The reactive power like the real power must balance (that is the reactive power produced on a system must equal the reactive power consumed) and can be supplied from the generators, however it is often more economical to supply such power from capacitors (see "Capacitors and reactors" below for more details).

Capacitors and reactors

Protective devices

Power systems in practice

Power systems are not constrained

A power system can contain any of the following components. Although some power engineers are integrating these elements

Power

Power Engineering deals with the generation, transmission and distribution of electricity as well as the design of a range of related devices. These include transformers, electric generators, electric motors and power electronics.

Transmission lines transmit power across the grid.

In many regions of the world, governments maintain an electrical network that connects a variety electric generators together with users of their power. This network is called a power grid. Users purchase electricity from the grid avoiding the costly exercise of having to generate their

own. Power engineers may work on the design and maintenance of the power grid as well as the power systems that connect to it. Such systems are called on-grid power systems and may supply the grid with additional power, draw power from the grid or do both.

Power engineers may also work on systems that do not connect to the grid. These systems are called off-grid power systems and may be used in preference to on-grid systems for a variety of reasons. For example, in remote locations it may be cheaper for a mine to generate its own power rather than pay for connection to the grid and in most mobile applications connection to the grid is simply not practical.

Today, most grids adopt three-phase electric power with alternating current. This choice can be partly attributed to the ease with which this type of power can be generated, transformed and used. Often (especially in the USA), the power is split before it reaches residential customers whose low-power appliances rely upon single-phase electric power. However, many larger industries and organizations still prefer to receive the three-phase power directly because it can be used to drive highly efficient electric motors such as three-phase induction motors.

Transformers play an important role in power transmission because they allow power to be converted to and from higher voltages. This is important because higher voltages suffer less power loss during transmission. This is because higher voltages allow for lower current to deliver the same amount of power, as power is the product of the two. Thus, as the voltage steps up, the current steps down. It is the current flowing through the components that result in both the losses and the subsequent heating. These losses, appearing in the form of heat, are equal to the current squared times the electrical resistance through which the current flows, so as the voltage goes up the losses are dramatically reduced.

For these reasons, electrical substations exist throughout power grids to convert power to higher voltages before transmission and to lower voltages suitable for appliances after transmission.

Components

Power engineering is a network of interconnected components which convert different forms of energy to electrical energy. Modern power engineering consists of three main subsystems: the generation subsystem, the transmission subsystem, and the distribution subsystem. In the generation subsystem, the power plant produces the electricity. The transmission subsystem transmits the electricity to the load centers. The distribution subsystem continues to transmit the power to the customers.

Generation

Generation of electrical power is a process whereby energy is transformed into an electrical form. There are several different transformation processes, among which are chemical, photo-voltaic, and electromechanical. Electromechanical energy conversion is used in converting energy from coal, petroleum, natural gas, uranium, water flow, and wind into electrical energy. Of these, all except the wind energy conversion process take advantage of the synchronous AC generator coupled to a steam, gas or hydro turbine such that the turbine converts steam, gas, or water flow into rotational energy, and the synchronous generator then converts the rotational energy of the turbine into electrical energy. It is the turbine-generator conversion process that is by far most economical and consequently most common in the industry today.

The AC synchronous machine is the most common technology for generating electrical energy. It is called synchronous because the composite magnetic field produced by the three stator windings rotate at the same speed as the magnetic field produced by the field winding on the rotor. A simplified circuit model is used to analyze steady-state operating conditions for a synchronous machine. The phasor diagram is an effective tool for visualizing the relationships between internal voltage, armature current, and terminal voltage. The excitation control system is used on synchronous machines to regulate terminal voltage, and the turbine-governor system is used to regulate the speed of the machine.

The operating costs of generating electrical energy is determined by the fuel cost and the efficiency of the power station. The efficiency depends on generation level and can be obtained from the heat rate curve. We may also obtain the incremental cost curve from the heat rate curve. Economic dispatch is the process of allocating the required load demand between the available generation units such that the cost of operation is minimized.

Transmission

The electricity is transported to load locations from a power station to a transmission subsystem. Therefore we may think of the transmission system as providing the medium of transportation for electric energy. The transmission system may be subdivided into the bulk transmission system and the sub-transmission system. The functions of the bulk transmission are to interconnect generators, to interconnect various areas of the network, and to transfer electrical energy from the generators to the major load centers. This portion of the system is called "bulk" because it delivers energy only to so-called bulk loads such as the distribution system of a town, city, or large industrial plant. The function of the sub-transmission system is to interconnect the bulk power system with the distribution system.

Transmission circuits may be built either underground or overhead. Underground cables are used predominantly in urban areas where acquisition of overhead rights of way are costly or not possible. They are also used for transmission under rivers, lakes and bays. Overhead transmission is used otherwise because, for a given voltage level, overhead conductors are much less expensive than underground cables.

The transmission system is a highly integrated system. It is referred to the substation equipment and transmission lines. The substation equipment contain the transformers, relays, and circuit breakers. Transformers are important static devices which transfer electrical energy from one circuit with another in the transmission subsystem. Transformers are used to step up the voltage on the transmission line to reduce the power loss which is dissipated on the way.[23] A relay is functionally a level-detector; they perform a switching action when the input voltage (or current) meets or exceeds a specific and adjustable value. A circuit breaker is an automatically-operated electrical switch designed to protect an electrical circuit from damage caused by overload or short circuit. A change in the status of any one component can significantly affect the operation of the entire system. There are three possible causes for power flow limitations to a transmission line. These causes are thermal overload, voltage instability, and rotor angle instability. Thermal overload is caused by excessive current flow in a circuit causing overheating. Voltage instabiliy is said to occur when the power required to maintain voltages at or above acceptable levels exceeds the available power. Rotor angle instability is a dynamic problem

that may occur following faults, such as short circuit, in the transmission system. It may also occur tens of seconds after a fault due to poorly damped or undamped oscillatory response of the rotor motion.

Distribution

The distribution system transports the power from the transmission system to the customer. The distribution systems are typically radial because networked systems are more expensive. The equipment associated with the distribution system includes the substation transformers connected to the transmission systems, the distribution lines from the transformers to the customers and the protection and control equipment between the transformer and the customer. The protection equipment includes lightning protectors, circuit breakers, disconnectors and fuses. The control equipment includes voltage regulators, capacitors, relays and demand side management equipment.

See also

- Electric power transmission
- Energy economics
- Fault tolerance
- Power distribution
- Power electronics
- Power generation
- Power system protection
- Stationary engineer

External links

- IEEE Power Engineering Society [24]
- Jadavpur University, Department of Power Engineering [25]
- Power Engineering International Magazine Articles [26]
- Power Engineering Magazine Articles [27]
- American Society of Power Engineers, Inc. [28]
- National Institute for the Uniform Licensing of Power Engineer Inc. [29]

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[29] http://www.niulpe.org/

Central Mechanical Engineering Research Institute

Central Mechanical Engineering Research Institute CMERI is an engineering research institute based in Durgapur, West Bengal, India. It was established in February 1958 with the specific task of development of mechanical engineering technology and is funded by the Council of Scientific and Industrial Research (CSIR).

It conducts research in varied fields of engineering and technology aimed at providing assistance to mechanical engineering industries in the form of feasibility studies, research, training and consultancy. It conducts several short term courses in emerging and cutting-edge technology.[1]

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Centrifugal fan

A **centrifugal fan** (also **squirrel-cage fan**, as it looks like a hamster wheel) is a mechanical device for moving air or gases. It has a fan wheel composed of a number of fan blades, or ribs, mounted around a hub. As shown in Figure 1, the hub turns on a driveshaft that passes through the fan housing. The gas enters from the side of the fan wheel, turns 90 degrees and accelerates due to centrifugal force as it flows over the fan blades and exits the fan housing.[1]

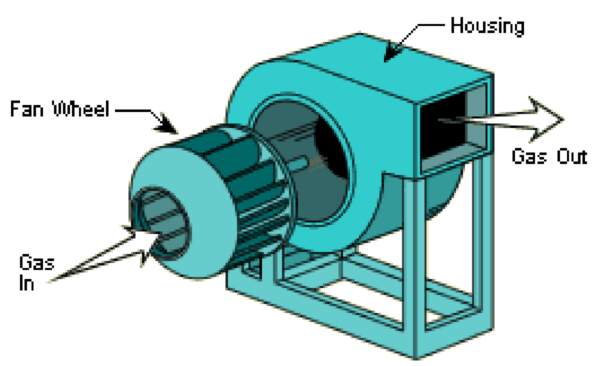

Figure 1: Components of a centrifugal fan

Centrifugal fans can generate pressure rises in the gas stream. Accordingly, they are well-suited for industrial processes and air pollution control systems. They are also common in central heating/cooling systems.

Fan components

The major components of a typical centrifugal fan include the fan wheel, fan housing, drive mechanism, and inlet and/or outlet dampers.

Types of drive mechanisms

The fan drive determines the speed of the fan wheel (impeller) and the extent to which this speed can be varied. There are three basic types of fan drives.[1]

Direct drive

The fan wheel can be linked directly to the shaft of an electric motor. This means that the fan wheel speed is identical to the motor's rotational speed. With this type of fan drive mechanism, the fan speed cannot be varied unless the motor speed is adjustable.

Belt drive

Belt driven fans use multiple belts that rotate in a set of sheaves mounted on the motor shaft and the fan wheel shaft.

This type of drive mechanism is depicted in figure 2. The belts transmit the mechanical energy from the motor to the fan.

The fan wheel speed depends upon the ratio of the diameter of the motor sheave to the diameter of the fan wheel sheave and can be obtained from this equation:[1]

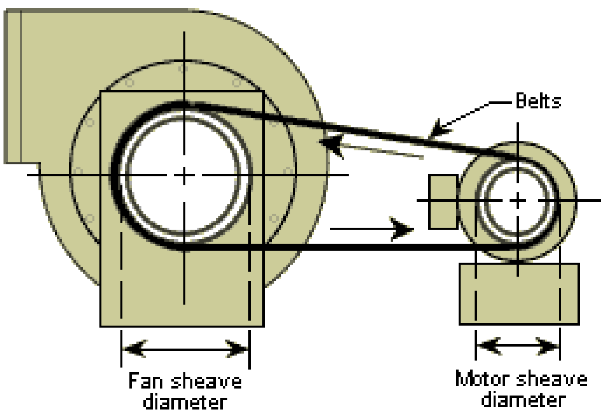

Figure 2: Centrifugal fan with a belt drive

$$rpm_{fan} = rpm_{motor}\left(\frac{D_{motor}}{D_{fan}}\right)$$

where:

rpm_{fan}	= fan wheel speed, revolutions per minute
rpm_{motor}	= motor nameplate speed, revolutions per minute
D_{motor}	= diameter of the motor sheave
D_{fan}	= diameter of the fan wheel sheave

Fan wheel speeds in belt-driven fans are fixed unless the belts slip. Belt slippage can reduce the fan wheel speed several hundred revolutions per minute (rpm).

Variable drive

Variable drive fans use hydraulic or magnetic couplings (between the fan wheel shaft and the motor shaft) that allow control of the fan wheel speed independent of the motor speed. The fan speed controls are often integrated into automated systems to maintain the desired fan wheel speed.[1]

An alternate method of varying the fan speed is by use of an electronic variable-speed drive which controls the speed of the motor driving the fan. This offers better overall energy efficiency at reduced speeds than mechanical couplings.

Fan dampers

Fan dampers are used to control gas flow into and out of the centrifugal fan. They may be installed on the inlet side or on the outlet side of the fan, or both. Dampers on the outlet side impose a flow resistance that is used to control gas flow. Dampers on the inlet side are designed to control gas flow and to change how the gas enters the fan wheel.

Inlet dampers reduce fan energy usage due to their ability to affect the airflow pattern into the fan.[1]

Fan ribs

The fan wheel consists of a hub on which a number of fan blades are attached. The fan blades on the hub can be arranged in three different ways: forward-curved, backward-curved or radial.[1]

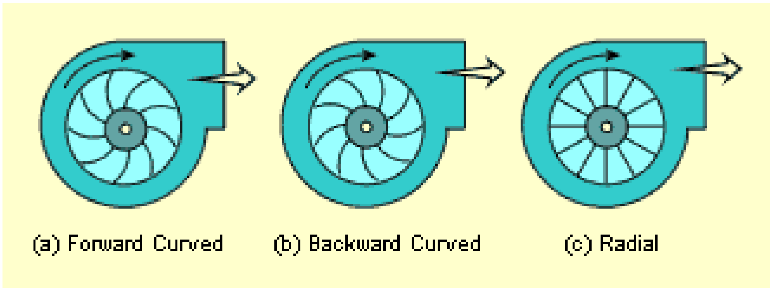

Figure 3: Centrifugal fan blades

Forward-curved blades

Forward-curved blades, as in Figure 3(a), use blades that curve in the direction of the fan wheel's rotation. These are especially sensitive to particulates. Forward-curved blades are for high flow, low pressure applications.

Backward-curved blades

Backward-curved blades, as in Figure 3(b), use blades that curve against the direction of the fan wheel's rotation. The backward curvature mimics that of an airfoil cross section and provides good operating efficiency with relatively economical construction techniques. These types of fan wheels are used in fans designed to handle gas streams with low to moderate particulate loadings. They can be easily fitted with wear protection but certain blade curvatures can be prone to solids build-up.

Backward curved fans can have a high range of specific speeds but are most often used for medium specific speed applications-- high pressure, medium flow applications.

Backward-curved fans are much more energy efficient than radial blade fans and so, for high horsepower applications may be a suitable alternative to the lower cost radial bladed fan.

Straight radial blades

Radial fan blades, as in Figure 3(c), extend straight out from the hub. A radial blade fan wheel is often used on particulate-laden gas streams because it is the least sensitive to solids build-up on the blades, but it is often characterized by greater noise output. High speeds, low volumes, and high pressures are common with radial fans, and are often used in vacuum cleaners, pneumatic material conveying systems, and similar processes.

Centrifugal fan ratings

Ratings found in centrifugal fan performance tables and curves are based on standard air SCFM. Fan manufacturers define standard air as clean, dry air with a density of 0.075 pounds mass per cubic foot (1.2kg/m^3), with the barometric pressure at sea level of 29.92 inches of mercury (101.325kPa) and a temperature of 70°F (21°C). Selecting a centrifugal fan to operate at conditions other than standard air requires adjustment to both static pressure and brake horsepower. The volume of air will not be affected in a given system because a fan will move the same amount of air regardless of the air density.

If a centrifugal fan is to operate at a non-standard density, then corrections must be made to static pressure and brake horsepower. At higher than standard elevation (sea level) and higher than standard temperature, air density is lower than standard density. Centrifugal fans that are specified for continuous operation at higher temperatures need to be selected taking into account air density corrections. Again, a centrifugal fan is a constant volume device that will move the same amount of air at two different temperatures.

If, for example, a centrifugal fan moves 1,000 ft^3/min (28 m^3/min) at 70 °F (21 °C) it will also move 1,000 ft^3/min (28 m^3/min) at 200 °F (93 °C). Centrifugal fan air volume delivered by the centrifugal fan is not affected by density. However, since the 200 °F (93 °C) air weighs much less than the 70 °F (21 °C) air, the centrifugal fan will create less static pressure and will require less brake horsepower. Selecting a centrifugal fan to operate at conditions other than standard air requires adjustment to both static pressure and power. When a centrifugal fan is specified for a given CFM and static pressure at conditions other than standard, an air density correction factor must be applied to select the proper size fan to meet the new condition. Since 200 °F (93 °C) air weighs only 80% of 70 °F (21 °C) air, the centrifugal fan will create less pressure. To get the actual pressure required at 200 °F (93 °C), the designer would have to multiply the pressure at standard conditions by an air density correction factor of 1.25 (i.e., 1.0 / 0.8) to get the system to operate correctly. To get the actual power at 200 °F (93 °C), the designer would have to divide the power at standard conditions by the air density correction factor.

Air Movement and Control Association (AMCA)

The centrifugal fan performance tables provide the fan RPM and power requirements for the given CFM and static pressure at standard air density. When the centrifugal fan performance is not at standard conditions, the performance must be converted to standard conditions before entering the performance tables. Centrifugal fans rated by the Air Movement and Control Association (AMCA) are tested in laboratories with test setups that simulate installations that are typical for that type of fan. Usually they are tested and rated as one of four standard installation types as designated in AMCA Standard 210.[2]

AMCA Standard 210 defines uniform methods for conducting laboratory tests on housed fans to determine airflow rate, pressure, power and efficiency, at a given speed of rotation. The purpose of AMCA Standard 210 is to define exact procedures and conditions of fan testing so that ratings provided by various manufacturers are on the same basis and may be compared. For this reason, fans must be rated in SCFM.

See also

- Fan (mechanical)
- Ducted fan
- Standard temperature and pressure
- Wind turbine

External links

- Fan Engineering Data and Selection Guide by Cincinnati Fan [3]

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Chilled water

Chilled water is a commodity often used to cool a building's air and equipment, especially in situations where many individual rooms must be controlled separately, such as a hotel. The chilled water can be supplied by a vendor, such as a public utility or created at the location of the building that will use it, which has been the norm.

Use

Chilled water cooling is very different from typical residential air conditioning where a refrigerant is pumped through an air handler to cool the air.

Regardless of who provides it, the chilled water (between 40° and 45°F) is pumped through an → air handler, which captures the heat from the air, then disperses the air throughout the area to be cooled.[1] [2]

Site generated

The chilled water, which absorbed heat from the air, is sent via return lines to a → cooling tower, which is a heat exchange device used to transfer waste heat to the atmosphere. The extent to which the cooling tower decreases the temperature depends upon the outside temperature, the relative humidity and the atmospheric pressure. The water will be lowered to the Wet-bulb temperature or dry-bulb temperature before proceeding to the → water chiller, where it is cooled to between 40° and 45°F and pumped to the air handler, where the cycle is repeated.[3] The equipment required includes chillers, cooling towers, pumps and electrical control equipment. The initial capital outlay for these is substantial

and maintenance costs can fluctuate. Adequate space must be included in building design for the physical plant and access to equipment.

Utility generated

The chilled water, which absorbed heat from the air, is sent via return lines back to the utility facility, where the process described in the previous section occurs. Utility generated chilled water eliminates the need for chillers and cooling towers at the property, reduces capital outlays and eliminates ongoing maintenance costs. The physical space saved can also become rentable, increasing revenue.[3]

Utility supplied chilled water has been used successfully since the 1960’s in many cities, and technological advances in the equipment, controls and trenchless installation have increased efficiency and lowered costs.[3]

The advantage of utility-supplied chilled water is based on economy of scale. A utility can operate one large system more economically than a customer can operate the individual system in one building. The utility's system also has back-up capacity to protect against sudden outages. The cost of such "insurance" is also markedly lower than what it would be for an individual structure.

The use of utility supplied chilled water is most cost effective when it is designed into the building’s infrastructure or when chiller/cooling tower equipment must be replaced. Commercial customers often lower their air conditioning costs from 10-20% by purchasing chilled water.[3]

External links

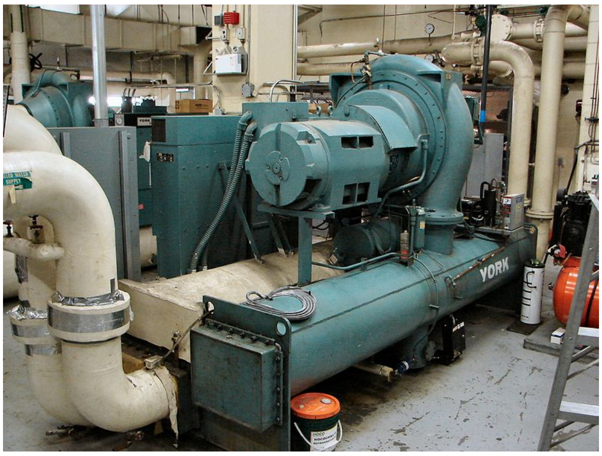
- CoolToolsTM Chilled Water Plant Design and Specification Guide [4]
- Operations and Maintenance of Chilled Water Systems [5]

References

[1] How Stuff Works: How Air Conditioners Work-Chilled-water and Cooling-tower AC Units (http://home.howstuffworks.com/ac4.htm)
[2] Air conditioning and refrigeration guide: Chilled Water Air Conditioning (http://www.air-conditioning-and-refrigeration-guide.com/chilled-water-air-conditioning.html)
[3] Jacksonville Business Journal: July 11, 2003-JEA's cool idea can save by Chuck Day (http://www.bizjournals.com/jacksonville/stories/2003/07/14/focus2.html)
[4] http://www.taylor-engineering.com/downloads/cooltools/CT-016_Design_Guide.pdf
[5] http://www.nttinc.com/PDF/CW.pdf

Chiller

A **chiller** is a machine that removes heat from a liquid via a vapor-compression or absorption refrigeration cycle. A vapor-compression water chiller comprises the 4 major components of the vapor-compression refrigeration cycle (compressor, evaporator, condenser, and some form of metering device). These machines can implement a variety of refrigerants. Absorption chillers utilize water as the refrigerant and rely on the strong affinity between the water and a lithium bromide solution to achieve a refrigeration effect. Most often, pure water is chilled, but this water may also contain a percentage of glycol and/or corrosion inhibitors; other fluids such as thin oils can be chilled as well.



York International water-cooled chiller.

Use in air conditioning

In air conditioning systems, chilled water is typically distributed to heat exchangers, or **coils**, in → air handling units, or other type of terminal devices which cool the air in its respective space(s), and then the chilled water is re-circulated back to the chiller to be cooled again. These cooling coils transfer sensible heat and latent heat from the air to the chilled water, thus cooling and usually dehumidifying the air stream. A typical chiller for air conditioning applications is rated between 15 to 1500 tons (180,000 to 18,000,000 BTU/h or 53 to 5,300 kW) in cooling capacity. Chilled water temperatures can range from 35 to 45 degrees Fahrenheit or 1.5 to 7 degrees Celsius, depending upon application requirements.

Use in industry

In industrial application, chilled water or other liquid from the chiller is pumped through process or laboratory equipment. Industrial chillers are used for controlled cooling of products, mechanisms and factory machinery in a wide range of industries. They are often used in the plastic industry in injection and blow molding, metal working cutting oils, welding equipment, die-casting and machine tooling, chemical processing, pharmaceutical formulation, food and beverage processing, vacuum systems, X-ray diffraction, power supplies and power generation stations, analytical equipment, semiconductors, compressed air and gas cooling. They are also used to cool high-heat specialized items such as MRI machines and lasers.

The chillers for industrial applications can be centralized, where each chiller serves multiple cooling needs, or decentralized where each application or machine has its own chiller. Each approach has its advantages. It is also possible to have a combination of both central and decentral chillers, especially if the cooling requirements are the same for some applications or points of use, but not all.

Decentral chillers are usually small in size (cooling capacity), usually from 0.2 tons to 10 tons. Central chillers generally have capacities ranging from ten tons to hundreds or thousands of tons.

Chilled water is used to cool and dehumidify air in mid- to large-size commercial, industrial, and institutional (CII) facilities. Water chillers can be either water cooled, air-cooled, or evaporatively cooled. Water-cooled chillers incorporate the use of → cooling towers which improve the chillers' thermodynamic effectiveness as compared to air-cooled chillers. This is due to heat rejection at or near the air's wet-bulb temperature rather than the higher, sometimes much higher, dry-bulb temperature. Evaporatively cooled chillers offer efficiencies better than air cooled, but lower than water cooled.

Water cooled chillers are typically intended for indoor installation and operation, and are cooled by a separate condenser water loop and connected to outdoor cooling towers to expel heat to the atmosphere.

Air Cooled and Evaporatively Cooled chillers are intended for outdoor installation and operation. Air cooled machines are directly cooled by ambient air being mechanically circulated directly through the machine's condenser coil to expel heat to the atmosphere. Evaporatively cooled machines are similar, except they implement a mist of water over the condenser coil to aid in condenser cooling, making the machine more efficient than a traditional air cooled machine. No remote cooling tower is typically required with either of these types of packaged air cooled or evaporatively cooled chillers.

Where available, cold water readily available in nearby water bodies might be used directly for cooling, or to replace or supplement cooling towers. The Deep Lake Water Cooling System in Toronto, Canada, is an example. It dispensed with the need for cooling towers, with a significant cut in carbon emissions and energy consumption. It uses cold lake water to cool the chillers, which in turn are used to cool city buildings via a district cooling system. The return water is used to warm the city's drinking water supply which is desirable in this cold climate. Whenever a chiller's heat rejection can be used for a productive purpose, in addition to the cooling function, very high thermal effectivenesses are possible.

Vapor-Compression Chiller Technology

There are basically four different types of compressors used in vapor compression chillers: → Reciprocating compression, scroll compression, → screw-driven compression, and centrifugal compression are all mechanical machines that can be powered by electric motors, steam, or gas turbines. They produce their cooling effect via the "reverse-Rankine" cycle, also known as 'vapor-compression'. With evaporative cooling heat rejection, their coefficients-of-performance (COPs) are very high and typically 4.0 or more.

In recent years, application of Variable Speed Drive (VSD) technology has increased efficiencies of vapor compression chillers. The first VSD was applied to centrifugal compressor chillers in the late 1970s and has become the norm as the cost of energy has increased. Now, VSDs are being applied to rotary screw and scroll technology compressors.

How Absorption Technology Works

Absorption chillers' thermodynamic cycle are driven by heat source; this heat is usually delivered to the chiller via steam, hot water, or combustion. Compared to electrically powered chillers, they have very low electrical power requirements - very rarely above 15 kW combined consumption for both the solution pump and the refrigerant pump. However, their heat input requirements are large, and their COPs are often 0.5 (single-effect) to 1.0 (double-effect). For the same tonnage capacity, they require much larger → cooling towers than vapor-compression chillers. However, absorption chillers, from an energy-efficiency point-of-view, excel where cheap, high grade heat or waste heat is readily available. In extremely sunny climates, solar energy has been used to operate absorption chillers.

The single effect absorption cycle uses water as the refrigerant and lithium bromide as the absorbent. It is the strong affinity that these two substances have for one another that makes the cycle work. The entire process occurs in almost a complete vacuum.

1. Solution Pump – A dilute lithium bromide solution is collected in the bottom of the absorber shell. From here, a hermetic solution pump moves the solution through a shell and tube heat exchanger for preheating.

2. Generator – After exiting the heat exchanger, the dilute solution moves into the upper shell. The solution surrounds a bundle of tubes which carries either steam or hot water. The steam or hot water transfers heat into the pool of dilute lithium bromide solution. The solution boils, sending refrigerant vapor upward into the condenser and leaving behind concentrated lithium bromide. The concentrated lithium bromide solution moves down to the heat exchanger, where it is cooled by the weak solution being pumped up to the generator.

3. Condenser – The refrigerant vapor migrates through mist eliminators to the condenser tube bundle. The refrigerant vapor condenses on the tubes. The heat is removed by the cooling water which moves through the inside of the tubes. As the refrigerant condenses, it collects in a trough at the bottom of the condenser.

4. Evaporator – The refrigerant liquid moves from the condenser in the upper shell down to the evaporator in the lower shell and is sprayed over the evaporator tube bundle. Due to the extreme vacuum of the lower shell [6 mm Hg (0.8 kPa) absolute pressure], the refrigerant liquid boils at approximately 39°F (3.9°C), creating the refrigerant effect. (This vacuum is created by hygroscopic action - the strong affinity lithium bromide has for water - in the Absorber directly below.)

5. Absorber – As the refrigerant vapor migrates to the absorber from the evaporator, the strong lithium bromide solution from the generator is sprayed over the top of the absorber tube bundle. The strong lithium bromide solution actually pulls the refrigerant vapor into solution, creating the extreme vacuum in the evaporator. The absorption of the refrigerant vapor into the lithium bromide solution also generates heat which is removed by the cooling water. The now dilute lithium bromide solution collects in the bottom of the lower shell, where it flows down to the solution pump. The chilling cycle is now completed and the process begins once again.

Industrial chiller technology

Industrial chillers typically come as complete packaged closed-loop systems, including the chiller unit, condenser, and pump station with recirculating pump, expansion valve, no-flow shutdown, internal cold water tank, and temperature control. The internal tank helps maintain cold water temperature and prevents temperature spikes from occurring. Closed loop industrial chillers recirculate a clean coolant or clean water with condition addititives at a constant temperature and pressure to increase the stability and reproducibility of water-cooled machines and instruments. The water flows from the chiller to the application's point of use and back.

If the water temperature differentials between inlet and outlet are high, then a large external water tank would be used to store the cold water. In this case the chilled water is not going directly from the chiller to the application, but goes to the external water tank which acts as a sort of "temperature buffer." The cold water tank is much larger than the internal water tank. The cold water goes from the external tank to the application and the return hot water from the application goes back to the external tank, not to the chiller.

The less common open loop industrial chillers control the temperature of a liquid in an open tank or sump by constantly recirculating it. The liquid is drawn from the tank, pumped through the chiller and back to the tank. An adjustable thermostat senses the makeup liquid temperature, cycling the chiller to maintain a constant temperature in the tank.

One of the newer developments in industrial water chillers is the use of water cooling instead of air cooling. In this case the condenser does not cool the hot refrigerant with ambient air, but uses water cooled by a → cooling tower. This development allows a reduction in energy requirements by more than 15% and also allows a significant reduction in the size of the chiller due to the small surface area of the water based condenser and the absence of fans. Additionally, the absence of fans allows for significantly reduced noise levels.

Most industrial chillers use refrigeration as the media for cooling, but some rely on simpler techniques such as air or water flowing over coils containing the coolant to regulate temperature. Water is the most commonly used coolant within process chillers, although coolant mixtures (mostly water with a coolant additive to enhance heat dissipation) are frequently employed.

Industrial chiller selection

Important specifications to consider when searching for industrial chillers include the power source, chiller IP rating, chiller cooling capacity, evaporator capacity, evaporator material, evaporator type, condenser material, condenser capacity, ambient temperature, motor fan type, noise level, internal piping materials, number of compressors, type of compressor, number of fridge circuits, coolant requirements, fluid discharge temperature, and COP (the ratio between the cooling capacity in RT to the energy consumed by the whole chiller in KW). For medium to large chillers this should range from 3.5-4.8 with higher values meaning higher efficiency. Chiller efficiency is often specified in kilowatts per refrigeration ton (kW/RT).

Process pump specifications that are important to consider include the process flow, process pressure, pump material, elastomer and mechanical shaft seal material, motor voltage, motor electrical class, motor IP rating and pump rating. If the cold water

temperature is lower than -5ºC, then a special pump needs to be used to be able to pump the high concentrations of ethylene glycol. Other important specifications include the internal water tank size and materials and full load amperage.

Control panel features that should be considered when selecting between industrial chillers include the local control panel, remote control panel, fault indicators, temperature indicators, and pressure indicators.

Additional features include emergency alarms, hot gas bypass, city water switchover, and casters.

Refrigerants

A vapor-compression chiller uses a refrigerant internally as its working fluid. Many refrigerants options are available; when selecting a chiller, the application cooling temperature requirements and refrigerant's cooling characteristics need to be matched. Important parameters to consider are the operating temperatures and pressures.

There are several environmental factors that concern refrigerants, and also affect the future availability for chiller applications. This is a key consideration in intermittent applications where a large chiller may last for 25 years or more. Ozone depletion potential (ODP) and global warming potential (GWP) of the refrigerant need to be considered. ODP and GWP data for some of the more common vapor-compression refrigerants:

Refrigerant	ODP	GWP
R-134a	0	1300
R-123	0.012	120
R-22	0.05	1700
R401a	0.027	970
R404a	0	3260
R407a	0	???
R407c	0	1525
R408a	0.016	3020
R409a	0.039	1290
R410a	0	1725
R500	0.7	???
R502	0.18	5600

See also

- HVAC
- → Cooling tower
- Evaporative cooling
- Chemical engineering
- → Mechanical engineering
- Architectural engineering
- Building services engineering

Coefficient of performance

The **coefficient of performance** or COP (sometimes CP), of a heat pump is the ratio of the change in heat at the "output" (the heat reservoir of interest) to the supplied work:

$$COP = \frac{|\Delta Q|}{\Delta W}$$

where

- is the change in heat at the heat reservoir of interest, and
- is the work consumed by the heat pump.

(Note: COP has no units, therefore in this equation, heat and work must be expressed in the same units.)

The COP for heating and cooling are thus different, because the heat reservoir of interest is different. When one is interested in how well a machine cools, the COP is the ratio of the heat removed from the cold reservoir to input work. However, for heating, the COP is the ratio of the heat removed from the cold reservoir plus the heat added to the hot reservoir by the input work to input work:

$$COP_{heating} = \frac{|\Delta Q_{cold}| + \Delta W}{\Delta W}$$

$$COP_{cooling} = \frac{|\Delta Q_{cold}|}{\Delta W}$$

where

- is the heat moved from the cold reservoir (to the hot reservoir).

Derivation

According to the first law of thermodynamics, in a reversible system we can show that $Q_{hot} = Q_{cold} + W$ and $W = Q_{hot} - Q_{cold}$, where Q_{hot} is the heat given off by the hot heat reservoir and Q_{cold} is the heat taken in by the cold heat reservoir.
Therefore, by substituting for W,

$$COP_{heating} = \frac{Q_{hot}}{Q_{hot} - Q_{cold}}$$

For a heat pump operating at maximum theoretical efficiency (i.e. Carnot efficiency), it can be shown that $\frac{Q_{hot}}{T_{hot}} = \frac{Q_{cold}}{T_{cold}}$ and $Q_{cold} = \frac{Q_{hot}T_{cold}}{T_{hot}}$, where T_{hot} and T_{cold} are the absolute temperatures of the hot and cold heat reservoirs respectively.

Hence, at maximum theoretical efficiency,

$$COP_{heating} = \frac{T_{hot}}{T_{hot} - T_{cold}}$$

Similarly,

$$COP_{cooling} = \frac{Q_{cold}}{Q_{hot} - Q_{cold}} = \frac{T_{cold}}{T_{hot} - T_{cold}}$$

It can also be shown that $COP_{cooling} = COP_{heating} - 1$. Note that these equations must use the absolute temperature, such as the Kelvin scale.

$COP_{heating}$ applies to heat pumps and $COP_{cooling}$ applies to air conditioners or refrigerators. For heat engines, see Efficiency. Values for actual systems will always be less than these theoretical maximums.

Example

A geothermal heat pump operating at $COP_{heating}$ 3.5 provides 3.5 units of heat for each unit of energy consumed (e.g. 1 kWh consumed would provide 3.5 kWh of output heat). The output heat comes from both the heat source and 1 kWh of input energy, so the heat-source is cooled by 2.5 kWh, not 3.5 kWh.

A heat pump of $COP_{heating}$ 3.5, such as in the example above, could be less expensive to use than even the most efficient gas furnace.

A heat pump cooler operating at $COP_{cooling}$ 2.0 removes 2 units of heat for each unit of energy consumed (e.g. such an air conditioner consuming 1 kWh would remove heat from a building's air at a rate of 2 kWh).

The COP of heat pumps (300%-350% efficient) make them much more efficient than high-efficiency gas-burning furnaces (90-99% efficient), and electric heating (100%). However, this does not always mean they are less expensive to operate. The 2008 US average price per therm (100,000 BTU) of electricity was $3.33 while the average price per therm of natural gas was $1.33.[1] Using these prices, a heat pump with a COP of 3.5 would cost $0.95[2] to provide one therm of heat, while a high efficiency gas furnace with 95% efficiency would cost $1.40[3] to provide one therm of heat. With these average prices, the heat pump costs 32% less[4] to provide the same amount of heat. The savings (if any) will depend on the actual cost of electricity and natural gas, which can both vary widely.

Conditions of use

While the COP is partly a measure of the efficiency of a heat pump, it is also a measure of the conditions under which it is operating: the COP of a given heat pump will rise as the input temperature increases or the output temperature decreases because it is linked to a warm temperature distribution system like underfloor heating.

See also

- Seasonal energy efficiency ratio (DSEER)
- → Thermal efficiency
- Vapor-compression refrigeration
- Air conditioner
- HVAC
- Heat Pump

External links

- Discussion on changes to COP of a heat pump depending on input and output temperatures [5]

References

[1] Based on average prices of 11.36 cents per kWh for electricity (http://www.eia.doe.gov/cneaf/electricity/epm/table5_3.html) and $13.68 per thousand cubic feet for natural gas (http://tonto.eia.doe.gov/dnav/ng/hist/n3010us3a.htm), and conversion factors of 29.308 kWh per therm and 97.2763 cubic feet per therm (http://www.eia.doe.gov/kids/energyfacts/science/energy_calculator.html).
[2] $3.33/3.5~$0.95
[3] $1.33/.95~$1.40
[4] ($1.40-$0.95)/$1.40~32%
[5] http://www.icax.co.uk/gshp.html

Collapse action

Collapse action is a device behaviour that snaps a switch into place, usually using a bistable element. When flipping a light switch, strain on one spring increases until it flips position, pulling down the switch. Collapse action allows you to remove your hand from the switch without risk it falls to the down position, as the force needed to overcome the resistance is too great. The action also does not exert force in the lower position, avoiding the spontaneous rise to the up position that a spring invites.

See also

- switch
- hysteresis
- buckling spring

Compliant mechanism

In → mechanical engineering, **compliant mechanisms** are flexible mechanisms that transfer an input force or displacement to another point through elastic body deformation. These are usually monolithic (single-piece) or jointless structures with certain advantages over the rigid-body, or jointed, mechanisms.

Since the compliant mechanisms are single-piece structures, there is no need of assembly. With no joints, "rubbing" between two parts or friction as seen at the joints of rigid body mechanisms is absent. Compliant mechanisms are elastic. They do not have the backlash common in rigid-body, jointed mechanisms. They are cheaper to make than the jointed variety.

Compliant mechanisms are usually designed using two techniques, the first being a pseudo-rigid-body model and the second, the topology optimization. Other techniques are being conceived to design these mechanisms.

The *flexible drive* or *resilient drive*, often used to → couple an electric motor to a machine (for example. a pump), is one example. The drive consists of a rubber "spider" sandwiched between two metal dogs. One dog is fixed to the motor shaft and the other to the pump shaft. The flexibility of the rubber part compensates for any slight misalignment between the motor and the pump.

Compliant mechanisms are found in micro-electromechanical systems. For example, amplifying compliant mechanisms are used in micro-accelerometers and electro-thermal micro-actuators.

On Dec 17, 2007, the first International Symposium on Compliant Mechanisms was held at the Indian Institute of Science, Bangalore.

Research Labs and Researchers

- University of Michigan Compliant Mechanism Design Lab [1]
- Brigham Young University compliant mechanisms research [2]
- The Multidisciplinary and Multiscale Device and Design Laboratory (M2D2) at the Indian Institute of Science, Bangalore [3]
- Prof. Sridhar Kota's Home Page [4]
- Prof. Martin Culpepper at MIT Precision Compliant Systems Laboratory [5]
- Prof. Shorya Awtar at University of Michigan [6]
- Prof. Just L. Herder at Delft University of Technology [7]
- Prof. G. K. Ananthasuresh at IISc, Bangalore [8]
- Prof. Stephen L. Canfield at Tennessee Tech University [9]
- Prof. Charles Kim at Bucknell University [10]
- Dr. Anupam Saxena at IIT Kanpur, India [11]

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[2] http://research.et.byu.edu/llhwww/
[3] http://www.mecheng.iisc.ernet.in/~m2d2/
[4] http://www-personal.umich.edu/~kota/
[5] http://pcsl.mit.edu/
[6] http://www-personal.umich.edu/~awtar/
[7] http://mms.tudelft.nl/staff/herder/main.htm
[8] http://www.mecheng.iisc.ernet.in/~suresh/
[9] http://www.tntech.edu/ME/Faculty_Bios/scanfieldbio.html
[10] http://www.bucknell.edu/x16384.xml
[11] http://home.iitk.ac.in/~anupams/

Constant air volume

Constant Air Volume (**CAV**) is a type of heating, ventilating, and air-conditioning (HVAC) system. In a simple CAV system, the supply air flow rate is constant, but the supply air temperature is varied to meet the thermal loads of a space.[1]

Most CAV systems are small, and serve a single thermal zone. However, variations such as CAV with reheat, CAV multizone, and CAV primary-secondary systems can serve multiple zones and larger buildings.

In mid to large size buildings, new central CAV systems are somewhat rare. Due to fan energy savings potential, → variable air volume systems are more common. However, in small buildings and residences, CAV systems are often the system of choice due to simplicity, low cost, and reliability. Such small CAV systems often have *on/off control*, rather than supply air temperature modulation, to vary their heating or cooling capacities.

There are two types of CAV systems that are commonly in use to modify the supply air temperature: the terminal reheat system and the mixed air system.

The terminal reheat system cools the air in the air handling unit down to the lowest possible needed temperature within its zone of spaces. This supplies a comfortable quality to the space, but wastes energy.

The mixed air system has two air streams, typically one for the coldest and one for the hottest needed air temperature in the zone. The two air streams are strategically combined to offset the space's load. The mixed air system option is not as proficient at controlling the humidity, yet it does do well at controlling the temperature. (reference: Heating/Piping/Air Conditioning, December 1993 p.53-57)

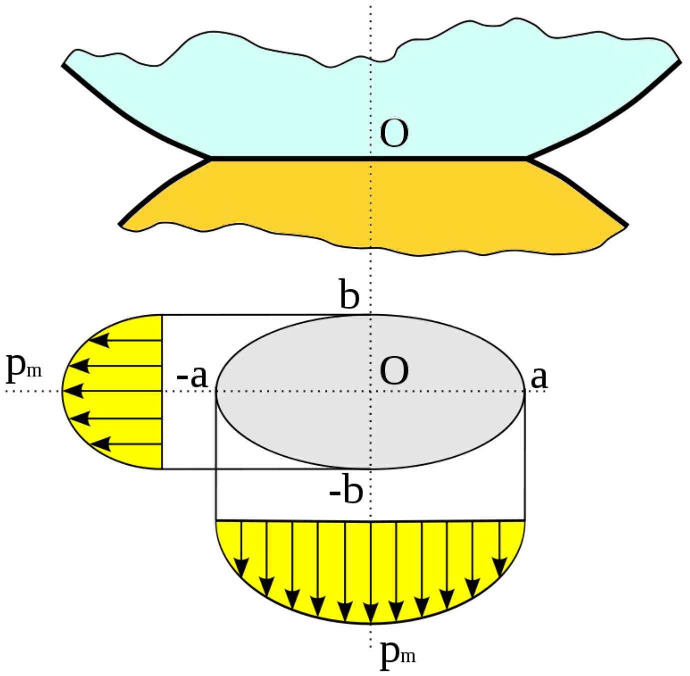
See also

- HVAC
- ASHRAE
- SMACNA
- BACnet
- LonWorks
- → Variable air volume

References

[1] Systems and Equipment volume of the *ASHRAE Handbook*, ASHRAE, Inc., Atlanta, GA, 2004

Contact mechanics



Contact between two spheres.

Contact mechanics is the study of the deformation of solids that touch each other at one or more points. The physical and mathematical formulation of the subject is built upon the mechanics of materials and continuum mechanics. The original work in this field dates back to the publication of the paper "On the contact of elastic solids" ("Ueber die Berührung fester elastischer Körper" [1]) by Heinrich Hertz in 1882. Hertz was attempting to understand how the optical properties of multiple, stacked lenses might change with the force holding them together. Results in this field have since been extended to all branches of engineering, but are most essential in the study of tribology and indentation hardness.

Introduction

Contact mechanics is an area of physics in which the motion of two or more bodies in space is restricted by additional constraints. These so called unilateral constraints ensure that bodies once coming into contact do not penetrate each other. Once the general equations for a contact problem are set up, different solution schemes can be used to simulate the behaviour of bodies in contact and to compute displacement and stress fields. There are several possibilities to classify contact problems. Generally contact with and without friction is distinguished.

In case of analytical solution methods for contact problems the following classification was introduced. Contact may occur between bodies in two distinct ways. A **conforming contact** is one in which the two bodies touch at multiple points before any deformation takes place (i.e., they just "fit together"). The opposite is **non-conforming contact**, in which the shapes of the bodies are dissimilar enough that, under no load, they only touch at a point (or possibly along a line). In the non-conforming case, the contact area is small compared to the sizes of the objects and the stresses are highly concentrated in this area.

Such distinctions however do not have to be made when numerical solution schemes are employed to solve contact problems. These methods do not rely on further assumptions within the solution process since they base solely on the general formulation of the underlying equations. Besides the standard equations describing the deformation and motion of bodies to additional inequalities can be formulated. The first simply restricts the motion and deformation of the bodies by the assumption that no penetration can occur. Hence the gap g_N between two bodies can only be positive or zero

$$g_N \geq 0$$

where $g_N = 0$ denotes contact. The second assumption in contact mechanics is related to the fact, that no tension force is allowed to occur within the contact area (contacting bodies can be lifted up without adhesion forces). This leads to an inequality which the stresses have to obey at the contact interface. It is formulated for the contact pressure $p_N = \mathbf{t} \cdot \mathbf{n}$

$$p_N \leq 0 \,.$$

Since for contact, $g_N = 0$, the contact pressure is always negative, $p_N < 0$, and further for non contact the gap is open, $g_N > 0$, and the contact pressure is zero, $p_N = 0$, the so called Kuhn-Tucker form of the contact constraints can be written as

$$g_N \geq 0\,, \quad p_N \leq 0\,, \quad p_N\, g_N = 0\,.$$

These conditions are valid in a general way. The mathematical formulation of the gap depends upon the kinematics of the underlying theory of the solid (e.g., linear or nonlinear solid in two- or three dimensions, beam or shell model),

Complex forces and moments are transmitted between the bodies where they touch, so problems in contact mechanics can become quite sophisticated. Typically, a frame of reference is defined in which the objects (possibly in motion relative to one another) are static. They interact through surface tractions (or pressures/stresses) at their interface. As an example, consider two objects which meet at some surface S in the (x , y)-plane. One of the bodies will experience a (normally-directed) pressure $p = p(x,y)$ and (in-plane) surface traction $q = q(x,y)$ over the region S. In terms of a Newtonian force balance, the forces:

$$P_z = \iint_S p(x,y)\, dS$$

and

$$Q_x = \iint_S q_x(x,y)\, dS$$

$$Q_y = \iint_S q_y(x,y)\, dS$$

must be equal and opposite to the forces established in the other body. The moments corresponding to these forces:

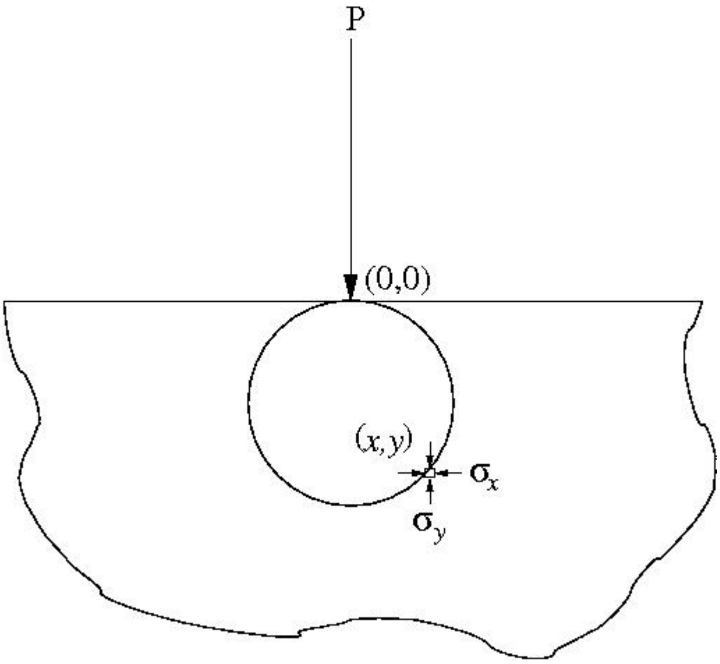
$$M_x = \iint_S p(x,y) y\, dS$$

$$M_y = -\iint_S p(x,y)x\,dS$$
$$M_z = \iint_S (q_y(x,y)x - q_x(x,y)y)\,dS$$

are also required to cancel between bodies so that they are kinematically immobile.

Loading on a Half-Plane

- Loading at a Point - Objects in contact will deform under the influence of the tractions mentioned above and there are a number of elasticity solutions that are applicable to determining these deformations. The starting point is understanding the effect of a "point-load" applied to an elastic half-plane, shown in the figure to the right. Like all problems in elasticity, this is a boundary value problem subject to the conditions:



Schematic of the loading on a plane by force P at a point (0,0).

$$\sigma_z(x,z) = -P\delta(x,z)$$

(i.e., there are no shear stresses on the surface and singular normal force P applied at (0,0)). Applying these conditions to the governing equations of elasticity produces the result:

$$\sigma_x = -\frac{2P}{\pi}\frac{x^2 z}{(x^2+z^2)^2}$$
$$\sigma_z = -\frac{2P}{\pi}\frac{z^3}{(x^2+z^2)^2}$$
$$\sigma_{xz} = -\frac{2P}{\pi}\frac{xz^2}{(x^2+z^2)^2}$$

for some point, (x,y), in the half-plane. The circle shown in the figure indicates a surface on which the prinicipal shear stress is constant. From this stress field, the strain components and thence displacements of all material points may be determined.

- Loading over a Region (*a*,*b*) - This above is an important result that can be built upon. Suppose, rather than a point load P, a distributed load $p(x)$is applied to the surface

instead, over the range $a < x < b$. The principle of linear superposition can be applied to determine the resulting stress field as the solution to the integral equations:

$$\sigma_x = -\frac{2z}{\pi}\int_a^b \frac{p(x')(x-x')^2\,dx'}{[(x-x')^2+z^2]^2}$$

$$\sigma_z = -\frac{2z^3}{\pi}\int_a^b \frac{p(x')(x-x')^2\,dx'}{[(x-x')^2+z^2]^2}$$

$$\sigma_{xz} = -\frac{2z^2}{\pi}\int_a^b \frac{p(x')(x-x')\,dx'}{[(x-x')^2+z^2]^2}$$

- Shear Loading over a region (a, b)- The same principle applies for loading on the surface in the plane of the surface. These kinds of tractions would tend to arise as a result of friction. The solution is similar the above (for both singular loads Q and distributed loads $q(x)$) but altered slightly:

$$\sigma_x = -\frac{2}{\pi}\int_a^b \frac{q(x')(x-x')^3\,dx'}{[(x-x')^2+z^2]^2}$$

$$\sigma_z = -\frac{2z^2}{\pi}\int_a^b \frac{q(x')(x-x')\,dx'}{[(x-x')^2+z^2]^2}$$

$$\sigma_{xz} = -\frac{2z}{\pi}\int_a^b \frac{q(x')(x-x')^2\,dx'}{[(x-x')^2+z^2]^2}$$

These results may themselves be superposed onto those given above for normal loading.

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See also

- Hertzian contact stress
- Stress (physics)
- Contact (mechanics)

Cooling tower

Cooling towers are heat removal devices used to transfer process waste heat to the atmosphere. Cooling towers may either use the evaporation of water to remove process heat and cool the working fluid to near the wet-bulb air temperature or rely solely on air to cool the working fluid to near the dry-bulb air temperature. Common applications include cooling the circulating water used in oil refineries, chemical plants, power stations and building cooling. The towers vary in size from small roof-top units to very large hyperboloid structures (as in Image 1) that can be up to 200 metres tall and 100 metres in diameter, or rectangular structures (as in Image 2) that can be over 40 metres tall and 80 metres long. Smaller towers are normally factory-built, while larger ones are constructed on site.

Image 1: Natural draft wet cooling hyperbolic towers at Didcot Power Station, UK

Image 2:A mechanical induced draft cooling tower

A hyperboloid cooling tower was patented by Frederik van Iterson and Gerard Kuypers in 1918. [1]

Classification by use

Cooling towers can generally be classified by use into either *HVAC* (air-conditioning) or *industrial* duty.

HVAC

An HVAC cooling tower is a subcategory rejecting heat from a → chiller. Water-cooled chillers are normally more energy efficient than air-cooled chillers due to heat rejection to tower water at or near wet-bulb temperatures. Air-cooled chillers must reject heat at the dry-bulb temperature, and thus have a lower average reverse-Carnot cycle effectiveness. Large office buildings, hospitals, and schools typically use one or more cooling towers as part of their air conditioning systems. Generally, industrial cooling towers are much larger than HVAC towers.

HVAC use of a cooling tower pairs the cooling tower with a water-cooled chiller or water-cooled condenser. A *ton* of air-conditioning is the removal of 12,000 Btu/hour (3517 W). The *equivalent ton* on the cooling tower side actually rejects about 15,000 Btu/hour (4396 W) due to the heat-equivalent of the energy needed to drive the chiller's compressor. This *equivalent ton* is defined as the heat rejection in cooling 3 U.S. gallons/minute (1,500 pound/hour) of water 10 °F (5.56 °C), which amounts to 15,000 Btu/hour, or a chiller coefficient-of-performance (COP) of 4.0. This COP is equivalent to an energy efficiency ratio (EER) of 13.65.


In rare cases, a plant's cooling towers have even been painted to improve public perception as with the Cruas Nuclear Power Plant.

Industrial cooling towers

Industrial cooling towers can be used to remove heat from various sources such as machinery or heated process material. The primary use of large, industrial cooling towers is to remove the heat absorbed in the circulating cooling water systems used in power plants, petroleum refineries, petrochemical plants, natural gas processing plants, food processing plants, semi-conductor plants, and other industrial facilities. The circulation rate of cooling water in a typical 700 MW coal-fired power plant with a cooling tower amounts to about 71,600 cubic metres an hour (315,000 U.S. gallons per minute)[2] and the circulating water requires a supply water make-up rate of perhaps 5 percent (i.e., 3,600 cubic metres an hour).

If that same plant had no cooling tower and used **once-through cooling** water, it would require about 100,000 cubic metres an hour [3] and that amount of water would have to be continuously returned to the ocean, lake or river from which it was obtained and continuously re-supplied to the plant. Furthermore, discharging large amounts of hot water may raise the temperature of the receiving river or lake to an unacceptable level for the local ecosystem. Elevated water temperatures can kill fish and other aquatic organisms. (See *thermal pollution*.) A cooling tower serves to dissipate the heat into the atmosphere instead and wind and air diffusion spreads the heat over a much larger area than hot water can distribute heat in a body of water. Some coal-fired and nuclear power plants located in coastal areas do make use of once-through ocean water. But even there, the offshore discharge water outlet requires very careful design to avoid environmental problems.

Petroleum refineries also have very large cooling tower systems. A typical large refinery processing 40,000 metric tonnes of crude oil per day (300,000 barrels per day) circulates about 80,000 cubic metres of water per hour through its cooling tower system.

The world's tallest cooling tower is the 200 metre tall cooling tower of Niederaussem Power Station.

Heat transfer methods

With respect to the → heat transfer mechanism employed, the main types are:

Image 3: Mechanical draft crossflow cooling tower used in an HVAC application

- *Wet cooling towers* or simply *cooling towers* operate on the principle of evaporation. The working fluid and the evaporated fluid (usually H_2O) are one and the same.
- *Dry coolers* operate by → heat transfer through a surface that separates the working fluid from ambient air, such as in a heat exchanger, utilizing convective heat transfer. They do not use evaporation.
- *Fluid coolers* are hybrids that pass the working fluid through a tube bundle, upon which clean water is sprayed and a fan-induced draft applied. The resulting heat transfer performance is much closer to that of a wet cooling tower, with the advantage provided by a dry cooler of protecting the working fluid from environmental exposure.

In a wet cooling tower, the warm water can be cooled to a temperature lower than the ambient air dry-bulb temperature, if the air is relatively dry. (see: dew point and psychrometrics). As ambient air is drawn past a flow of water, evaporation occurs. Evaporation results in saturated air conditions, lowering the temperature of the water to the wet bulb air temperature, which is lower than the ambient dry bulb air temperature, the difference determined by the humidity of the ambient air.

To achieve better performance (more cooling), a medium called *fill* is used to increase the surface area between the air and water flows. *Splash fill* consists of material placed to interrupt the water flow causing splashing. *Film fill* is composed of thin sheets of material upon which the water flows. Both methods create increased surface area.

Air flow generation methods

With respect to drawing air through the tower, there are three types of cooling towers:


Image 4: A forced draft cooling tower

- *Natural draft*, which utilizes buoyancy via a tall chimney. Warm, moist air *naturally* rises due to the density differential to the dry, cooler outside air. Warm moist air is less dense than drier air at the same pressure. This moist air buoyancy produces a current of air through the tower.
- *Mechanical draft*, which uses power driven fan motors to force or draw air through the tower.
  - *Induced draft*: A mechanical draft tower with a fan at the discharge which pulls air through tower. The fan *induces* hot moist air out the discharge. This produces low entering and high exiting air velocities, reducing the possibility of *recirculation* in which discharged air flows back into the air intake. This fan/fill arrangement is also known as *draw-through*. (see Image 2, 3)
  - *Forced draft*: A mechanical draft tower with a blower type fan at the intake. The fan *forces* air into the tower, creating high entering and low exiting air velocities. The low exiting velocity is much more susceptible to recirculation. With the fan on the air intake, the fan is more susceptible to complications due to freezing conditions. Another disadvantage is that a forced draft design typically requires more motor horsepower than an equivalent induced draft design. The forced draft benefit is its ability to work with high static pressure. They can be installed in more confined spaces and even in some indoor situations. This fan/fill geometry is also known as *blow-through*. (see Image 4)
- Fan assisted natural draft. A hybrid type that appears like a natural draft though airflow is assisted by a fan.

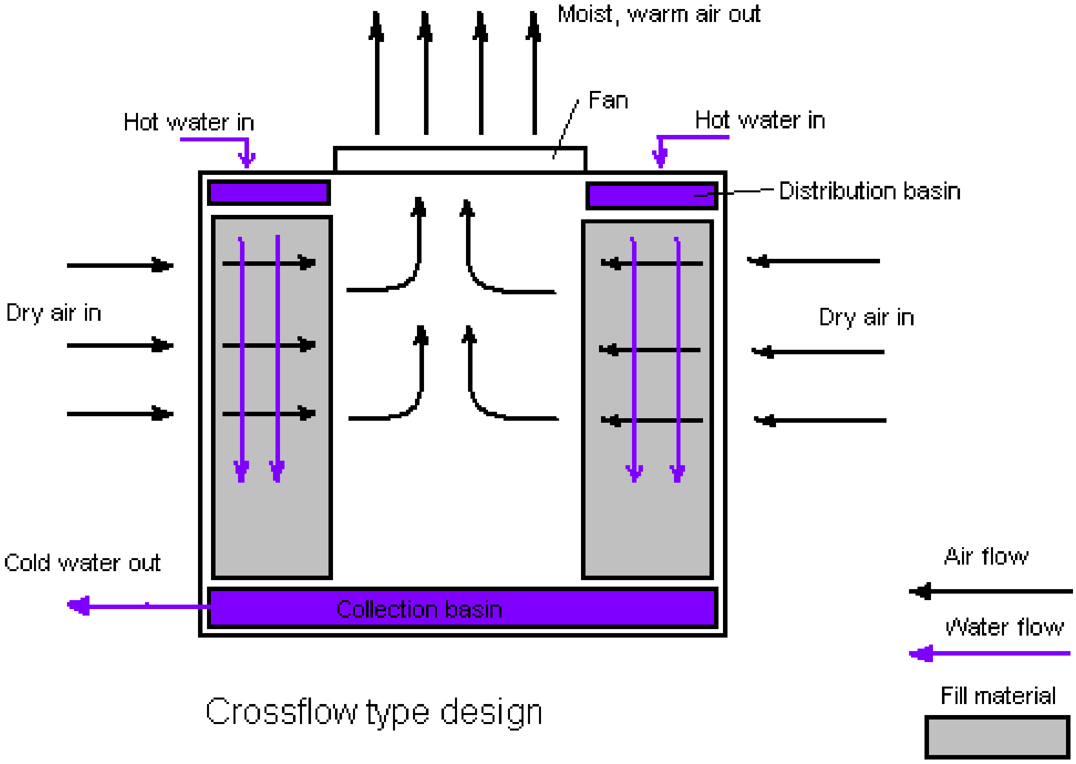
Hyperboloid (a.k.a. hyperbolic) cooling towers (Image 1) have become the design standard for all natural-draft cooling towers because of their structural strength and minimum usage of material. The hyperboloid shape also aids in accelerating the upward convective air flow, improving cooling efficiency. They are popularly associated with nuclear power plants. However, this association is misleading, as the same kind of cooling towers are often used at large coal-fired power plants as well. Similarly, not all nuclear power plants have cooling towers, instead cooling their heat exchangers with lake, river or ocean water.

Categorization by air-to-water flow

Crossflow

Crossflow is a design in which the air flow is directed perpendicular to the water flow (see diagram below). Air flow enters one or more vertical faces of the cooling tower to meet the fill material. Water flows (perpendicular to the air) through the fill by gravity. The air continues through the fill and thus past the water flow into an open plenum area. A

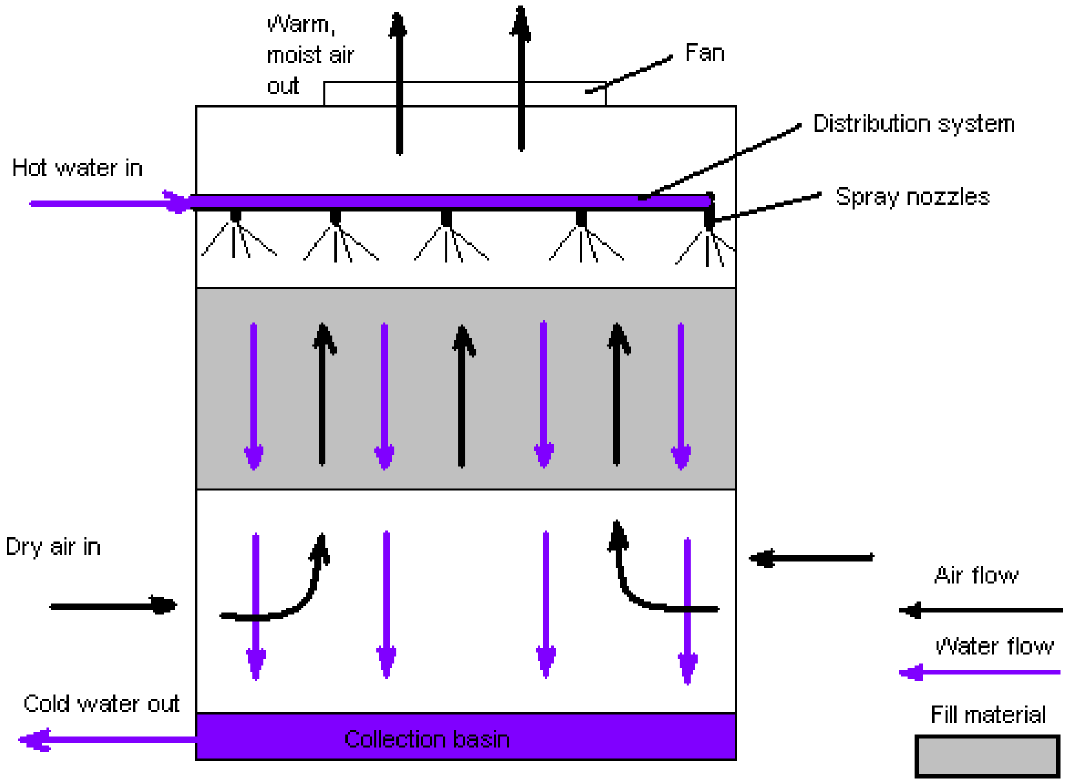
distribution or *hot water basin* consisting of a deep pan with holes or *nozzles* in the bottom is utilized in a crossflow tower. Gravity distributes the water through the nozzles uniformly across the fill material.



Crossflow type design

Counterflow

In a counterflow design the air flow is directly opposite to the water flow (see diagram below). Air flow first enters an open area beneath the fill media and is then drawn up vertically. The water is sprayed through pressurized nozzles and flows downward through the fill, opposite to the air flow.



Counterflow type design

Common to both designs:

- The interaction of the air and water flow allow a partial equalization and evaporation of water.
- The air, now saturated with water vapor, is discharged from the cooling tower.
- A *collection* or *cold water basin* is used to contain the water after its interaction with the air flow.

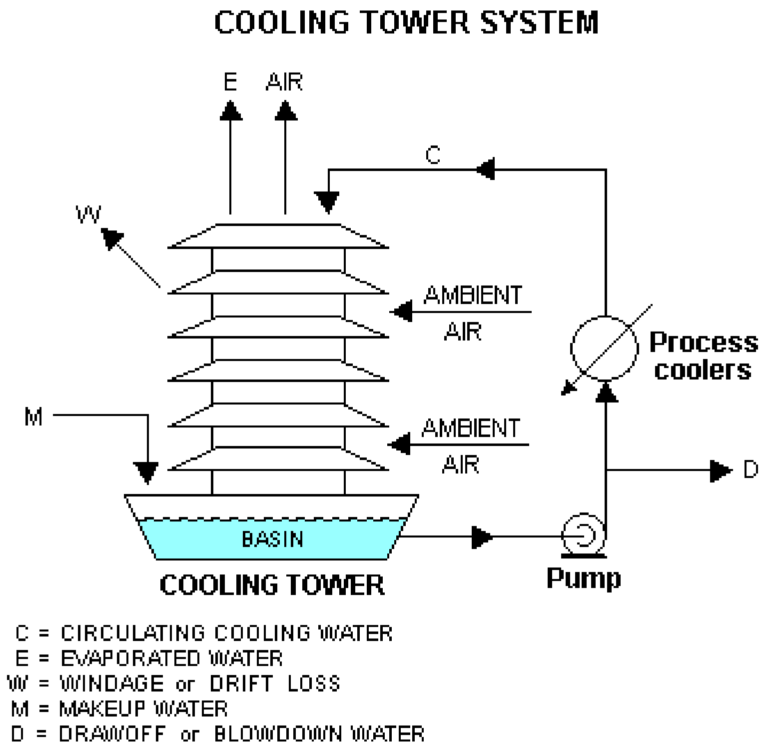
Both crossflow and counterflow designs can be used in natural draft and mechanical draft cooling towers.

Cooling tower as a flue gas stack

At some modern power stations, equipped with flue gas purification like the Power Station Staudinger Grosskrotzenburg and the Power Station Rostock, the cooling tower is also used as a flue gas stack (industrial chimney). At plants without flue gas purification, this causes problems with corrosion.

Wet cooling tower material balance

Quantitatively, the material balance around a wet, evaporative cooling tower system is governed by the operational variables of makeup flow rate, evaporation and windage losses, draw-off rate, and the concentration cycles:[4]



M = Make-up water in m³/hr

C = Circulating water in m³/hr

D = Draw-off water in m³/hr

E = Evaporated water in m³/hr

W = Windage loss of water in m³/hr

X = Concentration in ppmw (of any completely soluble salts … usually chlorides)

$\mathbf{X_M}$ = Concentration of chlorides in make-up water (M), in ppmw

$\mathbf{X_C}$ = Concentration of chlorides in circulating water (C), in ppmw

Cycles = Cycles of concentration = X_C / X_M (dimensionless)

ppmw = parts per million by weight

In the above sketch, water pumped from the tower basin is the cooling water routed through the process coolers and condensers in an industrial facility. The cool water absorbs heat from the hot process streams which need to be cooled or condensed, and the absorbed

heat warms the circulating water (C). The warm water returns to the top of the cooling tower and trickles downward over the fill material inside the tower. As it trickles down, it contacts ambient air rising up through the tower either by natural draft or by forced draft using large fans in the tower. That contact causes a small amount of the water to be lost as windage (W) and some of the water (E) to evaporate. The heat required to evaporate the water is derived from the water itself, which cools the water back to the original basin water temperature and the water is then ready to recirculate. The evaporated water leaves its dissolved salts behind in the bulk of the water which has not been evaporated, thus raising the salt concentration in the circulating cooling water. To prevent the salt concentration of the water from becoming too high, a portion of the water is drawn off (D) for disposal. Fresh water makeup (M) is supplied to the tower basin to compensate for the loss of evaporated water, the windage loss water and the draw-off water.

A water balance around the entire system is:

$$M = E + D + W$$

Since the evaporated water (E) has no salts, a chloride balance around the system is:

$$M (X_M) = D (X_C) + W (X_C) = X_C (D + W)$$

and, therefore:

$$\mathbf{X_C / X_M = \text{Cycles of concentration} = M \div (D + W) = M \div (M - E) = 1 + [E \div (D + W)]}$$

From a simplified heat balance around the cooling tower:

$$\mathbf{E = C \cdot \Delta T \cdot c_p \div H_V}$$

where:

$\mathbf{H_V}$ = latent heat of vaporization of water = ca. 2260 kJ / kg

$\mathbf{\Delta T}$ = water temperature difference from tower top to tower bottom, in °C

$\mathbf{c_p}$ = specific heat of water = ca. 4.184 kJ / (kg · °C)

Windage (or drift) losses (W) from large-scale industrial cooling towers, in the absence of manufacturer's data, may be assumed to be:

W = 0.3 to 1.0 percent of C for a natural draft cooling tower without windage drift eliminators

W = 0.1 to 0.3 percent of C for an induced draft cooling tower without windage drift eliminators

W = about 0.005 percent of C (or less) if the cooling tower has windage drift eliminators

Cycles of concentration represents the accumulation of dissolved minerals in the recirculating cooling water. Draw-off (or blowdown) is used principally to control the buildup of these minerals.

The chemistry of the makeup water including the amount of dissolved minerals can vary widely. Makeup waters low in dissolved minerals such as those from surface water supplies (lakes, rivers etc.) tend to be aggressive to metals (corrosive). Makeup waters from ground water supplies (wells) are usually higher in minerals and tend to be scaling (deposit minerals). Increasing the amount of minerals present in the water by cycling can make water less aggressive to piping however excessive levels of minerals can cause scaling problems.

As the cycles of concentration increase the water may not be able to hold the minerals in solution. When the solubility of these minerals have been exceeded they can precipitate out as mineral solids and cause fouling and heat exchange problems in the cooling tower or the heat exchangers. The temperatures of the recirculating water, piping and heat exchange surfaces determine if and where minerals will precipitate from the recirculating water. Often a professional water treatment consultant will evaluate the makeup water and the operating conditions of the cooling tower and recommend an appropriate range for the cycles of concentration. The use of water treatment chemicals, pretreatment such as water softening, pH adjustment, and other techniques can affect the acceptable range of cycles of concentration.

Concentration cycles in the majority of cooling towers usually range from 3 to 7. In the United States the majority of water supplies are well waters and have significant levels of dissolved solids. On the other hand one of the largest water supplies, New York City, has a surface supply quite low in minerals and cooling towers in that city are often allowed to concentrate to 7 or more cycles of concentration.

Besides treating the circulating cooling water in large industrial cooling tower systems to minimize scaling and fouling, the water should be filtered and also be dosed with biocides and algaecides to prevent growths that could interfere with the continuous flow of the water.[4] For closed loop evaporative towers, corrosion inhibitors may be used, but caution should be taken to meet local environmental regulations as some inhibitors use chromates.

Ambient conditions dictate the efficiency of any given tower due to the amount of water vapor the air is able to absorb and hold, as can be determined on a psychrometric chart.

Cooling towers and Legionnaires' disease

Another very important reason for using biocides in cooling towers is to prevent the growth of ***Legionella***, including species that cause legionellosis or ***Legionnaires' disease***, most notably *L. pneumophila*[5]. The various *Legionella* species are the cause of *Legionnaires' disease* in humans and transmission is via exposure to aerosols—the inhalation of mist droplets containing the bacteria. Common sources of *Legionella* include cooling towers used in open recirculating evaporative cooling water systems, domestic hot water systems, fountains, and similar disseminators that tap into a public water supply. Natural sources include freshwater ponds and creeks.

Cooling tower and water discharge of a nuclear power plant

French researchers found that *Legionella* spread through the air up to 6 kilometres from a large contaminated cooling tower at a petrochemical plant in Pas-de-Calais, France. That outbreak killed 21 of the 86 people that had a laboratory-confirmed infection.[6]

Drift (or windage) is the term for water droplets of the process flow allowed to escape in the cooling tower discharge. Drift eliminators are used in order to hold drift rates typically to 0.001%-0.005% of the circulating flow rate. A typical drift eliminator provides multiple directional changes of airflow while preventing the escape of water droplets. A well-designed and well-fitted drift eliminator can greatly reduce water loss and potential for

Legionella or other chemical exposure.

Many governmental agencies, cooling tower manufacturers and industrial trade organizations have developed design and maintenance guidelines for preventing or controlling the growth of *Legionella* in cooling towers. Below is a list of sources for such guidelines:

- Centers for Disease Control and Prevention [7]PDF (1.35 MB) - Procedure for Cleaning Cooling Towers and Related Equipment (pages 239 and 240 of 249)
- Cooling Technology Institute [8]PDF (240 KB) - Best Practices for Control of Legionella, July, 2006
- Association of Water Technologies [9]PDF (964 KB) - Legionella 2003
- California Energy Commission [10]PDF (194 KB) - Cooling Water Management Program Guidelines For Wet and Hybrid Cooling Towers at Power Plants
- SPX Cooling Technologies [11]PDF (119 KB) - Cooling Towers Maintenance Procedures
- SPX Cooling Technologies [12]PDF (789 KB) - ASHRAE Guideline 12-2000 - Minimizing the Risk of Legionellosis
- SPX Cooling Technologies [13]PDF (83.1 KB) - Cooling Tower Inspection Tips {especially page 3 of 7}
- Tower Tech Modular Cooling Towers [14]PDF (109 KB) - Legionella Control
- GE Infrastructure Water & Process Technologies Betz Dearborn [15]PDF (195 KB) - Chemical Water Treatment Recommendations For Reduction of Risks Associated with Legionella in Open Recirculating Cooling Water Systems

Cooling tower fog

Under certain ambient conditions, plumes of water vapor (fog) can be seen rising out of the discharge from a cooling tower (see Image 1), and can be mistaken as smoke from a fire. If the outdoor air is at or near saturation, and the tower adds more water to the air, saturated air with liquid water droplets can be discharged—what we see as fog. This phenomenon typically occurs on cool, humid days, but is rare in many climates.

Cooling Tower Operation In Freezing Weather

Cooling towers with malfunctions can freeze during very cold weather. Typically, freezing starts at the corners of a cooling tower with a reduced or absent heat load. Increased freezing conditions can create growing volumes of ice, resulting in increased structural loads. During the winter, some sites continuously operate cooling towers with 40 °F (4 °C) water leaving the tower. Basin heaters, tower draindown, and other freeze protection methods are often employed in cold climates.

- Do not operate the tower unattended.
- Do not operate the tower without a heat load. This can include basin heaters and heat trace. Basin heaters maintain the temperature of the water in the tower pan at an acceptable level. Heat trace is a resistive element that runs along water pipes located in cold climates to prevent freezing.
- Maintain design water flow rate over the fill.
- Manipulate airflow to maintain water temperature above freezing point.[16]

Some commonly used terms in the cooling tower industry

- **Drift** - Water droplets that are carried out of the cooling tower with the exhaust air. Drift droplets have the same concentration of impurities as the water entering the tower. The drift rate is typically reduced by employing baffle-like devices, called drift eliminators, through which the air must travel after leaving the fill and spray zones of the tower.
- **Blow-out** - Water droplets blown out of the cooling tower by wind, generally at the air inlet openings. Water may also be lost, in the absence of wind, through splashing or misting. Devices such as wind screens, louvers, splash deflectors and water diverters are used to limit these losses.
- **Plume** - The stream of saturated exhaust air leaving the cooling tower. The plume is visible when water vapor it contains condenses in contact with cooler ambient air, like the saturated air in one's breath fogs on a cold day. Under certain conditions, a cooling tower plume may present fogging or icing hazards to its surroundings. Note that the water evaporated in the cooling process is "pure" water, in contrast to the very small percentage of drift droplets or water blown out of the air inlets.
- **Blow-down** - The portion of the circulating water flow that is removed in order to maintain the amount of dissolved solids and other impurities at an acceptable level. It may be noted that higher TDS (total dissolved solids) concentration in solution results in greater potential cooling tower efficiency. However the higher the TDS concentration, the greater the risk of scale, biological growth and corrosion.
- **Leaching** - The loss of wood preservative chemicals by the washing action of the water flowing through a wood structure cooling tower.
- **Noise** - Sound energy emitted by a cooling tower and heard (recorded) at a given distance and direction. The sound is generated by the impact of falling water, by the movement of air by fans, the fan blades moving in the structure, and the motors, gearboxes or drive belts.
- **Approach** - The approach is the difference in temperature between the cooled-water temperature and the entering-air wet bulb temperature (twb). Since the cooling towers are based on the principles of evaporative cooling, the maximum cooling tower efficiency depends on the wet bulb temperature of the air. The wet-bulb temperature is a type of temperature measurement that reflects the physical properties of a system with a mixture of a gas and a vapor, usually air and water vapor
- **Range** - The range is the temperature difference between the water inlet and water exit.
- **Fill** - Inside the tower, fills are added to increase contact surface as well as contact time between air and water. Thus they provide better heat transfer. The efficiency of the tower also depends on them. There are two types of fills that may be used:
  - **Film type fill** (causes water to spread into a thin film)
  - **Splash type fill** (breaks up water and interrupts its vertical progress)

Fire hazards

Cooling towers which are constructed in whole or in part of combustible materials can support propagating internal fires. The resulting damage can be sufficiently severe to require the replacement of the entire cell or tower structure. For this reason, some codes and standards[17] recommend combustible cooling towers be provided with an automatic fire sprinkler system. Fires can propagate internally within the tower structure during maintenance when the cell is not in operation (such as for maintenance or construction), and even when the tower is in operation, especially those of the induced-draft type because of the existence of relatively dry areas within the towers[18] .

Stability


Ferrybridge power station

Being very large structures, they are susceptible to wind damage, and several spectacular failures have occurred in the past. At Ferrybridge power station on 1 November 1965, the station was the site of a major structural failure, when three of the cooling towers collapsed due to vibrations in 85mph winds. Although the structures had been built to withstand higher wind speeds, the shape of the cooling towers meant that westerly winds were funnelled into the towers themselves, creating a vortex. Three out of the original eight cooling towers were destroyed and the remaining five were severely damaged. The towers were rebuilt and all eight cooling towers were strengthened to tolerate adverse weather conditions. Building codes were changed to include improved structural support, and wind tunnel tests introduced to check tower structures and configuration.

See also

- Architectural engineering
- Cooling water
- Deep lake water cooling
- Evaporative cooler
- Fossil fuel power plant
- HVAC (Heating, ventilating and air conditioning)
- Hyperboloid structure
- → Mechanical engineering
- Power station
- Willow Island disaster

External links

- Cooling Towers: Design and Operation Considerations [19]
- What is a cooling tower? [20] - Cooling Technology Institute
- "Cooling Towers" - includes diagrams [21] - Virtual Nuclear Tourist

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[2] Cooling System Retrofit Costs (http://www.epa.gov/waterscience/presentations/maulbetsch.pdf) EPA Workshop on Cooling Water Intake Technologies, John Maulbetsch, Maulbetsch Consulting, May 2003
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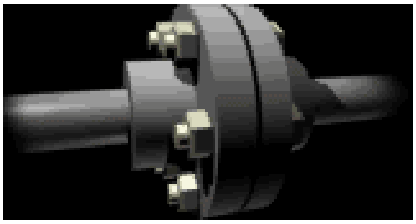
[5] Ryan K.J.; Ray C.G. (editors) (2004). *Sherris Medical Microbiology* (4th Edition ed.). McGraw Hill. ISBN 0-8385-8529-9.
[6] Airborne Legionella May Travel Several Kilometers (http://www.medscape.com/viewarticle/521680) (access requires free registration)
[7] http://www.cdc.gov/ncidod/dhqp/pdf/guidelines/Enviro_guide_03.pdf
[8] http://www.cti.org/downloads/WTP-148.pdf
[9] http://www.awt.org/Legionella03.pdf
[10] http://www.energy.ca.gov/2005publications/CEC-700-2005-025/CEC-700-2005-025.PDF
[11] http://spxcooling.com/pdf/M99-1342.pdf
[12] http://spxcooling.com/pdf/guide12.pdf
[13] http://spxcooling.com/pdf/M92-1474C.pdf
[14] http://www.towertechinc.com/documents/Legionella_Control_White_Paper_05072004.pdf
[15] http://www.gewater.com/pdf/tech73.pdf
[16] SPX Cooling Technologies: Operating Cooling Towers in Freezing Weather (http://spxcooling.com/pdf/H-003B.pdf)PDF (1.45 MB)
[17] National Fire Protection Association (NFPA). NFPA 214, *Standard on Water-Cooling Towers* (http://www.nfpa.org/aboutthecodes/AboutTheCodes.asp?DocNum=214).
[18] NFPA 214, *Standard on Water-Cooling Towers.* (http://www.nfpa.org/aboutthecodes/AboutTheCodes.asp?DocNum=214) Section A1.1
[19] http://www.cheresources.com/ctowerszz.shtml
[20] http://www.cti.org/whatis/coolingtowerdetail.shtml
[21] http://www.nucleartourist.com/systems/ct.htm

Coupling

This article describes a mechanical connection between two things. For other meanings, see Coupling (disambiguation).

A **coupling** is a device used to connect two shafts together at their ends for the purpose of transmitting power. Couplings do not normally allow disconnection of shafts during operation, though there do exist torque limiting couplings which can slip or disconnect when some torque limit is exceeded.


Rotating coupling

The primary purpose of couplings is to join two pieces of rotating equipment while permitting some degree of misalignment or end movement or both. By careful selection, installation and maintenance of couplings, substantial savings can be made in reduced maintenance costs and downtime.

Uses

Shaft couplings are used in machinery for several purposes, the most common of which are the following.[1]

- To provide for the connection of shafts of units that are manufactured separately such as a motor and generator and to provide for disconnection for repairs or alternations.
- To provide for misalignment of the shafts or to introduce mechanical flexibility.
- To reduce the transmission of shock loads from one shaft to another.
- To introduce protection against overloads.
- To alter the vibration characteristics of rotating units.

Types of shaft couplings

Rigid coupling

Rigid couplings are used when precise shaft alignment is required; shaft misalignment will affect the coupling's performance as well as its life. Examples:

- Sleeve or muff coupling
- Clamp or split-muff or compression coupling
- Flange coupling

Flexible coupling

Flexible couplings are designed to transmit torque while permitting some radial and axial and angular misalignment. Flexible couplings can accommodate angular misalignment up to a few degrees and some parallel misalignment. Examples:

- Bushed pin type coupling
- Universal coupling
- Oldham coupling
- Bellows coupling — low backlash.
- Spider or → jaw coupling — elastomeric inserts for flexibility, vibration reduction.
- Thompson coupling

- → Resilient coupling
- → Disc coupling
- Waldron coupling

Some applications like printing machines, roll forming machines, laminating machines, corrugated paper machines and paper making machines require an extreme and variable parallel offset. For these machines the coupling Schmidt-Kupplung is a solution.

Torque limiting coupling

Torque limiting couplings, or torque limiters, protect systems against overtorque conditions.

Requirements of good shaft alignment / good coupling setup

- it should be easy to connect or disconnect the coupling.
- it should transmit the full power from one shaft to other without losses.
- it does allow some misalignment between the two adjacent shaft roation axis.
- it is the goal to minimise the remaining misalignment in running operation to maximise power transmission and to maximise machine runtime (coupling and bearing and sealings lifetime).
- it should have no projecting parts.
- it is recommended to use manufacturer's alignment target values to set up the machine train to a defined non-zero alignment, due to the fact that later when the machine is at operation temperature the alignment condition is perfect

Tools to measure shaft axis alignment condition

- it is possible to measure the alignment with dial gages or feeler gages using various mechanical setups.
- it is recommended to take care of bracket sag, parallaxe error while reading the values.
- it is very convenient to use laser shaft alignment technique to perform the alignment task within highest accuracy.
- it is required to align the machine better, the laser shaft alignment tool can help to show the required moves at the feet positions.

Coupling maintenance and failure

Coupling maintenance is generally a simple matter, requiring a regularly scheduled inspection of each coupling. It consists of:

- Performing visual inspections, checking for signs of wear or fatigue, and cleaning couplings regularly.
- Checking and changing lubricant regularly if the coupling is lubricated. This maintenance is required annually for most couplings and more frequently for couplings in adverse environments or in demanding operating conditions.
- Documenting the maintenance performed on each coupling, along with the date.[2]
  Even with proper maintenance, however, couplings can fail. Underlying reasons for failure, other than maintenance, include:
- Improper installation

- Poor coupling selection
- Operation beyond design capabilities.[2]
  The only way to improve coupling life is to understand what caused the failure and to correct it prior to installing a new coupling. Some external signs that indicate potential coupling failure include:
- Abnormal noise, such as screeching, squealing or chattering
- Excessive vibration or wobble
- Failed seals indicated by lubricant leakage or contamination.[2]

Checking the coupling balance

Couplings are normally balanced at the factory prior to being shipped, but they occasionally go out of balance in operation. Balancing can be difficult and expensive, and is normally done only when operating tolerances are such that the effort and the expense are justified. The amount of coupling unbalance that can be tolerated by any system is dictated by the characteristics of the specific connected machines and can be determined by detailed analysis or experience.[2]

See also

- Clutch
- → Laser shaft alignment
- Compression fitting
- Piping and plumbing fittings

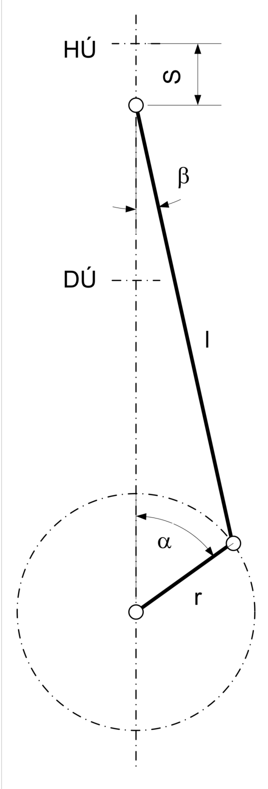
External links

- Shaft Coupling Glossary [3]
- List of coupling types [4]
- Laser Measurement Systems for Shaft & Machine Alignment [5]
- SkilFab Engineering www.skillfabcouplings.com - Leading Coupling Manufacturer [6]

References

[1] http://www.totalpumps.co.nz/products/couplings/
[2] Boyle, B.(2008) "Tracking the causes of coupling failure" *Plant Services* (http://www.plantservices.com/articles/2008/197.html) Explore coupling maintenance and the telltale signs of failure to maximize coupling life and ensure reliable system operations.
[3] http://www.unionmillwright.com/shaft.html
[4] http://www.roymech.co.uk/Useful_Tables/Drive/Drive_Couplings.html
[5] http://www.alignmentsupplies.com
[6] http://www.skilfabcouplings.com

Crank (mechanism)



A **crank** is an arm at right angles to a shaft (an axle or spindle), by which motion is imparted to or received from the shaft; it is also used to change circular into → reciprocating motion, or reciprocating into circular motion. The arm may be a bent portion of the shaft, or a separate arm keyed to it.

One application is human-powered turning of the axle. Often there is a bar perpendicular to the other end of the arm, often with a freely rotatable handle on it to hold in the hand, or in the case of operation by a foot (usually with a second arm for the other foot), with a freely rotatable pedal.

Examples

Familiar examples include:

Using a hand

- mechanical pencil sharpener
- fishing reel and other → reels for cables, wires, ropes, etc.
- manually operated car window
- the crank set that drives a trikke through its handles.

Using the feet

- the crankset that drives a bicycle via the pedals.
- → treadle sewing machine

Engines

Almost all reciprocating engines use cranks to transform the back-and-forth motion of the pistons into rotary motion. The cranks are incorporated into a crankshaft.

History

The eccentrically mounted handle of the rotary handmill which originated in 5th century BC Spain and ultimately spread all over the Roman Empire constitutes a crank.[1] [2] In China, hand-operated cranks appeared during the Han Dynasty (202 BC-220 AD), as Han era glazed-earthenware tomb models portray, and was used thereafter in China for silk-reeling and hemp-spinning, for the agricultural winnowing fan, in the water-powered flour-sifter, for hydraulic-powered metallurgic bellows, and in the well windlass.[3]

Tibetan operating a quern (1938). The perpendicular handle of such rotary handmills works as a crank.[1] [2]

An iron crank handle has been excavated in Augst, Germany. The 82.5 cm long piece with a 15 cm long handle is of yet unknown purpose and dates to no later than ca. 250 AD.[4] The earliest evidence for the crank as part of a machine, that is in combination with a connecting rod, appears in late Roman water-powered saw mills dating from the late 3rd (at Hierapolis) to 6th century AD (at Ephesus respectively Gerasa).[5]

The crank appears again in the early 9th century in several of the hydraulic devices described by the Banū Mūsā brothers in their *Book of Ingenious Devices*. A device shown in the 9th century Carolingian manuscript *Utrecht Psalter* is a crank handle used with a rotary grindstone.[6] Scholars point to the use of crank handles in trepanation drills in a 10th century work by the Spanish Muslim surgeon Abu al-Qasim al-Zahrawi (936–1013).[6] The Benedictine monk Theophilus Presbyter (c. 1070–c.1125) described crank handles "used in the turning of casting cores" according to Needham.[7]

Al-Jazari (1136–1206) described a crank and connecting rod system in a rotating machin in two of his water-raising machines.[8] His twin-cylinder pump incorporated a crankshaft which, like the modern crankshaft, consisted of a wheel setting several crank pins into motion, with the wheel's motion being circular and the pins moving back-and-forth in a straight line.[9]

The Italian physican and inventor Guido da Vigevano (c. 1280–1349) made illustrations for a paddle boat and a war carriages that were propelled by manually turned crankshafts and gear wheels.[10] The crank became common in Europe by the early 15th century, seen in the works of those such as the military engineer Konrad Kyeser (1366–after 1405).[10]

Cranks were formerly common on some machines in the early 20th century; for example almost all phonographs before the 1930s were powered by clockwork motors wound with cranks, and internal combustion engines of automobiles were usually started with cranks (known as ***starting handles*** [11] in the UK), before electric starters came into general use.

References

- Laur-Belart, Rudolf (1988), *Führer durch Augusta Raurica* (5th ed.), Augst
- Lucas, Adam Robert (2005), "Industrial Milling in the Ancient and Medieval Worlds. A Survey of the Evidence for an Industrial Revolution in Medieval Europe", *Technology and Culture* **46**: 1-30
- Ritti, Tullia; Grewe, Klaus; Kessener, Paul (2007), "A Relief of a Water-powered Stone Saw Mill on a Sarcophagus at Hierapolis and its Implications", *Journal of Roman Archaeology* **20**: 138–163

See also

- Winch
- → Piston motion equations
- Nothing grinder
- Sun and planet gear

External links and books

- Crank highlight: Hypervideo of construction and operation of a four cylinder internal combustion engine courtesy of Ford Motor Company [12]
- Needham, Joseph (1986). *Science and Civilization in China: Volume 4, Physics and Physical Technology, Part 2, Mechanical Engineering*. Taipei: Caves Books, Ltd.
- Kinematic Models for Design Digital Library (KMODDL) [21] - Movies and photos of hundreds of working mechanical-systems models at Cornell University. Also includes an e-book library [22] of classic texts on mechanical design and engineering.

References

[1] Ritti, Grewe & Kessener 2007, p. 159

[2] Lucas 2005, p. 5, fn. 9

[3] Needham, Joseph. (1986). Science and Civilization in China: Volume 4, Part 2, Mechanical Engineering. Taipei: Caves Books, Ltd. Pages 118–119.

[4] Laur-Belart 1988, p. 51–52, 56, fig. 42

[5] Ritti, Grewe & Kessener 2007, p. 161

[6] Needham, Volume 4, Part 2, 112.

[7] Needham, Volume 4, Part 2, 112–113.

[8] Ahmad Y Hassan. The Crank-Connecting Rod System in a Continuously Rotating Machine (http://www.history-science-technology.com/Notes/Notes 3.htm).

[9] Sally Ganchy, Sarah Gancher (2009), *Islam and Science, Medicine, and Technology*, The Rosen Publishing Group, p. 47, ISBN 1435850661

[10] Needham, Volume 4, Part 2, 113.

[11] Last car with a starting handle: Motoring Discussion forum (http://htdig.honestjohn.co.uk/forum/post/?t=56701)

[12] http://www.asterpix.com/console?as=1187646878192-e57383c789

Critical speed

In Solid mechanics, in the field of → rotordynamics, the **critical speed** is the theoretical angular velocity which excites the natural frequency of a rotating object, such as a shaft, propeller or gear. As the speed of rotation approaches the objects's natural frequency, the object begins to resonate which dramatically increases systemic vibration. The resulting resonance occurs regardless of orientation.

When the rotational speed is equal to the numerical value of the natural vibration then that speed is called critical speed.

For rotor bearing systems, critical speeds can be divided into two categories by their mode shape. Rigid body modes are spring mass damper systems, where the spring is the support bearing. Since almost all rotors have multiple bearings there are more than one rigid body mode. The second category is rotor bending modes where the shaft is the excited member in the system.

Rigid body modes for two bearing systems can be described as pitch or bounce modes. A pitch mode is a mode in which the deflection at each bearing is 180 degrees out of phase. A bounce mode is a mode in which the deflection at each bearing is in phase (phase angle near zero).

Critical speeds in rotor-bearing systems are excited by the eccentric center of gravity of the shaft. This is due to the static deflection under its own weight. The excitation force from unbalance is a function of the stiffness of the shaft and the shaft speed.

When a rotor approaches its first bending critical speed, the phase angle between the unbalance force and the resultant deflection approaches 90 degrees. Above the first critical speed, the rotor deflects 180 degrees behind the unbalance force. This does not occur for rigid body modes.

References

- Damping
- Oscillate
- Natural Frequency
- Resonance
- Vibration

D'Alembert–Euler condition

In mathematics and physics, especially the study of mechanics and fluid dynamics, the **d'Alembert-Euler condition** is a requirement that the streaklines of a flow are irrotational. Let **x** = **x**(**X**,*t*) be the coordinates of the point **x** into which **X** is carried at time *t* by a (fluid) flow. Let $\ddot{\mathbf{x}} = \frac{D^2\mathbf{x}}{Dt}$ be the second material derivative of **x**. Then the d'Alembert-Euler condition is:

$$\mathrm{curl}\ \mathbf{x} = \mathbf{0}.$$

The d'Alembert-Euler condition is named for Jean le Rond d'Alembert and Leonhard Euler who independently first described its use in the mid 1700's. It is not to be confused with the Cauchy-Riemann conditions.

References

- Truesdell, Clifford A. (1954). *The Kinematics of Vorticity*. Bloomington, IN: Indiana University Press. See sections 45–48.
- d'Alembert–Euler conditions [1] on the Springer Encyclopedia of Mathematics

References

[1] http://eom.springer.de/c/c020970.htm

DHCCI

DHCCI means **Diesel homogeneous charge compression ignition**.

See also

- Diesel (disambiguation)
- Automobile

External links

- Effects of Heat Release Mode on Emissions and Efficiencies of a Compound Diesel Homogeneous Charge Compression Ignition Combustion Engine [1]
- Reducing Greenhouse Gas Emissions from Light-Duty Motor Vehicles [2]

References

[1] http://scitation.aip.org/getabs/servlet/GetabsServlet?prog=normal&id=JETPEZ000128000002000446000001&idtype=cvips&gifs=yes
[2] http://www.nescaum.org/documents/rpt040923ghglightduty-execsumm.pdf/

DVVL

DVVL is:

- Discrete variable valve lift:
  - DVVLd: Discrete variable valve lift, includes dual cam phasing.
  - DVVLi: Discrete variable valve lift, includes intake valve cam phasing.

Damper (flow)

A **damper** is a valve or plate that stops or regulates the flow of air inside a duct, chimney, → VAV box, → air handler, or other air handling equipment. A damper may be used to cut off central air conditioning (heating or cooling) to an unused room, or to regulate it for room-by-room temperature and climate control. Its operation can be manual or automatic. Manual dampers are turned by a handle on the outside of a duct. Automatic dampers are used to regulate airflow constantly and are operated by electric or pneumatic motors, in turn controlled by a thermostat or building automation system.

Opposed blade dampers in a mixing duct.

In a chimney flue, a damper closes off the flue to keep the weather (and birds and other animals) out and warm or cool air in. This is usually done in the summer, but also sometimes in the winter between uses. In some cases, the damper may also be partly closed to help control the rate of combustion. The damper may be accessible only by reaching up into the fireplace by hand or with a woodpoker, or sometimes by a lever or knob that sticks down or out. On a woodburning stove or similar device, it is usually a handle on the vent duct as in an air conditioning system. Forgetting to open a damper before beginning a fire can cause serious smoke damage to the interior of a home, if not a house fire.

Automated zone dampers

An opposed-blade, motor-closed, motor-opened zone damper. The damper is shown in the "open" position.

A zone damper (also known as a **Volume Control Damper** or **VCD**) is a specific type of damper used to control the flow of air in an HVAC heating or cooling system. In order to improve efficiency and occupant comfort, HVAC systems are commonly divided up into multiple zones. For example, in a house, the main floor may be served by one heating zone while the upstairs bedrooms are served by another. In this way, the heat can be directed principally to the main floor during the day and principally to the bedrooms at night, allowing the unoccupied areas to cool down.

Close-up of the motor connections. This damper can switch the electrical power to control additional "slave" dampers, minimizing the electrical load on the damper's control circuitry and power transformer

Zone dampers as used in home HVAC systems are usually electrically powered. In large commercial installations, vacuum or compressed air may be used instead. In either case, the motor is usually connected to the damper via a mechanical coupling.

For electrical zone dampers, there are two principal designs.

In one design, the motor is often a small shaded-pole synchronous motor combined with a rotary switch that can disconnect the motor at either of the two stopping points ("damper open" or "damper closed"). In this way, applying power to the "open damper" terminal causes the motor to run until the damper is open while applying power at the "close damper" terminal causes the motor to run until the damper is closed. The motor is commonly powered from the same 24 volt ac power source that is used for the rest of the control system. This allows the zone dampers to be directly controlled by low-voltage thermostats and wired with low-voltage wiring. Because simultaneous closure of all dampers might harm the furnace or air handler, this style of damper is often designed to only obstruct a portion of the air duct, for example, 75%.

Another style of electrically powered damper uses a spring-return mechanism and a shaded-pole synchronous motor. In this case, the damper is normally opened by the force of the spring but can be closed by the force of the motor. Removal of electrical power re-opens the damper. This style of damper is advantageous because it is "fail safe"; if the control to the damper fails, the damper opens and allows air to flow. However, in most applications "fail safe" indicates the damper will close upon loss of power thus preventing the spread of smoke and fire to other areas. These dampers also may allow adjustment of the "closed" position so that they only obstruct, for example, 75% of the air flow when closed.

For vacuum- or pneumatically-operated zone dampers, the thermostat usually switches the pressure or vacuum on or off, causing a spring-loaded rubber diaphragm to move and

actuate the damper. As with the second style of electrical zone dampers, these dampers automatically return to the default position without the application of any power, and the default position is usually "open", allowing air to flow. Like the second style of electrical zone damper, these dampers may allow adjustment of the "closed" position.

Highly sophisticated systems may use some form of building automation such as BACnet or LonWorks to control the zone dampers. The dampers may also support positions other than fully open or fully closed and are usually capable of reporting their current position and, often, the temperature and volume of the air flowing past the smart damper.

Regardless of the style of damper employed, the systems are often designed so that when no thermostat is calling for air, all dampers in the system are opened. This allows air to continue to flow while the heat exchanger in a furnace cools down after a heating period completes.

Comparison to multiple furnaces/air handlers

Multiple zones can be implemented using either multiple, individually-controlled furnaces/air handlers or a single furnace/air handler and multiple zone dampers. Each approach has advantages and disadvantages.

Multiple furnaces/air handlers

Advantages:

- Simple mechanical and control design ("SPST thermostats")
- Redundancy: If one zone furnace fails, the others can remain working

Disadvantages:

- Cost. Furnaces cost much more than zone dampers
- Power consumption. Operating furnaces draw power whereas a zone damper only draws power while in motion from one state to the other (or, in some cases, a very small amount of power while holding closed).

Zone dampers

Advantages:

- Cost.
- Power consumption.

Disadvantages:

- Zone dampers are not 100% reliable. The motor-to-open/motor-to-closed style of electrically operated zone dampers aren't "fail safe" (that is, they do not fail to the open condition). However, zone dampers that are of the "Normally Open" type are fail-safe, in that they will fail to the open condition.
- No inherent redundancy for the furnace. A system with zone dampers is dependent upon a single furnace. If it fails, the system becomes completely inoperable.
- The system can be harder to design, requiring both "SPDT" thermostats (or relays) and the ability of the system to withstand the fault condition whereby all zone dampers are closed simultaneously.

Fire dampers

Fire dampers are fitted where ductwork passes through fire compartment walls / fire curtains as part of a fire control strategy. In normal circumstances, these dampers are held open by means of fusible links. When subjected to heat, these links fracture and allow the damper to close under the influence of the integral closing spring. The links are attached to the damper such that the dampers can be released manually for testing purposes. The damper is provided with an access door in the adjacent ductwork for the purpose of inspection and resetting in the event of closure.

See also

- Zone valve
- → Variable air volume (VAV)

External links

- Flextor Dampers FAQ [1]

References

[1] http://dampersandexpansionjoints.com/damper-expansion-joint-faq.html

Daxcon

Type	Private
Founded	1996
Headquarters	Bartonville, Illinois, USA
Key people	Mike Daxenbichler, CEO
Industry	Aerospace & Defense, Automotive, Agriculture, Consumer Products, Construction & Mining
Products	Consultation, Software, Training, Modeling
Employees	350 (2008)
Website	daxcon.com [1]

Daxcon Engineering, Inc. is a United States based company headquartered in Bartonville, Illinois, that provides engineering and manufacturing consultation to the Defense & Aerospace, Mining & Construction, Automotive, Consumer Products, and Agriculture industries.

History

Daxcon was founded in 1996 in Central Illinois to fulfill the demand for product design and engineering services. Daxcon's management team first started working in the engineering design industry in the 1980s. Throughout the last decade Daxcon has continued to expand their company with new offices in St. Louis, Missouri and Detroit, Michigan.

Daxcon has worked with several large companies such as Caterpillar, Inc., Ford Motor Company, Komatsu, Boeing, and Case New Holland.

Services

Daxcon provides services in several different divisions: Design Engineering, Finite Element Analysis, Training & Software, and Virtual Engineering.

Design Engineering

Daxcon performs design engineering in conjunction with various companies to speed up the project design, lower cost, and improve quality. Types of projects that Daxcon has worked on in the past include: Class A surfacing on interior/exterior components, engine and engine installation packaging, internal combustion engine performance, structural component design, intake and exhaust manifold design, HVAC design and packaging, and cooling package layout and design for generator and vehicle operations.

Finite Element Analysis

Finite Element Analysis involves studying a customer's product for any weakness that may be present in the material. Daxcon specifically uses the following formats for analysis: Failure Mode Effects Analysis (FMEA), linear and non-linear statistics, normal mode dynamics, thermally induced stress, load path characterization, weld fatigue life, mechanism simulations and animation, bolted joint study, and hand calculations.

Training & Software

Daxcon will create personalized training for each customer. With the use of a Learning Management System (LMS), Daxcon uses consulting agents to minimize the engineers' learning curves to expedite production. Because Daxcon is not affiliated with a specific hardware or software company, they will customize software for specific projects.

Virtual Engineering

Daxcon utilizes extensive 3D modeling. Daxcon converts 2D drawings into 3D parametric drawings, run complex 3D modeling simulations, and use many forms of CAD. Daxcon also trains companies to create their own 3D modeling and detailed 2D or 3D prints.

Industries

Daxcon has worked in several industries including; Defense & Aerospace, Mining & Construction, Automotive, Consumer Products, and Agriculture.

Defense & Aerospace

Daxcon has worked with several customers that require NOFORN security clearance. Along with NOFORN, Daxcon has also worked indepth with the guidelines and requirements within the industry, such as; MIL SPECS, design guidelines, model-based definition rules, security regulations, and audit standards. Daxcon has worked within the aerospace industry which has many of the same security and guidelines as the defense industry.

Mining & Construction

Daxcon does business with some of the largest construction equipment companies in the world. Many of these construction companies exercise continuous production and employ Daxcon to minimize any downtime from production. Daxcon also develops job specific vehicles. Along with the creation of both manufacturing processes and job specific vehicles, Daxcon creates and improves the components of specific vehicles, which is often similar to that of the automotive industry.

Automotive

Daxcon works with OEMs to provide the automotive industry with support when dealing with huge supply chains. Through direct access to the OEM CAD database, Daxcon works together with the automotive companies to ensure that products will be completed and are cost efficient. Daxcon engineers also work as consultants for companies in the development automobile components.

Consumer Products

Daxcon works with small companies to bring their new products to market. Daxcon uses FMEAs, or prototype analysis to assist in the search for patents for the new product. Daxcon assesses the marketability of new products to save small companies time and production costs. In addition to these tasks, Daxcon provides design work and assistance to individuals and/or small companies needing the manpower to develop an idea or design. Daxcon provides consumers project services from concept through production.

Agriculture

Daxcon works with agriculture industries to increase equipment efficiency, which in turn provides improved and increased profitability and reduces the risk of yield loss. Daxcon often uses a similar process in agriculture equipment as is used in both the construction and automotive industries.

See also

- Consultant
- Ford Motor Company
- Boeing
- Komatsu Limited
- Caterpillar, Inc.
- Case New Holland

References

- Dun & Bradstreet, U.S. Company Profile report
- Daxcon Human Resource Department
- Daxcon Headquarters

External links

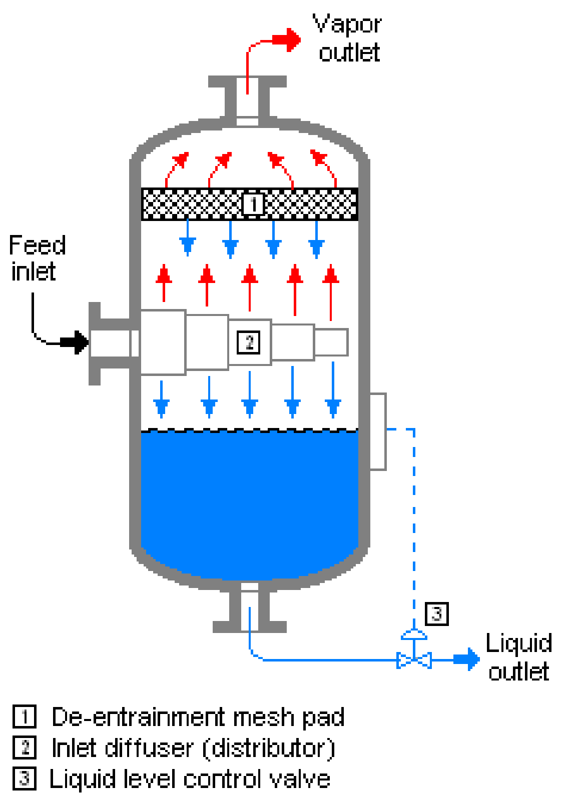
- Official site [1]
- NOFORN [2]

References

[1] http://www.daxcon.com/
[2] http://www.dss.mil/isec/nispom.htm

Demister (Vapor)

A **demister**, is a device often fitted to vapor liquid separator vessels to enhance the removal of liquid droplets entrained in a vapor stream. Demisters may be a mesh type coalescer, vane pack or other structure intended to aggregate the mist into droplets that are heavy enough to separate from the vapor stream.



A typical, large-scale, vapor-liquid separator as used in oil refineries, petrochemical and chemical plants

Demisters can reduce the residence time required to separate a given liquid droplet size thereby reducing the volume and associated cost of separator equipment. Demisters are often used where vapor quality is important in regard to entrained liquids particularly where separator equipment costs are high (e.g. high pressure systems) or where space or weight savings are advantageous.

Example: In the process of brine desalination on marine vessels, brine is flash heated into vapor. In flashing, vapor carries over droplets of brine which have to be separated before condensing, otherwise the distillate vapor would be contaminated with salt. This is the role of the demister. Demisted vapor condenses on tubes in the desalination plant, and product water is collected in the distillate tray.

See also

- Souders-Brown equation
- CWMS
- Separator
- Vane type separator
- Vessel Internals
- Gas Processors Suppliers Association (GPSA)

Detent

Detent is the term for a method, as well as the actual device, used to mechanically resist or arrest the rotation of a wheel, axle or spindle.

A detent can be used to intentionally divide a rotation into discrete increments, or as in perhaps its original concept and most rudimentary form, to simply arrest rotation in one direction.

Mechanics

Arresting movement

To arrest movement, the method commonly employs a small gravity or spring-actuated → lever paired with a notched wheel. The lever is mounted on a pivot point in proximity to the wheel (so that the end cannot swing completely around) and comes into contact with it at a tangential angle less than 90 degrees.

The vertical angle of the sides of the notches that face the direction that rotation is desired is generally acute (45 degrees or less), so that as the wheel rotates in that direction, the end of the lever is easily lifted or pushed out and over the top of a notch. Following this, the lever drops into the next notch and the next et cetera as the wheel or shaft continues to spin.

The angle of the backside of the notch is severe (usually 90 degrees or greater to the end of the lever) so that the lever cannot be pushed up or out of the notch if wheel attempts to turn in the opposite direction. The lever is jammed between the back of the notch and its pivot point, stopping movement in that direction against any force that the materials used can withstand. The wheel has little resistance moving in the direction desired, other than that required to lift or push the lever over the next notch.

Resisting movement

To resist movement (or when creating incremental steps), methods are employed which include a spring-loaded ball bearing that locates in small incremental depressions, or a piece of spring steel that snaps into position on flat surfaces or shallow notches milled into the shaft or wheel.

Examples

A well-known example of a detent can be seen on the popular game show "Wheel Of Fortune", which employs rubber "fingers" to stop the wheel at valid points after the wheel is spun by a contestant. Other common examples include:

- A balance control on a piece of stereo equipment which seems to "click" or "snap" into the center position of its rotation, indicating the point where the volumes of the left and right channels are equal or "balanced", or volume controls with a separate detent to match each of the digits on the control knob (typically 10).
- Rotary switches typically employ detents to keep the control shaft properly aligned with the appropriate contact.
- Any spring-powered wind-up toy employs one, in order to disallow unwinding of the spring.

- The ratchet wrench, which interestingly is employed to intentionally use force against the detent and comes in increasing variety of types. It was designed to allow one to keep the wrench engaged with the bolt or nut which it is turning, in an area where the swing arc of the wrench is limited, while being able to continue to turn it in one direction by simply pulling the handle back and letting the detent reposition itself. The repositioning allows the wrench to be forcibly turned again.
- The scroll wheels on many computer mice, employ detents to divide scrolling into discrete steps.

See also

- → Ball detent
- Ratchet (device)

Diagonal or mixed-flow compressor

A **diagonal or mixed-flow compressor** is effectively a cross between a centrifugal and axial-flow compressor. The American term diagonal-flow is very apt, because these compressors combine both axial and radial velocity components. The prime advantage is the relatively small diameter across the exit diffuser, compared with that of the equivalent centrifugal compressor. A diagonal-flow compressor is featured in the Pratt & Whitney Canada PW610F turbofan, recently certified for the Eclipse 500 Very Light Jet aircraft.

See also

- Mixed flow compressor
- Gas compressor

Diaphragm compressor

A **diaphragm compressor** is a variant of the classic → reciprocating compressor with backup and piston rings and rod seal. The compression of gas occurs by means of a flexible membrane, instead of an intake element. The back and forth moving membrane is driven by a rod and a crankshaft mechanism. Only the membrane and the compressor box come in touch with pumped gas. For this reason this construction is the best suited for pumping toxic and explosive gases. The membrane has to be reliable enough to take the strain of pumped gas. It must also have adequate chemical properties and sufficient temperature resistance.

A diaphragm compressor is the same as a membrane compressor.

Compression of hydrogen gas with a diaphragm compressor

The photograph included in this section depicts a three-stage diaphragm compressor used to compress hydrogen gas to 6,000 psi (41 MPa) for use in a prototype hydrogen and compressed natural gas (CNG) fueling station built in downtown Phoenix, Arizona by the Arizona Public Service company (an electric utilities company). → Reciprocating compressors were used to compress the natural gas.[1]

A three-stage diaphragm compressor

The prototype alternative fueling station was built in compliance with all of the prevailing safety, environmental and building codes in Phoenix to demonstrate that such fueling stations could be built in urban areas.[1]

In other systems high pressure electrolysis is used.

See also

- Gas compressor
- Diaphragm pump

References

[1] Alternative Fuel (Hydrogen) Pilot Plant Design Report (http://avt.inl.gov/pdf/hydrogen/h2stationreport.pdf) (Report INEEL / EXT-O3-00976 of the Idaho National Laboratory of the U.S. Department of Energy)

Disc coupling

A **disc coupling** is a high performance motion control (Servo) → coupling designed to be the torque transmitting element (by connecting two shafts together) while accommodating for shaft misalignment. It is designed to be flexible, while remaining torsionally strong under high torque loads. Typically, disc couplings can handle speeds up to 10,000 RPM.

There are two different styles of disc coupling:

	**Single Disc** Style couplings are composed of two hubs (the ends of the coupling, which are typically made from aluminum, but stainless steel is used as well) and a single, flat, stainless steel disc spring.
	**Double Disc** Style coupling is also composed of two hubs, but has an additional center spacer sandwiching two disc springs. The center spacer can be made out of the same material as the hubs, but is sometimes available in insulating acetal, which makes the coupling electrically isolating.

The difference between the two styles is that single disc couplings cannot accommodate parallel misalignment due to the complex bending that would be required of the lone disc. Double disc styles allow the two discs to bend in opposite directions to better manage parallel offset. The discs are fastened to the hubs (and center spacer on double disc styles) with tight fitting pins that do not allow any play or backlash between the disc and the hubs. The discs can be bent easily and as a result, disc couplings have some of the lowest bearing loads available in a motion control coupling.

Torsionally stiff and still flexible, disc couplings are a great solution for high speed applications. The downside is that they are more delicate than the average coupling and can be damaged if misused. Special care should be taken to ensure that misalignment is within the ratings of the coupling.

See also

- Oldham coupling
- → Resilient coupling
- Thompson coupling
- Universal coupling

Docking sleeve

In → mechanical engineering, a **docking sleeve** or **mounting boss** is a tube or enclosure used to couple two mechanical components together, or to retain two components together; this permits two equally-sized appendages to be connected together via insertion and fixing within the construction. Docking sleeves may be physically solid or flexible, their implementation varying widely according to the required application of the device. The most common application is the plastic appendage that receives a screw in order to attach two parts.

Drive by wire

Drive-by-wire, **DbW**, **by-wire**, or **x-by-wire** technology in the automotive industry replaces the traditional mechanical and hydraulic control systems with electronic control systems using electromechanical actuators and human-machine interfaces such as pedal and steering feel emulators. Hence, the traditional components such as the steering column, intermediate shafts, pumps, hoses, fluids, belts, coolers and brake boosters and master cylinders are eliminated from the vehicle. Examples include electronic throttle control and brake-by-wire.

Advantages

Safety can be improved by providing computer controlled intervention of vehicle controls with systems such as Electronic Stability Control (ESC), adaptive cruise control and Lane Assist Systems.

Ergonomics can be improved by the amount of force and range of movement required by the driver and by greater flexibility in the location of controls. This flexibility also significantly expands the number of options for the vehicle's design.

Parking can be made easier with reduced lock-to-lock steering wheel travel as with BMW's Active Steering System, or semi-automatic parallel parking which is available in some Toyota Prius in Japan, Lexus LS460 models worldwide and newer European Volkswagen models. Although neither of these are strictly Steer-by-Wire (SbW) because they retain mechanical linkages, they show the capabilities that are possible.

Disadvantages

The cost of DbW systems is often greater than conventional systems. The extra costs stem from greater complexity, development costs and the redundant elements needed to make the system safe. Failures in the control system could theoretically cause a runaway vehicle. The vehicle could still be stopped by turning the ignition off if this occurred.

Steer by Wire

This is currently used in electric forklifts and stockpickers and some tractors[1]. Its implementation in road vehicles is limited by concerns over reliability although it has been demonstrated in several concept vehicles such as ThyssenKrupp Presta Steering's Mercedes-Benz Unimog, General Motors' Hy-wire and Sequel and the Mazda Ryuga. A rear

wheel SbW system by Delphi called Quadrasteer is used on some pickup trucks but has had limited commercial success.

Competitors in the DARPA Grand Challenge, an automated driving competition, relied on 100% DbW systems, in some cases including a SbW system provided by the manufacturer [2].

This is not to be confused with Electric Power Steering.

Passenger car state-of-the-art

Electronic fuel injection metering in diesel and gasoline engines is now widely used. Electronic throttle control is also in widespread use for gasoline engine control. Electronic brake and steering systems have yet to find widespread application in passenger cars. This is primarily due to the significant safety implications of steering or braking systems without a redundant mechanical backup in case of failure of the DbW system. Although technically feasible (as demonstrated in aircraft fly-by-wire) the additional cost and service requirements have made these systems commercially uncompetitive to date. Hybrid vehicles (e.g. Toyota Prius) employ limited electronically controlled regenerative braking but the standard hydraulic braking system is retained. The growth in sales of hybrid and electric vehicles is likely to become an enabling factor for drive-by-wire systems in the future due to the availability of high power electrical supplies required for the new electrical actuators.

The future

Some fanciful theories and applications abound as to what the ultimate implications of DbW technology might be. It has been suggested that DbW might allow a car to become completely separate from its controls, meaning that a car of the future might theoretically be controlled by any number of different control systems: push buttons, joysticks, steering wheels, or even voice commands — whatever device that designers could come up with. This would have many advantages, such as:

- increased flexibility for handicapped or disabled drivers
- less weight in the car
- more space in the car

See also

- Brake-by-wire
- Electronic throttle control
- Fly-by-wire

External links

- Missing data compensation for safety-critical components in a drive-by wire system [3]
- Fusion of redundant information in brake-by-wire systems, using a fuzzy Voter [4]
- Position sensing in by-wire brake callipers using resolvers [5]

[1] http://www.motionsystemdesign.com/Issue/Article/47436/ArticleDraw.aspx
[2] http://ai.stanford.edu/~dstavens/darpa/Stanford.pdf
[3] http://www.ses.swin.edu.au/~rhoseinnezhad/ieee_tvt_1.pdf
[4] http://www.isif.org/2075D04.pdf

[5] http://www.ses.swin.edu.au/~rhoseinnezhad/ieee_tvt_2.pdf

Dropping point

The **dropping point** of a soap-thickened lubricating grease is the temperature at which it passes from a semi-solid to a liquid state under specific test conditions. It is an indication of the type of thickener used, and a measure of the cohesiveness of the oil and thickener of a grease.[1]

Dropping point is used in combination with other testable properties to determine the suitability of greases for specific applications. It is applicable only to greases that contain soap thickeners. Greases with other thickeners, such as many synthetic greases, do not change state. Instead, they separate oil, and the dropping point as a phase transition does not apply.

ASTM test procedure

The dropping point test procedures are given in ASTM standards D-566[2] and D-2265[3] . The test apparatus consists of a grease cup with a small hole in the bottom, test tube, two thermometers, a container, stirring device if required and an electric heater. The inside surfaces of the grease cup are coated with the grease to be tested. A thermometer is inserted into the cup and held in place so that the thermometer does not touch the grease. This assembly is placed inside a test tube. The test tube is lowered into the container which is filled with oil in D-556 and has an aluminum block in D-2265. Another thermometer is inserted into the oil/block.

To execute a test, the oil/block is heated, while being stirred, at a rate of 8 to 12°F per minute until the temperature is approximately 30°F below the expected dropping point. The heat is reduced until the test tube temperature is 4°F or less than the oil/block temperature. Once the temperature has stabilized the sample is inserted. The dropping point is the temperature recorded on the test tube thermometer, plus a correction factor for the oil/block temperature, when a drop of grease falls through the hole in the grease cup. If the drop trails a thread, the dropping temperature is the temperature at which the thread breaks.

D-2265 explains that the dropping point is useful to assist in identifying the type of grease, and for establishing and maintaining benchmarks for quality control. It adds that the results are not sufficient to assess service performance because dropping point is a static test.

Other test procedures

Equivalent to D566 and D2265:[1]

- IP 132
- ISO 2176:1995 Petroleum products -- Lubricating grease -- Determination of dropping point[4]
- DIN 51806

Other:

- National Standard of People’s Republic of China GB/T 4929 “Test Methods for Dropping Point of Grease”[5]

- S 1448(P-52)
- GOST 7134-73, Method B
- JIS K2220:2003 Lubricating grease
- DIN 51801 Dropping Point of Lubricating Grease

References

[1] Totten, G.E., *Handbook of Lubrication and Tribology Volume 1: Application and Maintenance*, CRC Press, 2006, ISBN 084932095X
[2] *ASTM D566 - 02 Standard Test Method for Dropping Point of Lubricating Grease* (http://www.astm.org/Standards/D566.htm), ASTM
[3] *ASTM D2265 - 06 Standard Test Method for Dropping Point of Lubricating Grease Over Wide Temperature Range* (http://www.astm.org/Standards/D2265.htm), ASTM
[4] *ISO 2176:1995 Petroleum products -- Lubricating grease -- Determination of dropping point* (http://www.iso.org/iso/iso_catalogue/catalogue_ics/catalogue_detail_ics.htm?csnumber=6975&ICS1=75&ICS2=100), ISO product page
[5] *SYD-4929A Lubricating Grease Dropping Point Tester* (http://shanghaichangji.en.ecplaza.net/67.asp), Shanghai Changji Geological Instrument Co., Ltd

Duality (mechanical engineering)

In → mechanical engineering, many terms are associated into pairs called **duals**. A dual of a relationship is formed by interchanging force (stress) and deformation (strain) in an expression.

Here is a partial list of mechanical dualities:

- force — deformation
- stress — strain
- stiffness method — flexibility method

Examples

Constitutive relation

- stress and strain (Hooke's law.)

$$\sigma = E\varepsilon \iff \varepsilon = \frac{1}{E}\sigma$$

See also

- Duality (electrical circuits)

References

- Fung, Y. C., *A First Course in CONTINUUM MECHANICS*, 2nd edition, Prentice-Hall, Inc. 1977

Dunkerley's Method

Dunkerley's method is used in mechanical engineering to determine the critical speed of a shaft-rotor system. Other methods include the → Rayleigh-Ritz method.

Whirling of a Shaft

No shaft can ever be perfectly straight or perfectly balanced. When an element of mass is a distance ‘ ’ from the axis of rotation, centrifugal force, will tend to pull the mass outward. The elastic properties of the shaft will act to restore the “straightness”. If the frequency of rotation is equal to one of the resonant frequencies of the shaft, whirling will occur. In order to save the machine from failure, operation at such whirling speeds must be avoided. Whirling is a complex phenomenon that can include harmonics but we are only going to consider synchronous whirl, where the frequency of whirling is the same as the rotational speed.

Dunkerley’s Formula (Approximation)

The whirling frequency of a symmetric cross section of a given length between two points is given by:

$$N = 94.25\sqrt{\frac{E\ I}{m\ L^3}}\,\text{RPM}$$

where E = young's modulus, I = Second moment of area, m = mass of the shaft, L= length of the shaft between points

A shaft with weights added will have an angular velocity of N (rpm) equivalent as follows:

$$\frac{1}{N_N^2} = \frac{1}{N_A^2} + \frac{1}{N_B^2} + \cdots + \frac{1}{N_n^2}$$

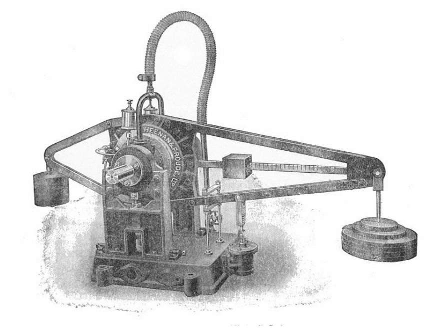
Background Information

- Vibration
- Mechanical resonance

Dynamometer

For the dynamometer used in railroading, see dynamometer car.

A **dynamometer** or **"dyno"** for short, is a device for measuring force or power. For example, the power produced by an engine, motor or other rotating prime mover can be calculated by simultaneously measuring torque and rotational speed (rpm).



Early hydraulic dynamometer, with dead-weight torque measurement.

A dynamometer can also be used to determine the torque and power required to operate a driven machine such as a pump. In that case, a *motoring* or *driving* dynamometer is used. A dynamometer that is designed to be driven is called an *absorption* or *passive* dynamometer. A dynamometer that can either drive or absorb is called a *universal* or *active* dynamometer.

In addition to being used to determine the torque or power characteristics of a machine under test (MUT), dynamometers are employed in a number of other roles. In standard emissions testing cycles such as those defined by the US Environmental Protection Agency (US EPA), dynamometers are used to provide simulated road loading of either the engine (using an engine dynamometer) or full powertrain (using a chassis dynamometer). In fact, beyond simple power and torque measurements, dynamometers can be used as part of a testbed for a variety of engine development activities such as the calibration of engine management controllers, detailed investigations into combustion behavior and tribology.

In the medical realm, hand dynamometers are used for routine screening of grip strength and initial and ongoing evaluation of patients with hand trauma and dysfunction. They are also used to measure grip strength in patients where compromise of the cervical nerve roots or peripheral nerves is suspected. In the rehabilitation, kinesiology and ergonomics realms, dynamometers are used for measuring grip, arm and leg strength of athletes, patients and workers to evaluate performance, task demands and physical status.

Principles of operation

An absorbing dynamometer acts as a load that is driven by the prime mover that is under test (e.g. Pelton wheel). The dynamometer must be able to operate at any speed, and load the prime mover to any level of torque that the test requires. A dynamometer is usually equipped with some means of measuring the operating torque and speed.

The dynamometer must absorb the power developed by the prime mover. The power absorbed by the dynamometer must generally be dissipated to the ambient air or transferred to cooling water. Regenerative dynamometers transfer the power to electrical power lines.

Dynamometers can be equipped with a variety of control systems. If the dynamometer has a torque regulator, it operates at a set torque while the prime mover operates at whatever speed it can attain while developing the torque that has been set. If the dynamometer has a speed regulator, it develops whatever torque is necessary to force the prime mover to operate at the set speed.

A motoring dynamometer acts as a motor that drives the equipment under test. It must be able to drive the equipment at any speed and develop any level of torque that the test requires.

In most dynamometers power (P) is not measured directly; it must be calculated from torque (τ) and angular velocity (ω) values or force (F) and linear velocity (v):

$$P = \tau \cdot \omega$$

or

$$P = F \cdot v$$

where

P is the power in watts

τ is the torque in newton metres

ω is the angular velocity in radians per second

F is the force in newtons

v is the linear velocity in metres per second

Division by a conversion constant may be required depending on the units of measure used.

For imperial units,

$$P_{\mathrm{hp}} = \frac{\tau_{\mathrm{lb\cdot ft}} \cdot \omega_{\mathrm{rpm}}}{5252}$$

where

P_{hp} is the power in horsepower

$\tau_{\mathrm{lb\cdot ft}}$ is the torque in pound-feet

ω_{rpm} is the rotational velocity in revolutions per minute

For metric units,

$$P_{\mathrm{kW}} = \frac{\tau_{\mathrm{N\cdot m}} \cdot \omega_{\mathrm{rpm}}}{9549}$$

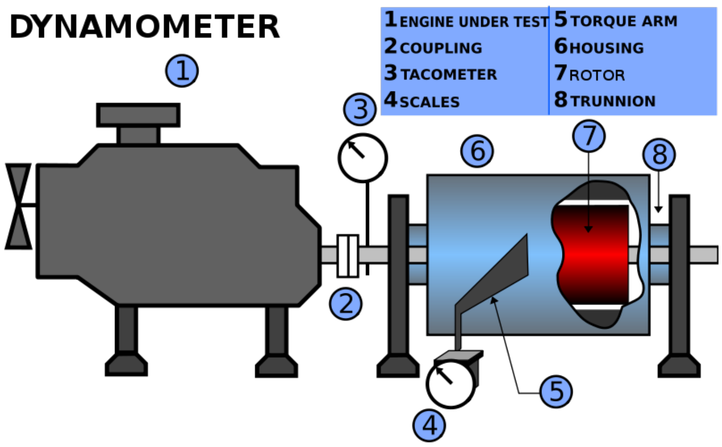
where

P_{kW} is the power in kilowatts

$\tau_{\mathrm{N\cdot m}}$ is the torque in newton metres

ω_{rpm} is the rotational velocity in revolutions per minute

Detailed dynamometer description



Electrical dynamometer setup showing engine, torque measurement arrangement and tachometer

A dynamometer consists of an absorption (or absorber/driver) unit, and usually includes a means for measuring torque and rotational speed. An absorption unit consists of some type of rotor in a housing. The rotor is coupled to the engine or other equipment under test and is free to rotate at whatever speed is required for the test. Some means is provided to develop a braking torque between dynamometer's rotor and housing. The means for developing torque can be frictional, hydraulic, electromagnetic etc. according to the type of absorption/driver unit.

One means for measuring torque is to mount the dynamometer housing so that it is free to turn except that it is restrained by a torque arm. The housing can be made free to rotate by using → trunnions connected to each end of the housing to support the dyno in pedestal mounted trunnion bearings. The torque arm is connected to the dyno housing and a weighing scales is positioned so that it measures the force exerted by the dyno housing in attempting to rotate. The torque is the force indicated by the scales multiplied by the length of the torque arm measured from the center of the dynamometer. A load cell transducer can be substituted for the scales in order to provide an electrical signal that is proportional to torque.

Another means for measuring torque is to connect the engine to the dynamometer through a torque sensing coupling or torque transducer. A torque transducer provides an electrical signal that is proportional to torque.

With electrical absorption units, it is possible to determine torque by measuring the current drawn (or generated) by the absorber/driver. This is generally a less accurate method and not much practiced in modern time, but it may be adequate for some purposes.

A wide variety of tachometers are available for measuring speed. Some types can provide an electrical signal that is proportional to speed.

When torque and speed signals are available, test data can be transmitted to a data acquisition system rather than being recorded manually. Speed and torque signals can also be recorded by a chart recorder or plotter.

Types of dynamometers

In addition to classification as *Absorption*, *Motoring* or *Universal* as described above, dynamometers can be classified in other ways.

A dyno that is → coupled directly to an engine is known as an *engine dyno*.

A dyno that can measure torque and power delivered by the power train of a vehicle directly from the drive wheel or wheels (without removing the engine from the frame of the vehicle), is known as a *chassis dyno*.

Dynamometers can also be classified by the type of absorption unit or absorber/driver that they use. Some units that are capable of absorption only can be combined with a motor to construct an absorber/driver or universal dynamometer. The following types of absorption/driver units have been used:

Types of absorption/driver units

- Eddy current or electromagnetic brake (absorption only)
- Magnetic Powder brake (absorption only)
- Hysteresis Brake (absorption only)
- Electric motor/generator (absorb or drive)
- Fan brake (absorption only)
- Hydraulic brake (absorption only)
- Mechanical friction brake or Prony brake (absorption only)
- Water brake (absorption only)

Eddy Current type absorber

EC dynamometers are currently the most common absorbers used in modern chassis dynos. The EC absorbers provide the quick load change rate for rapid load settling. Most are air cooled, but some are designed to require external water cooling systems.

Eddy current dynamometers require an electrically conductive core, shaft or disc, moving across a magnetic field to produce resistance to movement. Iron is a common material, but copper, aluminum and other conductive materials are usable.

In current (2009) applications, most EC brakes use cast iron discs, similar to vehicle disc brake rotors, and use variable electromagnets to change the magnetic field strength to control the amount of braking.

The electromagnet voltage is usually controlled by a computer, using changes in the magnetic field to match the power output being applied.

Sophisticated EC systems allow steady state and controlled acceleration rate operation.

Powder Dynamometer

A powder dynamometer is similar to an eddy current dynamometer, but a fine magnetic powder is placed in the air gap between the rotor and the coil. The resulting flux lines create "chains" of metal particulate which are constantly built and broken apart during rotation creating great torque. Powder dynamometers are typically limited to lower RPM due to heat dissipation issues.

Hysteresis Dynamometers

Hysteresis dynamometers, use a steel rotor that is moved through flux lines generated between magnetic pole pieces. This design, as in the usual "disc type" eddy current absorbers, allows for full torque to be produced at zero speed, as well as at full speed. Heat dissipation is assisted by forced air. Hysteresis and "disc type" EC dynamometers are one of the most efficient technologies in small (200 hp (150 kW) and less) dynamometers. A hysteresis brake is an eddy current absorber which, unlike most "disc type" eddy current absorbers, puts the electromagnet coils inside a vented and ribbed cylinder and rotates the cylinder, instead of rotating a disc between electromagnets. The potential benefit for the hysteresis absorber is that the diameter can be decreased and operating rpm of the absorber may be increased.

Electric motor/generator dynamometer

Electric motor/generator dynamometers are a specialized type of adjustable-speed drives. The absorption/driver unit can be either an alternating current (AC) motor or a direct current (DC) motor. Either an AC motor or a DC motor can operate as a generator which is driven by the unit under test or a motor which drives the unit under test. When equipped with appropriate control units, electric motor/generator dynamometers can be configured as universal dynamometers. The control unit for an AC motor is a variable-frequency drive and the control unit for a DC motor is a DC drive. In both cases, regenerative control units can transfer power from the unit under test to the electric utility. Where permitted, the operator of the dynamometer can receive payment (or credit) from the utility for the returned power.

In engine testing, universal dynamometers can not only absorb the power of the engine but also, drive the engine for measuring friction, pumping losses and other factors.

Electric motor/generator dynamometers are generally more costly and complex than other types of dynamometers.

Fan Brake

A fan is used to blow air to provide engine load. Changing gearing or fan or simply measuring the max rpm attained.

Hydraulic brake

The hydraulic brake system consists of a hydraulic pump (usually a gear type pump), a fluid reservoir and piping between the two parts. Inserted in the piping is an adjustable valve and between the pump and the valve is a gauge or other means of measuring hydraulic pressure. Usually, the fluid used was hydraulic oil, but recent synthetic multi-grade oils may be a better choice. In simplest terms, the engine is brought up to the desired rpm and the valve is incrementally closed and as the pumps outlet is restricted, the load increases and the throttle is simply opened until at the desired throttle opening. Unlike most other systems, power is calculated by factoring flow volume (calculated from pump design specs), hydraulic pressure and rpm. Brake HP, whether figured with pressure, volume and rpm or with a different load cell type brake dyno, should produce essentially identical power figures. Hydraulic dynos are renowned for having the absolutely quickest load change ability, just slightly surpassing the eddy current absorbers. The downside is that they require large quantities of hot oil under high pressure and the requirement for an oil

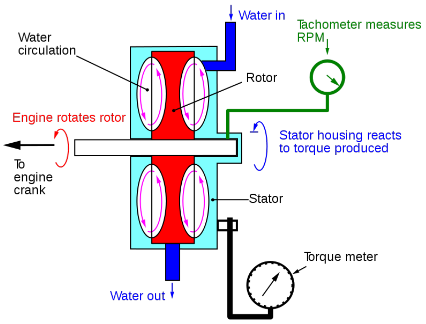
reservoir.

Water brake type absorber

The water brake absorber is sometimes mistakenly called a "hydraulic dynamometer". Water brake absorbers are relatively common, having been manufactured for many years and noted for their high power capability, small package, light weight, and relatively low manufacturing cost as compared to other, quicker reacting "power absorber" types.

Their drawbacks are that they can take a relatively long period of time to "stabilize" their load amount and the fact that they require a constant supply of water to the "water brake housing" for cooling. In many parts of the country, environmental regulations now prohibit "flow through" water and large water tanks must be installed to prevent contaminated water from entering the environment.

The schematic shows the most common type of water brake, the variable level type. Water is added until the engine is held at a steady rpm against the load. Water is then kept at that level and replaced by constant draining and refilling, which is needed to carry away the heat created by absorbing the horsepower. The housing attempts to rotate in response to the torque produced but is restrained by the scale or torque metering cell which measures the torque.

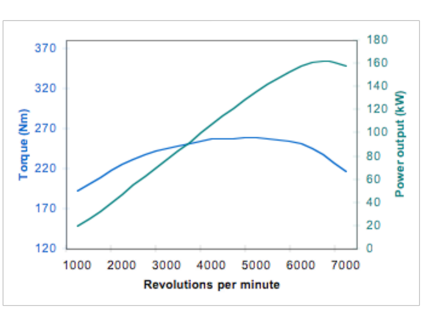


This schematic shows a water brake which is actually a fluid coupling with the housing restrained from rotating. It is very similar to a water pump with no outlet.

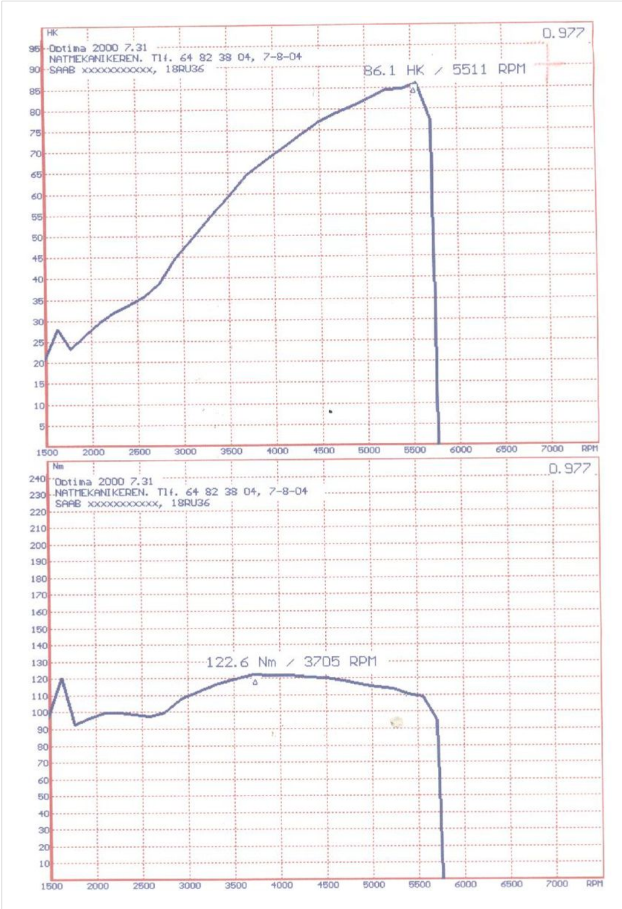
How dynamometers are used for engine testing

Dynamometers are useful in the development and refinement of modern day engine technology. The concept is to use a dyno to measure and compare power transfer at different points on a vehicle, thus allowing the engine or drivetrain to be modified to get more efficient power transfer. For example, if an engine dyno shows that a particular engine achieves 400 N·m (300 lbf·ft) of torque, and a chassis dynamo shows only 350 N·m (260 lbf·ft), one would know to look to the drivetrain for the major improvements. Dynamometers are typically very expensive pieces of equipment, reserved for certain fields that rely on them for a particular purpose.

General testing methods with types of dynamometer systems



A **Brake** dynamometer applies variable load on the engine and measures the engine's ability to move or hold the rpm as related to the "braking force" applied. It is usually connected to a computer which records the applied braking torque and calculates the power output of the engine based on information from a "load cell" or "strain gauge" and rpm (speed sensor).



An **Inertia** dynamometer provides a fixed inertial mass load and calculates the power required to accelerate that fixed, known mass and uses a computer to record rpm and acc. rate to calculate torque.

The engine is generally tested from somewhat above idle to its maximum rpm and the output is measured and plotted on a graph.

There are essentially only 2 types of dynamometer test procedures:

1. Steady State (only on brake dynamometers), where the engine is held at a specified rpm (or series of usually sequential rpms) for 3–5 seconds by the variable brake loading as provided by the PAU (power absorber unit).
2. Sweep Test (inertia or brake dynamometers), where the engine is tested under a load (inertia or brake loading), but allowed to "sweep" up in rpm in a continuous fashion, from a specified lower "starting" rpm to a specified "end" rpm.

Types of Sweep Tests:

1. Inertia Sweep: An inertia dyno system that provides a fixed inertial mass flywheel and computes the power required to accelerate the flywheel (load) from the starting to the ending rpm. The actual rotational mass of the engine or engine and vehicle in the case of a chassis dyno is not known and the variability of even tire mass will skew power results. The inertia value of the flywheel is "fixed", so low power engines are under load for a much longer time and internal engine temperatures are usually too high by the end of the test, skewing optimal "dyno" tuning settings away from the outside world's optimal tuning settings. Conversely, high powered engines, commonly complete a common "4th gear sweep" test in less than 10 seconds, which is not a reliable load condition as compared to operation in the outside world. By not providing enough time under load,

internal combustion chamber temps are unrealistically low and power readings, especially past the power peak, are skewed low.

2. Loaded Sweep Tests (brake dyno type)consist of 2 types:
   1. Simple fixed Load Sweep Test: A fixed load, of somewhat less than the engine's output, is applied during the test. The engine is allowed to accelerate from its starting rpm to its ending rpm, varying in its acceleration rate, depending on power output at any particular rpm point Power is calculated using torque * rpm / 5252 + the power required to accelerate the dyno and engine's / vehicle's rotating mass.
   2. Controlled Acceleration Sweep Test: Similar in basic usage as the above Simple fixed Load Sweep Test, but with the addition of active load control that targets a specific rate of acceleration. Commonly, 20fps/ps is used.

The advantage of controlled acc. rate is that the acc. rate used is relatively common from low power to high power engines and unnatural overextension and contraction of "test duration duration" is avoided, providing more accurate and repeatable test and tuning results.

There is still the remaining issue of potential power reading error due to the variable engine / dyno / vehicle's total rotating mass. Most modern computer controlled brake dyno systems are capable of deriving that "inertial mass" value to eliminate the error.

Interestingly, A "sweep test" will always be suspect, as many "sweep" users ignore the inertial mass factor and prefer to use a blanket "factor" on every test, on every engine or vehicle. Inertia dyne systems aren't capable of deriving "inertial mass" and are forced to use the same inertial mass.

Using Steady State testing eliminates the inertial mass error, as there is no acceleration during a test.

Engine dynamometer

An engine dynamometer measures power and torque directly from the engine's crankshaft (or → flywheel), when the engine is removed from the vehicle. These dynos do not account for power losses in the drivetrain, such as the gearbox, transmission or differential etc.

HORIBA engine dynamometer TITAN

Chassis dynamometer


Saab 96 on chassis dynamometer

A chassis dynamometer measures power delivered to the surface of the "drive roller" by the drive wheels. The vehicle is often parked on the roller or rollers, which the car then turns and the output is measured.

Modern roller type chassis dyne systems use the Salvisberg roller,[1] which improved traction and repeatability over smooth or knurled drive rollers.

On a motorcycle, typical power loss at higher power levels, mostly through tire flex, is about 10% and gearbox chain and other power transferring parts are another 2% to 5% .

Other types of chassis dynamometers are available that eliminate the potential wheel slippage on old style drive rollers and attach directly to the vehicle's hubs for direct torque measurement from the axle. Hub mounted dynos include units made by Dynapack and Rototest.

Chassis dynos can be fixed or portable.

Modern chassis dynamometers can do much more than display RPM, horsepower, and torque. With modern electronics and quick reacting,low inertia dyne systems, it is now possible to tune to best power and the smoothest runs, in realtime.

In retail settings it is also common to "tune the air fuel ratio" , using a wideband oxygen sensor which is graphed along with RPM.

Some, like Dynojet and others, can also add vehicle diagnostic information to the dyno graph as well. This is done by gathering data directly from the vehicle using on-board diagnostics communication.[2]

Because of frictional and mechanical losses in the various drivetrain components, the measured rear wheel brake horsepower is generally 15-20 percent less than the brake horsepower measured at the crankshaft or flywheel on an engine dynamometer.[3] Other sources, after researching several different "engine" dyno software packages, found that the engine dyno user can integrally add "frictional loss" channel factors of +10% to +15% to the flywheel power, raising the claim that 20% to 25% or even more power is actually lost between the crankshaft at high power outputs.

Common misconceptions about dynos

Drag racing: Horsepower and torque figures are a strong predictor but do not guarantee a specific 0-60 mph or 1/4 mile elapsed time (ET). An engine accelerating in a vehicle experiences different conditions than on a dyno. G forces and different temperatures as well as different modes of vibration in a vehicle can cause significant differences in power output. When attempting to crosscheck dynamometer power figures to drag strip performance, it is relatively consistent to compare improved brake hp figures to terminal

MPH.

Engine damage: Can dyno testing damage engines? A brake dyno, in steady state mode only provides a load that is equal the amount of power that the engine is making at any specifically selected rpm point. If the engine makes 200 brake HP at 5000 rpm, the dynamometer's brake or power absorber will provide exactly 200 hp (150 kW) of load against it, keeping the RPM at 5000 rpm. That's a realistic load, it's as if the engine was in a vehicle pulling a large trailer up a hill. Should be no problem on the dyno - if there's no problem on the road. However, the apprehension over dyno testing and engine damage does have solid roots in fact. Old style dynamometers commonly used an inexpensive water brake type of power absorber. Load was increased or decreased by filling and draining water in the housing to change the amount of internal water volume to change the load, all the while draining and refilling the water to keep the water from boiling - It would sometimes take quite some time for the operator or computer to get inflow and outflow rates stabilized and that is the problem. It's not the "amount" of load, it's the amount of "time" spent trying to stabilize the load at the desired rpm.

Water brakes are still commonly used in applications where their small size and light weight are important and engine torque curves are relatively straight, as in large automotive and boats.

History

Gaspard de Prony invented the de Prony brake in 1821. The de Prony brake (or Prony brake) is considered to be one of the earliest dynamometers.

Froude Hofmann of Worcester, UK, manufactures engine and vehicle dynamometers. They credit William Froude with the invention of the hydraulic dynamometer in 1877 and say that the first commercial dynamometers were produced in 1881 by their predecessor company, Heenan & Froude.

In 1928, the German company "*Carl Schenck Eisengießerei & Waagenfabrik*" built the first vehicle dynamometers for brake tests with the basic design of the today's vehicle test stands.

The eddy current dynamometer was invented by Martin and Anthony Winther in about 1931. At that time, DC Motor/generator dynamometers had been in use for many years. A company founded by the Winthers, Dynamatic Corporation, manufactured dynamometers in Kenosha, Wisconsin until 2002. Dynamatic was part of Eaton Corporation from 1946 to 1995. In 2002, Dyne Systems of Jackson, Wisconsin acquired the Dynamatic dynamometer product line. Starting in 1938, Heenan and Froude manufactured eddy current dynamometers for many years under license from Dynamatic and Eaton.[4]

See also

- Dynamometer car for railroad usage
- Engine test stand dynamometer for engines, e.g. combustion engines
- Hand strength dynamometer

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External links

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- Concept2 [7] for a manufacturer of dynameters designed for measuring leg press, arm pull, and chest press of athletes.
- Dynos Explained [8] Sport Rider Magazine: How chassis dynamometers work with Marc Salvisberg of Factory Pro Dynamometer
- Power Dynamometers [9] Resource for main power dynamometers types explained

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[6] http://www.froudehofmann.com/about_1.htm
[7] http://www.concept2.co.uk/dyno/
[8] http://www.factorypro.com/magazine/mag_SPORDR_Dynos_explained.html
[9] http://www.powerdynamometers.com/

Embedment

Embedment is a phenomenon in → mechanical engineering in which the surfaces between mechanical members of a loaded joint embed. It can lead to failure by fatigue as described below, and is of particular concern when considering the design of critical → fastener joints.

Mechanism

The mechanism behind embedment is different from Creep. When the loading of the joint varies (e.g. due to vibration or thermal expansion) the protruding points of the imperfect surfaces will see local stress concentrations and yield until the stress concentration is relieved. Over time, surfaces can flatten an appreciable amount in the order of thousandths of an inch.

Consequences

In critical fastener joints, embedment can mean loss of preload. Flattening of a surface allows the strain of a screw to relax, which in turn correlates with a loss in tension and thus preload. In a bolted joints with particularly short grip lengths, the loss of preload due to embedment can be especially significant, causing complete loss of preload. Therefore, embedment can lead directly to loosening of a fastener joint and subsequent fatigue failure.

In bolted joints, most of the embedment occurs during torquing. Only embedment that occurs after installation can cause a loss of preload, and values of up to 0.0005 inches can be seen at each surface mate, as reported by SAE.

Prevention/Solutions

Embedment can be prevented by designing mating surfaces of a joint to have high surface hardness and very smooth surface finish. Exceptionally hard and smooth surfaces will have less susceptibility to the mechanism that causes embedment.

In most cases, some degree of embedment is inevitable. That said, short grip lengths should be avoided. For two bolted joints of identical design and installation, except the second having a longer grip length, the first joint will be more likely to loosen and fail. Since both joints have the same loading, the surfaces will experience the same amount of embedment. However, the relaxation in strain is less significant to the longer grip length and the loss in preload will be minimized. For this reason, bolted joints should always be designed with careful consideration for the grip length.

See also

- Stress relaxation
- Creep (deformation)
- Fatigue (material)

References

- Comer, Dr. Jess. (2005); "Source of Fatigue Failures of Threaded Fasteners", [1]
- T. Jaglinski, et al. (2007); "Study of Bolt Load Loss in Bolted Aluminum Joints", [2]

External links

- SAE Fatigue Design and Evaluation Committee [3]

References

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[3] http://www.fatigue.org/

Engineering design process

An **engineering design process** is a process used by engineers to help develop products. the engineering design is defined as

> … the process of devising a system, component or process to meet desired needs. It is a decision-making process (often iterative), in which the basic sciences, mathematics, and engineering sciences are applied to convert resources optimally to meet a stated objective. Among the fundamental elements of the design process are the establishment of objectives and criteria, synthesis, analysis, construction, testing, and evaluation.

This process can be divided up into a ten-step process, which includes identifying a need, defining the problem, conducting research, narrowing the research, analyzing set criteria, finding alternative solutions, analyzing possible solutions, making a decision, presenting the product, and communicating and selling the product. This process is not universal for all engineers or all processes. Individuals utilize their personal knowledge and experiences to follow the path to design success.

Identifying a need

The engineers themselves often do not identify a need, but rather society discovers a need and then presents that need to the engineering firm. The term “need” is fairly vague, but often refers to desire or shortage of a good. This “need” can sometimes be considered a necessity to some people but a luxury for others (Eide). Identification of the need is a basic engineering design process, without which engineering design is incomplete.

Defining the problem

Engineers must appropriately define the problem first in order to improve it. Solving an insignificant problem can cost a firm millions in funding and precious time.

Conducting research

Most of a productive engineer's time will be spent on research, locating, applying, and transferring information (Eide). They first must be well acquainted with as much information possible, which in turn produce a better solution. Here the engineer asks many questions, such as, "What has been written about it? Is something already on the market that may solve the problem? What is wrong with the way it is being done? What is right with the way it is being done? Who manufactures the current 'solution'? How much does it cost? Will people pay for a better one if it cost more? How much will they pay (or how bad is the problem)?" (Eide). All these questions will help the engineer get a better grasp on the problem at hand.

Another major part of this research step is determining the source of information. It is the engineers' job to sift through all of the gathered research and decide what is relevant. One sources available is an already existing solution. Reverse engineering is an effective learning technique if other "solutions" are available on the market (Eide). Other effective sources of information include the Internet, local libraries, available government documents, personal organizations, trade journals, vendor catalogs and individual experts available (Eide). It is very important to record these findings in a bibliography that way it is easy to find the information at a later date.

Narrowing the research

Up until now, the problem research and definition has been kept broad to allow for a large amount of possible solutions. Constraints are necessary because they eliminate any extreme solutions that would be inefficient, costly, and physically impossible to create.

Analyzing set criteria

Criteria, or "characteristics have to be established from experience, research, market studies, and customer preferences" (Eide) that are desired by the consumer. In this step, solutions are compared on a qualitative basis such as appearance, durability and cost. The importance of each characteristic must be agreed upon the team of engineers in order to find the top reasonable solutions to the problem.

Finding alternative solutions

In this step, a list of the possible solutions is made and the pros and cons of each solution are discussed. Engineers will sometimes create a checklist of characteristics of the possible solutions and decided what could be changed to better the final result. "Brainstorming" is a great way to decide what is good about the solution and what could be changed to better the solution.

Analyzing possible solutions

All possible alternative solutions have to be analyzed to determine their potential. At this point the engineer will again condense the possible solutions. Using mathematical and key engineering principles, the engineer analyzes the potential performance of the solution to determine if the solution is physically possible. During this analyzing process engineers review the laws of nature and determine whether the product is economically practical by using common sense (Eide).

Making a decision

Some decisions are easily made through analyzing and constraining from the previous steps, but at other times the decision on which solution to choose can be close to impossible. What makes decision making so tough is the trade offs of choosing one solution over the other. Often engineers can come up with impeccable solutions, detailing the strengths and weaknesses of all solutions, but in the end cannot make the decision of which is better on their own. One tool that can be helpful in the decision making process is to be organized. Having as much information possible about all the alternative solutions will make it easier to evaluate the product efficiently. Another crucial tool is to have the objective for the problem and important criteria clear in mind. Frequently when working on a problem, an engineer may get side tracked, so it’s important to remember the purpose of the solution.

Presenting the product

Details about the product can be given visually through sketches. It’s important to have accurate sketches in order to describe your ideas to technicians and drafters. Successful engineers will have to communicate accurately through “written, spoken and graphical languages in order to develop and interpret specifications” (Eide).

Communicating and selling the product

Here the engineer has to sell and explain the product in a persuading manner. Selling the product takes place all along the design process. Another way of communication is the written report, which may be read by both management and clients. These written reports can vary in formality, but usually contain an appropriate cover page, abstract, table of contents, body, conclusion and recommendation, and an appendix. Another common way of communicating the new product is through an oral presentation which presents the information convincently to the listener. The key to a good oral presentation is to be prepared, have good posture, good eye contact and project your voice loud and clearly. It’s important that the oral presentation gives enough information to get the idea across to the desired audience but not too much information to become overwhelming, and confusing.

“Design is the essencial of engineers.” (Eide) The purpose of engineering design revolves around our natural instincts as human beings to always strive for more, and that is why engineering is one of the fastest growing careers. Society will always strive for more than what is available, pushing engineers, designers, and inventors to continuously produce more innovative ideas. Through the engineering design process, engineers are given the tools and guidelines needed to successfully create these innovative ideas.

See also

- Engineering analysis
- Axiomatic product development lifecycle APDL
- Applied science
- Blueprint
- Design
- Design engineer
- Engineering
- Engineering design management
- Ideal final result
- Marketing
- New product development
- Traditional engineering

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Engineering fit

Fit refers to the mating of two mechanical components. Manufactured parts are very frequently required to mate with one another. They may be designed to slide freely against one another or they may be designed to bind together to form a single unit. The most common fit found in the machine shop is that of a shaft in a hole.

There are three general categories of fits: 1) Clearance fits for when it may be desirable for the shaft to rotate or slide freely within the hole, this is usually referred to as a "sliding fit." 2) Interference fits for when it is desirable for the shaft to be securely held within the hole, this is usually referred to as an → interference fit and 3) Transition fits for when it is desirable that the shaft to be held securely, yet not so securely that it cannot be disassembled, this is usually referred to as a Location or Transition fit.

Within each category of fit there are several classes ranging from high precision and narrow tolerance (allowance) to lower precision and wider tolerance. The choice of fit is dictated first by the use and secondly by the manufacturability of the parts.

Interference fits

Force fits

FN 1 to FN 5

Transition fits

LC 1 to LC 11 LT 1 to LT 6 LN 1 to LN 3

Clearance fits

RC 1 to RC 9

ISO Metric fits

ISO-R286 and ANSI B4.2-1978

See also

- Interchangeable parts

Envelope (motion)

In → mechanical engineering, an **envelope** is a solid representing all positions which may be occupied by an object during its normal range of motion.

Another (jargon) word for this is a **flop**.

Wheel envelope

In automobile design, a **wheel envelope** may be used to model all positions a wheel and tire combo may be expected to occupy during driving. This will take into account the maximum jounce and rebound allowed by the suspension system and the maximum turn and tilt allowed by the steering mechanism. Minimum and maximum tire inflation pressures and wear conditions may also be considered when generating the envelope.

This envelope is then compared with the wheel housing and other components in the area to perform an interference/collision analysis. The results of this analysis tell the engineers whether that wheel/tire combo will strike the housing and components under normal driving conditions. If so, either a redesign is in order, or that wheel/tire combo will not be recommended.

A different wheel envelope must be generated for each wheel/tire combo for which the vehicle is rated. Much of this analysis is done using CAD/CAE systems running on computers. Of course, high speed collisions, during an accident, are not considered "normal driving conditions", so the wheel and tire may very well contact other parts of the vehicle at that time.

Robot's working envelope

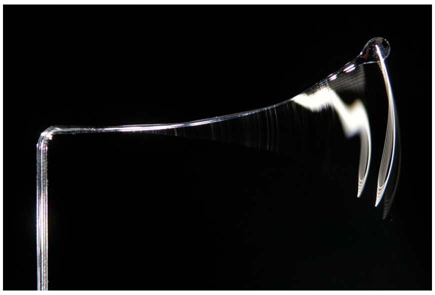
In robotics, the working envelope or work area is the volume of working or reaching space . Some factors of a robot's design (configurations, axes or degrees of freedom) influence its working envelope. [1]

References

[1] OSHA TECHNICAL MANUAL - SECTION IV: CHAPTER 4 (http://www.osha.gov/dts/osta/otm/otm_iv/otm_iv_4.html)

Euler–Bernoulli beam equation

Euler-Bernoulli beam theory (also known as **Engineer's beam theory**, **Classical beam theory** or just **beam theory**) is a simplification of the linear theory of elasticity which provides a means of calculating the load-carrying and deflection characteristics of beams. It was first enunciated circa 1750, but was not applied on a large scale until the development of the Eiffel Tower and the Ferris wheel in the late 19th century. Following these successful demonstrations, it quickly became a cornerstone of engineering and an enabler of the Second Industrial Revolution.



This vibrating glass beam may be modeled as a cantilever beam with acceleration, variable linear density, variable section modulus, some kind of dissipation, springy end loading, and possibly a point mass at the free end.

Additional analysis tools have been developed such as plate theory and finite element analysis, but the simplicity of beam theory makes it an important tool in the sciences, especially structural and → mechanical engineering.

History

The prevailing consensus is that Galileo Galilei made the first attempts at developing a theory of beams, but recent studies argue that Leonardo da Vinci was the first to make the crucial observations. Da Vinci lacked Hooke's law and calculus to complete the theory, whereas Galileo was held back by an incorrect assumption he made.[1]

The Bernoulli beam is named after Jacob Bernoulli, who made the significant discoveries. Leonhard Euler and Daniel Bernoulli were the first to put together a useful theory circa 1750.[2] At the time, science and engineering were generally seen as very distinct fields, and there was considerable doubt that a mathematical product of academia could be trusted for practical safety applications. Bridges and buildings continued to be designed by precedent until the late 19th century, when the Eiffel Tower and Ferris wheel demonstrated the validity of the theory on large scales.

The beam equation

The Euler-Bernoulli equation describes the relationship between the beam's deflection and the applied load:

$$\frac{\partial^2}{\partial x^2}\left(EI\frac{\partial^2 u}{\partial x^2}\right) = w.$$

The curve $u(x)$ describes the deflection u of the beam at some position x (recall that the beam is modeled as a one-dimensional object). w is a distributed load, in other words a force per unit length (analogous to pressure being a force per area); it may be a function of x , u , or other variables.

Note that E is the elastic modulus and that I is the second moment of area. I must be calculated with respect to the centroidal axis perpendicular to the applied loading. For an Euler-Bernoulli beam not under any axial loading this axis is called the neutral axis.

Often, $u = u(x)$, $w = w(x)$, and EI is a constant, so that:

$$EI\frac{d^4 u}{dx^4} = w(x).$$

This equation, describing the deflection of a uniform, static beam, is very common in engineering practice.

Successive derivatives of u have important meanings:

- u is the deflection.
- $\frac{\partial u}{\partial x}$ is the slope of the beam.
- $EI\frac{\partial^2 u}{\partial x^2}$ is the bending moment in the beam.
- $-\frac{\partial}{\partial x}\left(EI\frac{\partial^2 u}{\partial x^2}\right)$ is the shear force in the beam.

Stress

Besides deflection, the beam equation describes forces and moments and can thus be used to describe stresses. For this reason, the Euler-Bernoulli beam equation is widely used in engineering, especially civil and mechanical, to determine the strength (as well as deflection) of beams under bending.

Both the bending moment and the shear force cause stresses in the beam. The stress due to shear force is maximum along the neutral axis of the beam (when the width of the beam, t, is constant along the cross section of the beam; otherwise an integral involving the first moment and the beam's width needs to be evaluated for the particular cross section), and the maximum tensile stress is at either the top or bottom surfaces. Thus the maximum principal stress in the beam may be neither at the surface nor at the center but in some general area. However, shear force stresses are negligible in comparison to bending moment stresses in all but the stockiest of beams as well as the fact that stress concentrations commonly occur at surfaces, meaning that the maximum stress in a beam is likely to be at the surface.

It can be shown that the tensile stress experienced by the beam may be expressed as:

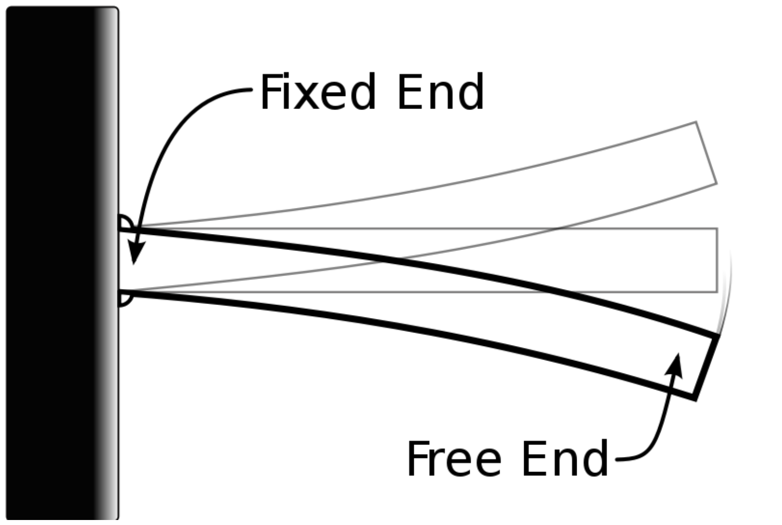
$$\sigma = \frac{Mc}{I} = Ec\frac{\partial^2 u}{\partial x^2}.$$

Here, c, a position along u , is the distance from the neutral axis to a point of interest; and M is the bending moment. Note that this equation implies that "pure" bending (of positive

sign) will cause zero stress at the neutral axis, positive (tensile) stress at the "top" of the beam, and negative (compressive) stress at the bottom of the beam; and also implies that the maximum stress will be at the top surface and the minimum at the bottom. This bending stress may be superimposed with axially applied stresses, which will cause a shift in the neutral (zero stress) axis.

Boundary considerations

The beam equation contains a fourth-order derivative in x , hence it mandates at most four conditions, normally boundary conditions. The boundary conditions usually model *supports*, but they can also model point loads, moments, or other effects.



A cantilever beam.

An example is a cantilever beam: a beam that is completely fixed at one end and completely free at the other. "Completely fixed" means that at the left end both deflection and slope are zero; "completely free" implies (though it may or may not be obvious) that at the right end both shear force and bending moment are zero. Taking the x coordinate of the left end as $0$and the right end as L (the length of the beam), these statements translate to the following set of boundary conditions (assume EI is a constant):

$$u|_{x=0} = 0 \quad ; \quad \left.\frac{\partial u}{\partial x}\right|_{x=0} = 0 \qquad \text{(fixed end)}$$
$$\left.\frac{\partial^2 u}{\partial x^2}\right|_{x=L} = 0 \quad ; \quad \left.\frac{\partial^3 u}{\partial x^3}\right|_{x=L} = 0 \qquad \text{(free end)}$$

Some commonly encountered boundary conditions include:

- $u = \frac{\partial u}{\partial x} = 0$represents a fixed support.
- $u = \frac{\partial^2 u}{\partial x^2} = 0$represents a pin connection (deflection and moment fixed to zero).
- $\frac{\partial^2 u}{\partial x^2} = \frac{\partial^3 u}{\partial x^3} = 0$represents no connection (no restraint) and no load.
- $-\frac{\partial}{\partial x}\left(EI\frac{\partial^2 u}{\partial x^2}\right) = F$ represents the application of a point load *F*.

Loading considerations

Applied loading may be represented either through boundary conditions or through the distributed function w. Using distributed loading is often favorable for simplicity. Boundary conditions are, however, often used to model loads depending on context; this practice being especially common in vibration analysis.

By nature, the distributed load is very often represented in a piecewise manner, since in practice a load isn't typically a "nice" continuous function. Point loads can be modeled with help of the Dirac delta function. For example, consider a static uniform cantilever beam of length L with an upward point load F applied at the free end. Using boundary conditions, this may be modeled through:

$$EI\frac{d^4u}{dx^4} = 0$$
$$u|_{x=0} = 0 \quad ; \quad \frac{du}{dx}\bigg|_{x=0} = 0$$
$$\frac{d^2u}{dx^2}\bigg|_{x=L} = 0 \quad ; \quad -EI\frac{d^3u}{dx^3}\bigg|_{x=L} = F$$

Using the Dirac function,

$$EI\frac{d^4u}{dx^4} = F\delta(x-L)$$
$$u|_{x=0} = 0 \quad ; \quad \frac{du}{dx}\bigg|_{x=0} = 0$$
$$\frac{d^2u}{dx^2}\bigg|_{x=L} = 0$$

Note that shear force boundary condition (third derivative) is removed, otherwise there would be a contradiction. These are equivalent boundary value problems, and both yield the following solution:

$$u = \frac{F}{6EI}(3Lx^2 - x^3)$$

The application of several point loads at different locations will lead to $u(x)$ being a piecewise function. Use of the Dirac function greatly simplifies such situations; otherwise the beam would have to be divided into sections, each with four boundary conditions solved separately. A well organized family of functions called Singularity functions are often used as a shorthand for the Dirac function, its derivative, and its antiderivatives.

Clever formulation of the load distribution allows for many interesting phenomena to be modeled. As an example, the vibration of a beam can be accounted for by using the load function:

$$w(x,t) = -\mu\frac{\partial^2 u}{\partial t^2}$$

where μ is the linear mass density of the beam, not necessarily a constant. With this time-dependent loading, the beam equation will be a partial differential equation:

$$\mu\frac{\partial^2 u}{\partial t^2} + \frac{\partial^2}{\partial x^2}\left(EI\frac{\partial^2 u}{\partial x^2}\right) = 0.$$

Another interesting example describes the deflection of a beam rotating with a constant angular frequency of ω:

$$w(u) = \mu\omega^2 u$$

This is a centripetal force distribution. Note that in this case, w is a function of the displacement (the dependent variable), and the beam equation will be an autonomous ordinary differential equation.

Extensions

The kinematic assumptions upon which the Euler-Bernoulli beam theory is founded allow it to be extended to more advanced analysis. Simple superposition allows for three-dimensional transverse loading. Using alternative constitutive equations can allow for viscoelastic or plastic beam deformation. Euler-Bernoulli beam theory can also be extended to the analysis of curved beams, beam buckling, composite beams, and geometrically nonlinear beam deflection.

Euler-Bernoulli beam theory does not account for the effects of transverse shear strain. As a result it underpredicts deflections and overpredicts natural frequencies. For thin beams (beam length to thickness ratios of the order 20 or more) these effects are of minor importance. For thick beams, however, these effects can be significant. More advanced beam theories such as the Timoshenko beam theory (developed by the Russian-born scientist Stephen Timoshenko) have been developed to account for these effects.

See also

- Bending
- Buckling
- Clapeyron's theorem
- Strain
- Applied mechanics
- Singularity function
- Flexural rigidity

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FINE MEP

Developer(s)	4M
Stable release	v9 / 2008
Operating system	Windows
Type	CAD, Building Information Modeling, Building services engineering
Website	4M website [1]

FINE MEP (Mechanical Electrical and Plumbing) is a BIM CAD software tool for Building services engineering design, built on top of IntelliCAD by 4M Software company. FINE BIM structure, provides a smart model shaping and high design accuracy, directly applied to the real 3D building model and its building services (HVAC, water supply, sewerage, electricity). Not only the building elements (i.e. walls, openings, roofs etc), but also the components of the mechanical/electrical installations themselves (i.e. pipes, heating units, fittings, cables etc) are all intelligent objects carrying their own attributes and interacting among each other. MEP design is supported by specific CAD commands (i.e. smart location of units/appliances, auto-routing commands for pipes/cables etc) and further facilitated through sophisticated recognition and validation algorithms, providing a user-friendly modeling environment.

All the three FINE MEP software applications, a) **FineHVAC** for HVAC design, b) **FineELEC** for Electrical design and c) **FineSANI** for Sanitary design, combine design and calculations within a synergistically integrated environment, performing all the required calculations directly from the drawings, and generating automatically all the case study results: Calculation sheets, technical reports, a complete series of final drawings updated with the calculation results (plan views, vertical diagrams, details), bill of materials, budget estimation and others. In addition, FINE MEP applications interact in a synergistic with the other vertical software applications of the 4M Building Design Suite (i.e. IDEA Architectural and STRAD Structural).

See also

- Building Information Modeling
- Building services engineering
- → Mechanical engineering
- Electrical engineering
- Hydraulic engineering
- IntelliCAD
- IDEA Architectural
- DWG
- Comparison of CAD, CAM and CAE file viewers
- Comparison of CAD editors for AEC

External links

- 4M - The manufacturer's website [2]
- The American Society of Heating, Refrigerating and Air- Conditioning Engineers [3]
- FineHVAC new generation [4]
- A success story for FINE MEP [5] by ITC, the IntelliCAD Technology Consortium
- FINE MEP meets the Olympic design needs [6] - AECCafe
- BIM for MEP [7] - AECbytes Vendorhub
- Managing BIM Technology in the Building Industry [8] - AECbytes Viewpoint #35: February 12 2008

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[5] http://www.intellicad.org/success-stories/buildling-design-case-study---elxis/
[6] http://www10.aeccafe.com/link/display_detail.php?link_id=26529
[7] http://www.aecbytes.com/vendorhub/BIMforMEP.html
[8] http://www.aecbytes.com/viewpoint/2008/issue_35.html

Fabio Perini S.p.A.

Type	Società per Azioni
Founded	Lucca, Italy (1966)
Founder(s)	Fabio Perini
Headquarters	Lucca, Italy
Area served	Worldwide
Key people	Alessandro Bulfon, CEO
Industry	→ Mechanical engineering
Products	Paper making and tissue converting industrial machinery
Services	Machine and production line installation; Training; Overhauling; Engineering solutions and replacement kits for obsolete parts Reconditioning and commercializing of second-hand tissue converting equipment.
Revenue	€ 169,000,000 (2006)
Employees	950 worldwide (2008)
Parent	Korber AG
Divisions	Körber PaperLink
Website	http://www.fp.kpl.net

Fabio Perini S.p.A. is an Italian engineering company specialized in machine design and manufacturing of industrial machinery for the paper making industry and the tissue converting industry. **Fabio Perini S.p.A.** is part of the German group **Körber AG**, under the paper division Körber PaperLink.

Brief History

Fabio Perini S.p.A. is a → mechanical engineering company established in Lucca, Italy, in 1966 by the inventor/entrepreneur Fabio Perini. The company is specialized in design and manufacturing of industrial machinery for the paper making industry and the tissue converting industry.

Based in Lucca, the company has eleven overseas branches located in three continents (Europe, America and Asia)[1] .

Since 1994 **Fabio Perini S.p.A.** is part of the German group **Körber AG**, under the division Körber PaperLink; **Körber AG** is a group specialized in manufacturing of industrial machinery.

History

Fabio Perini and the Company rising

Fabio Perini starts his activity in 1960 when he invents a machinery for the automatic cut of tissue paper.

In 1966 he founds his company, the **Fabio Perini**, with a view to designing new engineering technologies and manufacturing industrial machinery for the tissue converting industry.

With the change and the improvement of lifestyles, the Italian tissue industry raises noticeably during the 1960s.

This fact favours Fabio Perini's company which grows up until 1973, when the company is turned into a Società per Azioni, becoming the **Fabio Perini S.p.A.**.

Fabio Perini S.p.A.

Under the new form of Società per Azioni, **Fabio Perini S.p.A.** meets with a phase of international expansion. In the 1970s new offices are opened in Europe and America: two selling offices in Europe (Paris, 1974; Düsseldorf, 1976), one selling office in the USA (Green Bay, Wisconsin, 1978, at the *Green Bay Engineering Company*) and one manufacturing plant in Latin America (Joinville, Brazil, 1975).

During the '80s and the '90s further branches are opened in Asia (Yokohama,1984; Hong Kong,1985; Fuji,1991), Europe (London, 1984) and USA (Miami, 1990).

In about 20 years, thanks to many original design patents[2] , the company **Fabio Perini** transformed itself from a one-man business to a multinational enterprise able to cover up the 75% of the worldwide market of the paper making industry and the tissue converting machinery.

As acknowledgement of his entrepreneurship, in 1991 the founder Fabio Perini is ordered Knight of the Italian Republic, under the Order of Merit for Labour[3] .

Entering the Körber Group

In 1994 the founder Fabio Perini sells his company to the German multinational group Körber. Körber is a group of companies specialized in manufacturing of industrial machinery.

Körber PaperLink Logo

Fabio Perini S.p.A. headquarters remains in Lucca, Italy.

After that, the growing of the company goes on; three new overseas branches are opened in Asia: two selling offices (Singapore,1994; Seoul, 1995) and one manufacturing plant (Shanghai, 2002).

In 2003 **Perini Engraving S.r.l.** is opened in Lucca: **Perini Engraving** is a division of the Fabio Perini S.p.A. group specialized in the design and manufacturing of customized embossing rolls for tissue production.

Revenue

In 2006 **Fabio Perini S.p.A.** had a yearly turnover of 169,000,000 € (nearly 236,000,000 USD).

Products

Some of the machinery designed and manufactured by **Fabio Perini S.p.A.** are:

- Toilet roll and kitchen towel converting lines;
- Table napkin converting equipment;
- Embossers, laminators, printing units;
- Slitter rewinders for the production of industrial rolls;
- Customized embossing rolls for tissue production.

Publishing Activity

Since 1979 **Fabio Perini S.p.A.** publishes the *Perini Journal*, a six-monthly review completely dedicated to the tissue paper industry.

See Also

- Körber PaperLink
- Perini Journal
- Toilet roll
- Table napkin
- Kitchen Towel
- Embossing
- Tissue paper
- Pulp and paper industry

External links

- Fabio Perini S.p.A. official website [4]
- Körber PaperLink official website [5]
- Körber AG official website [6]
- Procter & Gamble chooses Fabio Perini technology [7]

References

[1] http://www.fp.kpl.net/en/contact/contactworldwide1.html?no_cache=1&tx_nawkplcontact_pi1
[2] http://v3.espacenet.com/searchResults?locale=en_V3&IN=Fabio+Perini&ST=advanced&compact=false&DB=EPODOC&submitted=true
[3] http://www.cavalieridellavoro.it/cavaliere.php?numero_brevetto=2192
[4] http://www.fp.kpl.net/en.html|
[5] http://www.kpl.net/|
[6] http://www.koerber.de/en/index.php|
[7] http://www.risiinfo.com/technologyarchives/Procter-Gamble-chooses-Fabio-Perini-technology.html|

Fan coil unit

A **fan coil unit** (FCU) is a simple device consisting of a heating or cooling coil and fan. It is part of an HVAC system found in residential, commercial, and industrial buildings. Typically a fan coil unit is not connected to ductwork, and is used to control the temperature in the space where it is installed, or serve multiple spaces. It is controlled either by a manual on/off switch or by thermostat.

Due to their simplicity, fan coil units are more economic to install than ducted or central heating systems with air handling units. However, they can be noisy because the fan is within the same space. Unit configurations are numerous including horizontal (ceiling mounted) or vertical (floor mounted).

Design and operation

The coil receives hot or cold water from a central plant, and removes or adds heat from the air through → heat transfer. Fan coil units can contain their own internal thermostat, or can be wired to operate with a remote thermostat.

Fan coil units circulate hot or cold water through a coil in order to condition a space. The unit gets its hot or cold water from a central plant, or mechanical room containing equipment for removing heat from the central building's closed-loop. The equipment used can consist of machines used to remove heat such as a → chiller or a → cooling tower and equipment for adding heat to the building's water such as a boiler or a commercial water heater.

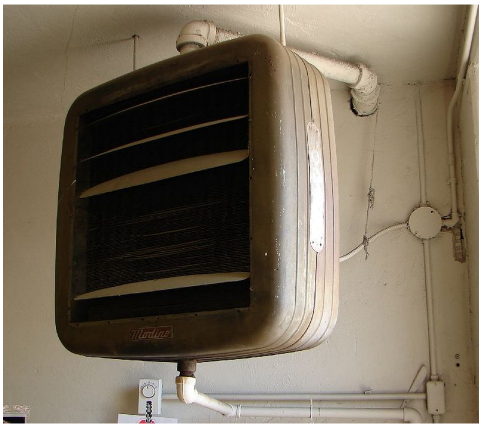
Fan coil units are divided into two types: Two (2) pipe fan coil units or Four (4) pipe fan coil units. Two pipe fan coil units have one (1) supply and one (1) return pipe. The supply pipe supplies either cold or hot water to the unit depending on the time of year. Four (4) pipe fan coil units have two (2) supply pipes and two (2) return pipes. This allows either hot or cold water to enter the unit at any given time.

Fan coil units may be connected to piping networks using various topology designs, such as "direct return", "reverse return", or "series decoupled". See ASHRAE Handbook "2008 Systems & Equipment", Chapter 12.

Examples of fan coil units:

- IEC - International Environmental Corporation [1]

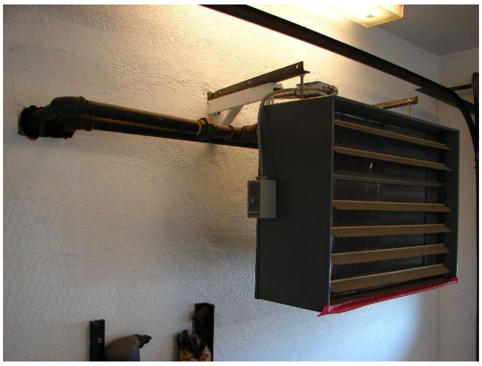
Areas of use



Fan coil units are typically used in spaces where economic installations are preferred such as unoccupied storage rooms, corridors, loading docks.

In high-rise buildings, fan coils may be stacked, located one above the other from floor to floor and all interconnected by the same piping loop.

Fan coil units are an excellent delivery mechanism for hydronic chiller boiler systems in large residential and light commercial applications. In these applications the fan coil units are mounted in bathroom ceilings and can be used to provide unlimited comfort zones - with the ability to turn off unused areas of the structure to save energy.



Installation

In high-rise residential construction, typically each fan coil unit requires a rectangular through-penetration in the concrete slab on top of which it sits. Usually, there are either 2 or 4 pipes made of ABS, steel or copper that go through the floor. The pipes are usually insulated with refrigeration insulation, such as acrylonitrile butadiene/polyvinyl chloride (AB/PVC) flexible foam (Rubatex or Armaflex brands) on all pipes or at least the cool lines.

Unit Ventilator

A unit ventilator is a fan coil unit that is used mainly in classrooms, hotels, apartments and condominium applications. A unit ventilator can be a wall mounted or ceiling hung cabinet, and is designed to use a fan to blow air across a coil, thus conditioning the space which it is serving.

Examples of unit ventilators:

- McQuay [2]
- Nesbitaire [3]
- Trane [4]

See also

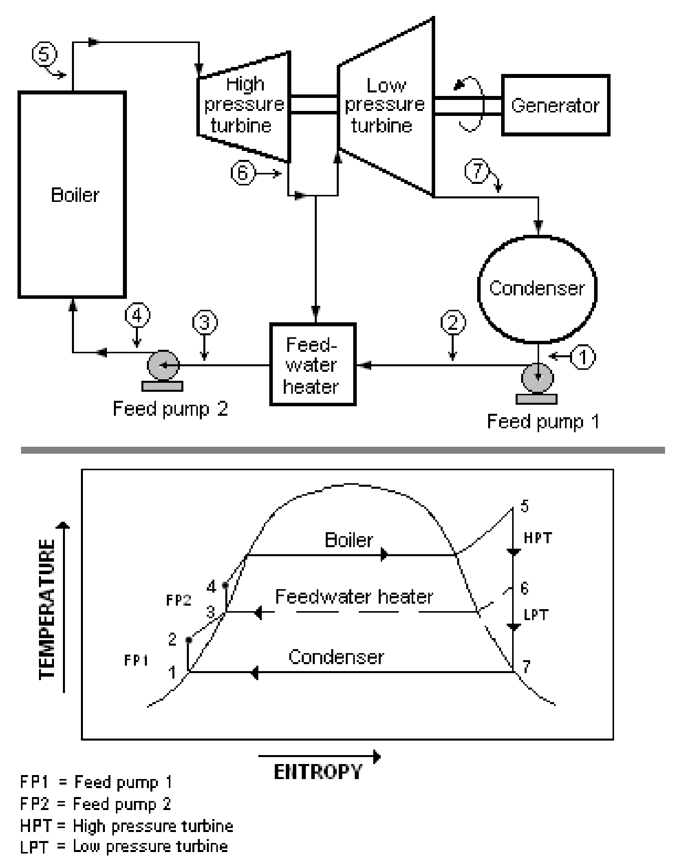
- Thermal insulation
- HVAC
- Construction
- Intumescent
- Firestop

References

[1] http://www.fancoil.com
[2] http://www.mcquay.com/McQuay/ProductInformation/UnitVent/UnitVentilators
[3] http://www.nesbittaire.com/na_vents_903.html
[4] http://www.trane.com/Commercial/Dna/View.aspx?i=1094

Feedwater heater

A **feedwater heater** is a power plant component used to pre-heat water delivered to a steam generating boiler.[1] [2] [3] Preheating the feedwater reduces the irreversibilities involved in steam generation and therefore improves the thermodynamic efficiency of the system.[4] This reduces plant operating costs and also helps to avoid thermal shock to the boiler metal when the feedwater is introduced back into the steam cycle.



A Rankine cycle with two steam turbines and a single open feedwater heater.

In a steam power plant (usually modeled as a modified Rankine cycle), feedwater heaters allow the feedwater to be brought up to the saturation temperature very gradually. This minimizes the inevitable irreversibilities associated with heat transfer to the working fluid (water). See the article on the Second Law of Thermodynamics for a further discussion of such irreversibilities.

Cycle discussion and explanation

It should be noted that the energy used to heat the feedwater is usually derived from steam extracted between the stages of the steam turbine. Therefore, the steam that *would be used* to perform expansion work in the turbine (and therefore generate power) is not utilized for that purpose. The percentage of the total cycle steam mass flow used for the feedwater heater is termed the extraction fraction[4] and must be carefully optimized for maximum power plant → thermal efficiency since increasing this fraction causes a decrease in turbine power output.

Feedwater heaters can also be *open* and *closed* heat exchangers. An open feedwater heater is merely a direct-contact heat exchanger in which extracted steam is allowed to mix with the feedwater. This kind of heater will normally require a feed pump at both the feed inlet and outlet since the pressure in the heater is between the boiler pressure and the condenser pressure. A deaerator is a special case of the open feedwater heater which is specifically designed to remove non-condensable gases from the feedwater.

Closed feedwater heaters are typically shell and tube heat exchangers where the feedwater passes throughout the tubes and is heated by turbine extraction steam. These do not require separate pumps before and after the heater to boost the feedwater to the pressure of the extracted steam as with an open heater. However, the extracted steam (which is most likely almost fully condensed after heating the feedwater) must then be throttled to the condenser pressure, an isenthalpic process that results in some entropy gain with a slight penalty on overall cycle efficiency.

Many power plants incorporate a number of feedwater heaters and may use both open and closed components.

Feedwater heaters are used in both fossil- and nuclear-fueled power plants. Smaller versions have also been installed on steam locomotives, portable engines and stationary engines. An economiser serves a similar purpose to a feedwater heater, but is technically different. Instead of using actual cycle steam for heating, it uses the lowest-temperature flue gas from the furnace (and therefore does not apply to nuclear plants) to heat the water before it enters the boiler proper. This allows for the heat transfer between the furnace and the feedwater to occur across a smaller average temperature gradient (for the steam generator as a whole). System efficiency is therefore further increased when viewed with respect to actual energy content of the fuel.

See also

- Fossil fuel power plant
- Power station
- Thermal power plant
- → Thermal efficiency

External links

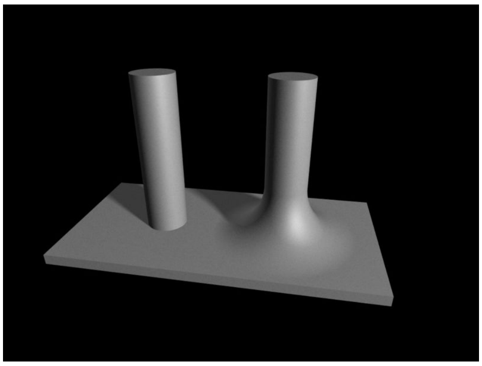
- Power plant diagram [5]

References

[1] British Electricity International (1991). *Modern Power Station Practice: incorporating modern power system practice* (3rd Edition (12 volume set) ed.). Pergamon. ISBN 0-08-040510-X.
[2] Babcock & Wilcox Co. (2005). *Steam: Its Generation and Use* (41st edition ed.). ISBN 0-9634570-0-4.
[3] Thomas C. Elliott, Kao Chen, Robert Swanekamp (coauthors) (1997). *Standard Handbook of Powerplant Engineering* (2nd edition ed.). McGraw-Hill Professional. ISBN 0-07-019435-1.
[4] Fundamentals of Steam Power (http://www.personal.utulsa.edu/~kenneth-weston/chapter2.pdf) by Kenneth Weston, University of Tulsa
[5] http://www.tva.gov/power/coalart.htm

Fillet (mechanics)

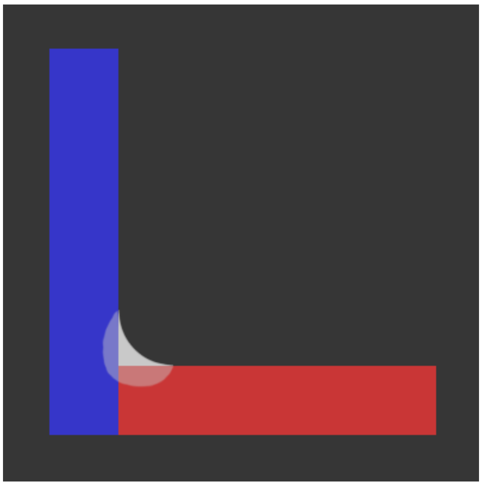
In → mechanical engineering, a **fillet** (pronounced /'fɪlɨt/) is a concave easing of an interior corner of a part design. A rounding of an exterior corner is called a "round".[1]



Example of a non-filleted pole (left) and a filleted pole (right)

Applications

- Stress concentration is a problem of load-bearing mechanical parts which is reduced by employing fillets on points and lines of expected high stress. These features effectively make the parts more durable and capable of bearing larger loads.
- For considerations in aerodynamics, fillets are employed to reduce interference drag where aircraft components such as wings, struts, and other surfaces meet one another.
- For manufacturing, concave corners are sometimes filleted to allow the use of round-tipped end mills to cut out an area of a material. This has a *cycle time* benefit if the round mill is simultaneously being used to mill complex curved surfaces.



It is common to find a fillet where two parts are welded together

Design process

Fillets can be quickly designed onto parts using 3d solid modeling engineering CAD software by invoking the function and picking edges of interest. Once these features are included in the CAD design of a part, they are often manufactured automatically using computer-numerical control.

Different packages use different names for the same operations. Autodesk Inventor and Solidworks refer to both concave and convex rounded edges as fillets, while referring to angled cuts of edges and concave corners as chamfers. Unigraphics refers to concave and convex rounded edges as *blends*. Pro/Engineer refers to rounded edges simply as *rounds*. Other 3D solid modeling software programs outside of engineering, such as gameSpace,

have similar functions.

Although some smooth edges connecting two simple flat features is generally simple for a computer to create and fast for a human user to specify, heavy use of fillets on complex geometry can overwhelm even the best CAD software.

See also

- Chamfer

External links

- Welding fillets [2]

References

[1] Madsen et al., "Engineering Drawing and Design" page 179. Delmar, 2004 ISBN 0-7668-1634-6
[2] http://www.unified-eng.com/scitech/weld/fillet.html

Flange

A **flange** is an external or internal rib, or rim (lip), for → strength, as the flange of an iron beam or I-beam (or a T-beam); or for a guide, as the flange of a train wheel; or for attachment to another object, as the flange on the end of a pipe, steam cylinder, etc, or on the lens mount of a camera. Thus a flanged rail is a rail with a flange on one side to keep wheels, etc., from running off. The term "flange" is also used for a kind of tool used to form flanges. By the use of flanges we can assemble or disassemble the pipes very easily.

Flanged railway wheel

Plumbing or Piping

See main article Plumbing or → Piping

Although *flange* generally refers to the actual raised rim or lip of a fitting, many flanged plumbing fittings are themselves known as 'flanges':

Common flanges used in plumbing are the Surrey flange or Danzey flange, York flange, Sussex flange and Essex flange. Surrey and York flanges fit to the top of the hot water tank allowing all the water to be taken without disturbance to the tank. They are often used to ensure an even flow of water to showers. An Essex flange requires a hole to be drilled in the side of the tank.


Surrey Flange

There is also a Warix flange which is the same as a York flange but the shower output is on the top of the flange and the vent on the side. The York and Warix flange have female adapters so that they fit onto a male tank, whereas the Surrey flange connects to a female tank.

A closet flange provides the mount for a toilet.

Pipe flanges

There are many different flange standards to be found worldwide. To allow easy functionality and inter-changeability, these are designed to have standardised dimensions. Common world standards include ASA/ANSI (USA), PN/DIN (European), BS10[1] (British/Australian), and JIS/KIS (Japanese/Korean).

In most cases these are not interchangeable (eg an ANSI flange will not mate against a JIS flange). Further many of the flanges in each standard are divided into "pressure classes", allowing flanges to be capable of taking different pressure ratings. Again these are not generally interchangeable (eg an ANSI 150# will not mate with an ANSI 300#). These "pressure classes" also have differing pressure and temperature ratings for different materials. "Pressure Classes" of → piping are usually developed for a process plant or power generating station; these "pressure classes" may be unique to the specific corporation, Engineering Procurement and Construction (EPC) contractor, or the process plant owner.

The flange faces are made to standardized dimensions and are typically "flat face", "raised face", "tongue and groove", or "ring joint" styles, although other obscure styles are possible.

Flange designs are available as "welding neck", "slip-on", "boss", "lap joint", "socket weld", "threaded", and also "blind".

ASME standards (U.S.)


ASME type flange on a gas pipeline

Pipe flanges that are made to standards called out by → ASME B16.5 or ASME B16.47 are typically made from forged materials and have machined surfaces. B16.5 refers to nominal pipe sizes (NPS) from 1/2 to 24. B16.47 covers NPSs from 26 to 60. Each specification further delineates flanges into classes 150, 300, 400, 600, 900, 1500 and 2500 for B16.5. B16.47 delineates its flanges into classes 75, 150, 300, 400, 600, 900.

The gasket type and bolt type are generally specified by the standard(s); however, sometimes the standards refer to the → ASME Boiler and Pressure Vessel Code (B&PVC) for details (see ASME Code Section VIII Division 1 - Appendix 2). These flanges are recognized by ASME Pipe Codes such as ASME B31.1 Power → Piping, and ASME B31.3 Process Piping.

Materials for flanges are usually under ASME designation: SA-105 (Specification for Carbon Steel Forgings for Piping Applications) , SA-266 (Specification for Carbon Steel Forgings for Pressure Vessel Components) or SA-182 (Specification for Forged or Rolled Alloy-Steel Pipe Flanges, Forged Fittings, and Valves and Parts for High-Temperature Service).

Other countries

Flanges in other countries also are manufactured according to the standards for materials, pressure ratings, etc. Such standards include DIN, BS [2] and/or ISO standards.

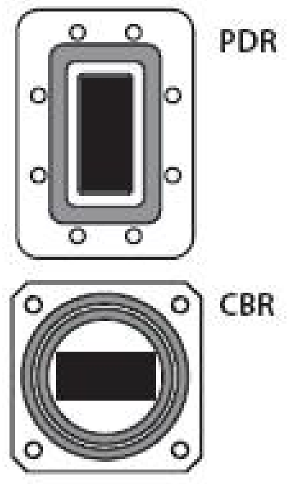
Vacuum flanges

A vacuum flange is a flange at the end of a tube used to connect vacuum chambers, tubing and vacuum pumps to each other.

Microwave RF

In microwave telecommunications, a **flange** is a type of cable joint which allows different types of waveguide to connect.

Several different microwave RF flange types exist, such as CAR, CBR, OPC, PAR, PBJ, PBR, PDR, UAR, UBR, UDR, and UPX.



Form factor of PDR and CBR flanges.

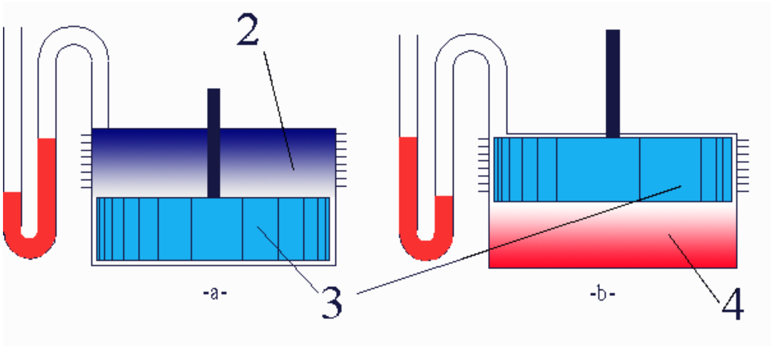
References

[1] http://www.bsigroup.com/bs10 BS10 Specification for flanges and bolting for pipes, valves and fittings
[2] http://www.bsigroup.com

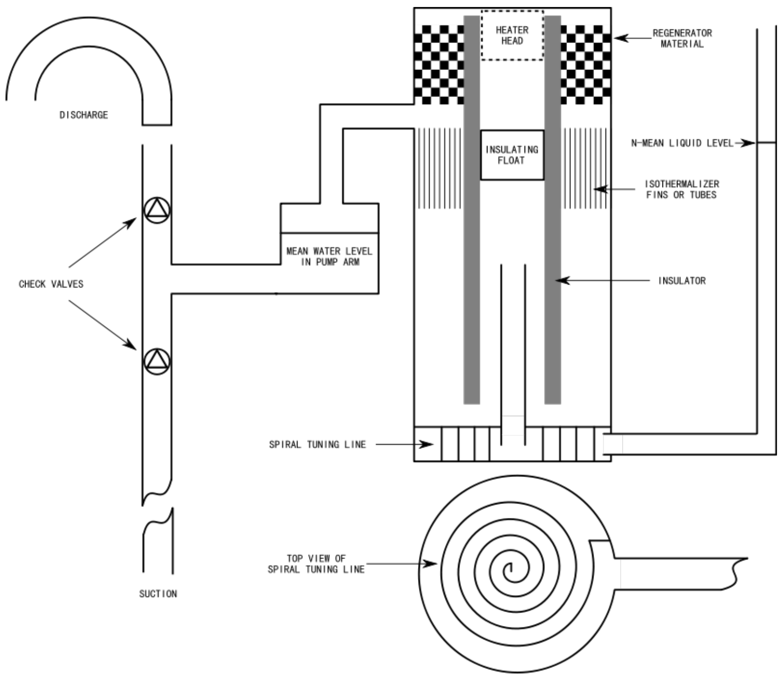
- ASME B16.5 Standard Pipe Flanges up to and including 24 inches nominal
- ASME B16.47 Standard Pipe Flanges above 24 inches
- ASME Section II (Materials), Part A - Ferrous Material Specifications
- Nayyar, Mohinder (1999). *Piping Handbook, Seventh Edition*. New York: McGraw-Hill. ISBN 0070471061.

Fluidyne engine

A **Fluidyne engine** is a beta or gamma type Stirling engine with one or more liquid pistons. It contains a working gas, and either two liquid pistons or one liquid piston and a displacer. In the classic configuration, the work produced via the water pistons is integrated with a water pump. The simple pump is external to the engine, and consists of two check valves, one on the intake and one on the outlet. In the engine, the loop of oscillating liquid can be thought of as acting as a displacer piston. The liquid in the single tube extending to the pump acts as the power piston. Traditionally the pump is open to the atmosphere, and the hydraulic head is small, so that the absolute engine pressure is close to atmospheric pressure. [1]



This is a Fluidyne variant with a solid displacer piston (3). In figure -a-, as the displacer moves from the cold compression space (2), to the hot expansion space (4) in figure -b-, the temperature of the gaseous working fluid is increased. This increases the pressure of the gaseous working fluid, and as it expands, work is done on the (red) liquid piston as it is pushed through the tube.



A Concentric-cylinder Fluidyne Pumping engine

See also

- Technical paper: "Stirling Engines and Irrigation Pumping" - C. D. West [2]
- DeSoto Solar Solar-Powered Fluidyne (Fluid Piston Stirling Cycle Engine) [3] Citat: "...It still offers the advantage of having only fluids (air and water) as moving parts - there's absolutely nothing that can wear out!..."

References

[1] Oak Ridge (US) National Labs (http://www.ornl.gov/~webworks/cppr/y2001/rpt/27113.pdf)
[2] http://www.ornl.gov/~webworks/cppr/y2001/rpt/27113.pdf
[3] http://www.iedu.com/DeSoto/Projects/Stirling/

Flywheel

A **flywheel** is a mechanical device with a significant moment of inertia used as a storage device for rotational energy. Flywheels resist changes in their rotational speed, which helps steady the rotation of the shaft when a fluctuating torque is exerted on it by its power source such as a piston-based (reciprocating) engine, or when the load placed on it is intermittent (such as a piston pump). Flywheels can be used to produce very high power pulses as needed for some experiments, where drawing the power from the public network would produce unacceptable spikes. A small motor can accelerate the flywheel between the pulses. Recently, flywheels have become the subject of extensive research as power storage devices for uses in vehicles; see flywheel energy storage.

Physics

Energy is stored in the rotor as kinetic energy, or more specifically, rotational energy:

Spoked flywheel

$$E_k = \frac{1}{2} \cdot I \cdot \omega^2$$

where

ω is the angular velocity, and

I is the moment of inertia of the mass about the center of rotation.

- The moment of inertia for a solid-cylinder is $I_z = \frac{1}{2}mr^2$,
- for a thin-walled cylinder is $I = mr^2$,
- and for a thick-walled cylinder is $I = \frac{1}{2}m({r_1}^2 + {r_2}^2)$.

where *m* denotes mass, and *r* denotes a radius. More information can be found at list of moments of inertia

When calculating with SI units, the standards would be for mass, kilograms; for radius, meters; and for angular velocity, radians per second. The resulting answer would be in Joules

The amount of energy that can safely be stored in the rotor depends on the point at which the rotor will warp or shatter. The hoop stress on the rotor is a major consideration in the

design of a flywheel energy storage system.

where

σ_t is the tensile stress on the rim of the cylinder

ρ is the density of the cylinder

r is the radius of the cylinder, and

ω is the angular velocity of the cylinder.

Examples of energy stored

You can use those equations to do 'back of the envelope' calculations and find the rotational energy stored in various flywheels. $I = kmr^2$, and k is from List of moments of inertia

object	k (varies with shape)	mass	diameter	angular velocity	energy stored, J	energy stored, kWh
bicycle wheel	1	1 kg	700 mm	150 rpm	15 J	4×10^{-6} kWh
bicycle wheel, double speed	1	1 kg	700 mm	300 rpm	60 J	16×10^{-6} kWh
bicycle wheel, double mass	1	2 kg	700 mm	150 rpm	30 J	8×10^{-6} kWh
Flintstones concrete car wheel	1/2	245 kg	500 mm	200 rpm	1.68 kJ	0.47×10^{-3} kWh
wheel on train @ 60km/h [1]	1/2	942 kg	1 m	318 rpm	65 kJ	18×10^{-3} kWh
giant dump truck wheel @ 18mph	1/2	1000 kg	2 m	79 rpm	17 kJ	4.8×10^{-3} kWh
small flywheel battery [2]	1/2	100 kg	600 mm	20000 rpm	9.8 MJ	2.7 kWh
regenerative braking flywheel for trains [3]	1/2	3000 kg	500 mm	8000 rpm	33 MJ	9.1 kWh
electrical power backup flywheel [4]	1/2	600 kg	500 mm	30000 rpm	92 MJ	26 kWh
the planet earth [5], Rotational energy	2/5	5.97×10^{24} kg	12725 km	~1 per day	2.6×10^{23} MJ	7.2×10^{22} kWh

See [6], [7], [8], [9], and Rotational energy

High energy materials

Flywheel from stationary engine. Note the castellated rim which was used to rotate the engine to the correct starting position by means of a lever.

For a given flywheel design, it can be derived from the above equations that the kinetic energy is proportional to the ratio of the hoop stress to the material density.

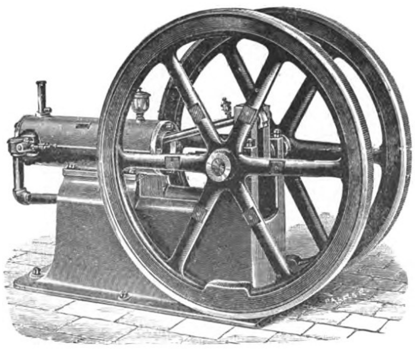
$$E_k \propto \frac{\sigma_t}{\rho}$$

This parameter could be called the specific tensile strength. The flywheel material with the highest specific tensile strength will yield the highest energy storage. This is one reason why carbon fiber is a material of interest.

Applications

A Landini tractor with massive flywheel

In application of flywheels in vehicles, the phenomenon of precession has to be considered. A rotating flywheel responds to any momentum that tends to change the direction of its axis of rotation by a resulting precession rotation. A vehicle with a vertical-axis flywheel would experience a lateral momentum when passing the top of a hill or the bottom of a valley (roll momentum in response to a pitch change). Two counter-rotating flywheels may be needed to eliminate this effect.



1898 illustration of a White and Middleton stationary engine; note the large twin flywheels.

The flywheel has been used since ancient times, the most common traditional example being the potter's wheel. In the Industrial Revolution, James Watt contributed to the development of the flywheel in the steam engine, and his contemporary James Pickard used a flywheel combined with a → crank to transform reciprocating into rotary motion.

In a more modern application, a momentum wheel is a type of flywheel useful in satellite pointing operations, in which the flywheels are used to point the satellite's instruments in the correct directions without the use of thruster rockets.

Flywheels are used in punching machines and riveting machines, where they store energy from the motor and release it during the operation cycle (punching and riveting).

History

The principle of the flywheel is already found in the Neolithic spindle and the potter's wheel.[10]

The flywheel as a general mechanical device for equalizing the speed of rotation is first described in the *Kitab al-Filaha* of the Andalusian engineer Ibn Bassal (fl. 1038-1075), who applies the device in a chain pump (saqiya) and noria.[11]

According to the American medievalist Lynn Townsend White, Jr., such a flywheel is also recorded in the *De diversibus artibus* (*On various arts*) of the German artisan Theophilus Presbyter (ca. 1070-1125), who records applying the device in several of his machines.[10][12]

Flywheel in the internal combustion engine

It is a heavy wheel mounted on the crank shaft. Its main function is to maintain the angular velocity of crank shaft fairly constant.

See also

- Gyroscope
- Inductor
- Reaction wheel
- Rotational energy
- Flywheel energy storage
- Regenerative braking
- Plug-in hybrid
- Rechargeable battery
- Electric double-layer capacitor
- List of energy topics

External links

- Flywheel highlight [13]: Hypervideo showing construction and operation of four cylinder internal combustion engine (courtesy of Ford Motor Company)
- Interesting Thing of the Day article on the Flywheel [14]: Written by Joe Kissell.

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Fretting Wear

Fretting wear is the repeated cyclical rubbing between two surfaces, which is known as fretting, over a period of time which will remove material from one or both surfaces in contact. It occurs typically in bearings, although most bearings have their surfaces hardened to resist the problem. Another problem occurs when cracks in either surface are created, known as fretting fatigue. It is the more serious of the two phenomena because it can lead to catastrophic failure of the bearing. An associated problem occurs when the small particles removed by wear are oxidised in air. The oxides are usually harder than the underlying metal, so wear accelerates as the harder particles abrade the metal surfaces further. Fretting corrosion acts in the same way, especially when water is present. Unprotected bearings on large structures like bridges can suffer serious degradation in behaviour, especially when salt is used during winter to deice the highways carried by the bridges. The problem of fretting corrosion was involved in the Silver Bridge tragedy and the Mianus River Bridge accident.

See also

- Bearings

Friction loss

Friction loss refers to that portion of pressure lost by fluids while moving through a pipe, hose, or other limited space.

Causes

Friction loss has several causes, including:

- Frictional losses depend on the conditions of flow and the physical properties of the system.
- Movement of fluid molecules against each other
- Movement of fluid molecules against the inside surface of a pipe or the like, particularly if the inside surface is rough, textured, or otherwise not smooth
- Bends, kinks, and other sharp turns in hose or → piping

In pipe flows the losses due to friction is of two kind first the skin-friction and the other is form-friction, the former one is due to the roughness in the inner part of the pipe where the fluid comes in the contact of the pipe material and the latter one is due to the obstructions present in the line of flow, it may be due to a bend or a control valve or anything which changes the course of motion of the flowing fluid.

- fluid may be liquid or gas

Firefighting applications

While friction loss has multiple applications, one of the most common is in the realm of firefighting. With the advent of modern power-takeoff (PTO) fire pumps, pressures created can sometimes overwhelm the ability of water to flow through a hose of a given diameter. As the velocity of water inside a hose increases, so does the friction loss. This resulting increase occurs as an exponential rate, thus an increase in the flow by a factor of X will result in an increase in friction loss by a factor of X^2. For example, doubling the flow through a hose will quadruple the friction loss. Ultimately, as the pressure created by a fire pump goes higher and higher the amount of water actually flowing through a hose to a given point lessens, threatening firefighting operations. Conversely, friction loss can restrict the distance which water can be lifted during fire department drafting operations.

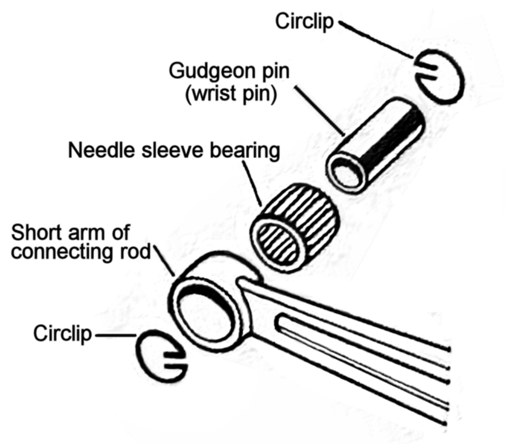
Formulas

The formula used most often in firefighting to express the amount of friction loss is:

$$\mathbf{FL = CQ^2L}$$

Where **FL** = friction loss (expressed in psi) **C** = coefficient of friction (based on the inside diameter of the hose and the inside jacket material) **Q** = flow rate in hundreds of gallons (gpm/100) **L** = Length of hose in hundreds of feet (L/100)

Gudgeon pin



Gudgeon pin connection at connecting rod. Gudgeon pin fits into gudgeons inside piston.

In internal combustion engines, the **gudgeon pin** (UK, **wrist pin** US) is that which connects the piston to the connecting rod and provides a bearing for the connecting rod to pivot upon as the piston moves.[1] In very early engine designs (including those driven by steam and also many very large stationary or marine engines), the gudgeon pin is located in a sliding crosshead that connects to the piston via a rod.

The gudgeon pin is typically a forged short hollow rod made of a steel alloy of high strength and hardness that may be physically separated from both the connecting rod and piston or crosshead.[1] The design of the gudgeon pin, especially in the case of small, high-revving automotive engines is challenging. The gudgeon pin has to operate under some of the highest temperatures experienced in the engine, with difficulties in lubrication due to its location, while remaining small and light so as to fit into the piston diameter and not unduly add to the reciprocating mass. The requirements for lightness and compactness demand a small diameter rod that is subject to heavy shear and bending loads, with some of the highest pressure loadings of any bearing in the whole engine. To overcome these problems, the materials used to make the gudgeon pin and the way it is manufactured are amongst the most highly-engineered of any mechanical component found in internal combustion engines.

Design Options

Gudgeon pins use two broad design configurations: semi-floating and fully-floating.[1] In the semi-floating configuration, the pin is usually fixed relative to the piston by an → interference fit with the journal in the piston. (This replaced the earlier set screw method.[2]) The connecting rod small end bearing thus acts as the bearing alone. In this configuration, only the small end bearing requires a bearing surface, if any. If needed, this is provided by either electroplating the small end bearing journal with a suitable metal, or more usually by inserting a sleeve bearing or needle bearing into the eye of the small end, which has an interference fit with the aperture of the small end. During overhaul, it is usually possible to replace this bearing sleeve if it is badly worn. The reverse configuration, fixing the gudgeon pin to the connecting rod instead of to the piston, is implemented using an interference fit with the small end eye instead, with the gudgeon pin journals in the piston functioning as bearings.[3] This arrangement is usually more difficult to manufacture and service because two bearing surfaces or inserted sleeves complicate the design. In addition, the pin must be precisely set so that the small end eye is central. Because of thermal expansion considerations, this arrangement was more usual for single-cylinder engines as opposed to multiple cylinder engines with long cylinder blocks and crankcases, until precision

manufacturing became more commonplace.

In the fully-floating configuration, a bearing surface is created both between the small end eye and gudgeon pin and the journal in the piston. The gudgeon pins are usually secured with circlips.[3] No interference fit is used in any instance and the pin 'floats' entirely on bearing surfaces. The average rubbing speed of each of the three bearings is halved and the load is shared across a bearing that is usually about three times the length of the semi-floating design with an interference fit with the piston.

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Heat transfer

Heat transfer is the transition of thermal energy from a hotter object to a cooler object ("object" in this sense designating a complex collection of particles which is capable of storing energy in many different ways). When an object or fluid is at a different temperature than its surroundings or another object, *transfer of thermal energy*, also known as heat transfer, or *heat exchange*, occurs in such a way that the body and the surroundings reach thermal equilibrium. Heat transfer always occurs from a higher-temperature object to a cooler temperature one as described by the second law of thermodynamics or the Clausius statement. Where there is a temperature difference between objects in proximity, heat transfer between them can never be stopped; it can only be slowed.

Conduction

Conduction is the transfer of heat by direct contact of particles of matter. The transfer of energy could be primarily by elastic impact as in fluids or by free electron diffusion as predominant in metals or phonon vibration as predominant in insulators. In other words, heat is transferred by conduction when adjacent atoms vibrate against one another, or as electrons move from atom to atom. Conduction is greater in solids, where atoms are in constant contact. In liquids (except liquid metals) and gases, the molecules are usually further apart, giving a lower chance of molecules colliding and passing on thermal energy.

Heat conduction is directly analogous to diffusion of particles into a fluid, in the situation where there are no fluid currents. This type of heat diffusion differs from mass diffusion in behaviour, only in as much as it can occur in solids, whereas mass diffusion is mostly limited to fluids.

Metals (eg. copper, platinum, gold, iron, etc.) are usually the best conductors of thermal energy. This is due to the way that metals are chemically bonded: metallic bonds (as

opposed to covalent or ionic bonds) have free-moving electrons which are able to transfer thermal energy rapidly through the metal.

As density decreases so does conduction. Therefore, fluids (and especially gases) are less conductive. This is due to the large distance between atoms in a gas: fewer collisions between atoms means less conduction. Conductivity of gases increases with temperature. Conductivity increases with increasing pressure from vacuum up to a critical point that the density of the gas is such that that molecules of the gas may be expected to collide with each other before they transfer heat from one surface to another. After this point in density, conductivity increases only slightly with increasing pressure and density.

To quantify the ease with which a particular medium conducts, engineers employ the *thermal conductivity*, also known as the *conductivity constant* or *conduction coefficient*, *k*. In thermal conductivity *k* is defined as "the quantity of heat, Q, transmitted in time (t) through a thickness (L), in a direction normal to a surface of area (A), due to a temperature difference (ΔT) [...]." Thermal conductivity is a material *property* that is primarily dependent on the medium's phase, temperature, density, and molecular bonding.

A heat pipe is a passive device that is constructed in such a way that it acts as though it has extremely high thermal conductivity.

Transient Conduction vs. steady state conduction. Steady state conduction is the form of conduction which happens when the temperature difference is constant, so that an equilibration time, the spatial distribution of temperatures in an object does not change (for example, a bar may be cold at one end and hot at the other, but the gradient of temperatures along the bar do not change with time). There also exist situations wherein the temperature drop or raise occurs more drastically, such as when a hot copper ball is dropped into oil at a low temperature, and the interest is in analysing the spatial change of temperature in the object over time. This mode of heat conduction can be referred to as unsteady mode of conduction or *transient conduction*. Analysis of these systems is more complex and (except for simple shapes) calls in for the application of approximation theories.

Lumped System Analysis. A common approximation in transient conduction, which may be used whenever heat conduction within an object is much faster than heat conduction across the boundary of the object, is *Lumped system analysis*. This is a method of approximation that suitably reduces one aspect of the transient conduction system (that within the object) to an equivalent steady state system (that is, it is assumed that the temperature within the object is completely uniform, although its value may be changing in time). In this method, a term known as the Biot number is calculated, which is defined as the ratio of resistance to heat transfer across the object's boundary with a uniform bath of different temperature, to the conductive heat resistance within the object. When the thermal resistance to heat transferred into the object is less than the resistance to heat being diffused completely within the object, the Biot number is small, and the approximation of spatially uniform temperature within the object can be used. As this is a mode of approximation, the Biot number must be less than 0.1 for accurate approximation and heat transfer analysis. The mathematical solution to the lumped system approximation gives Newton's law of cooling, discussed below.

Even if the Biot number is not less than 0.1, analysis can be continued, but the accuracy of the result reduces. This mode of analysis has been applied to forensic sciences to analyse the time of death of humans. Also it can be applied to HVAC (heating, ventilating and

air-conditioning, or building climate control), to ensure more nearly instantaneous effects of a change in comfort level setting.[1]

Convection

Convection is the transfer of heat energy between a solid surface and the nearby liquid or gas in motion. As fluid motion goes faster the convective heat transfer increases. The presence of bulk motion of fluid enhances the heat transfer between the solid surface and the fluid.[2]

There are two types of Convective Heat Transfer:

- Natural Convection: is when the fluid motion is caused by buoyancy forces that result from the density variations due to variations of temperature in the fluid. For example in the absence of a external source when the mass of the fluid is in contact with the hot surface its molecules separate and scatter causing the mass of fluid to become less dense. When this happens, the fluid is displaced vertically or horizontally while the cooler fluid gets denser and the fluid sinks. Thus the hotter volume transfers heat towards the cooler volume of that fluid.[3]
- Forced Convection: is when the fluid is forced to flow over the surface by external source such as fans and pumps. It creates an artificially induced convection current.[4]

Internal and external flow can also classify convection. Internal flow occurs when the fluid is enclosed by a solid boundary such as a flow through a pipe. An external flow occurs when the fluid extends indefinitely without encountering a solid surface. Both these convections, either natural or forced, can be internal or external as they are independent of each other.[3]

The formula for Rate of Convective Heat Transfer:[5]

$$q = hA(T_s - T_b)$$

A is the surface area of heat transfer. T_s is the surface temperature and while T_b is the temperature of the fluid at bulk temperature. However T_b varies with each situation and is the temperature of the fluid “far” away from the surface. The h is the constant heat transfer coefficient which depends upon physical properties of the fluid such as temperature and the physical situation in which convection occurs. Therefore, the heat transfer coefficient must be derived or found experimentally for every system analyzed. Formulae and correlations are available in many references to calculate heat transfer coefficients for typical configurations and fluids. For laminar flows the heat transfer coefficient is rather low compared to the turbulent flows, this is due to turbulent flows having a thinner stagnant fluid film layer on heat transfer surface.[6]

Radiation

Radiation is the transfer of heat energy through empty space. All objects with a temperature above absolute zero radiate energy at a rate equal to their emissivity multiplied by the rate at which energy would radiate from them if they were a black body. No medium is necessary for radiation to occur; radiation works even in and through a perfect vacuum. The energy from the Sun travels through the vacuum of space before warming the earth.

Both *reflectivity* and *emissivity* of all bodies is wavelength dependent. The temperature determines the wavelength distribution of the electromagnetic radiation as limited in

intensity by Planck’s law of black-body radiation. For any body the reflectivity depends on the wavelength distribution of incoming electromagnetic radiation and therefore the temperature of the source of the radiation. The emissivity depends on the wave length distribution and therefore the temperature of the body itself. For example, fresh snow, which is highly reflective to visible light, (reflectivity about 0.90) appears white due to reflecting sunlight with a peak energy wavelength of about 0.5 micrometres. Its emissivity, however, at a temperature of about -5C, peak energy wavelength of about 12 micrometres, is 0.99.

Gases absorb and emit energy in characteristic wavelength patterns that are different for each gas.

Visible light is simply another form of electromagnetic radiation with a shorter wavelength (and therefore a higher frequency) than infrared radiation. The difference between visible light and the radiation from objects at conventional temperatures is a factor of about 20 in frequency and wavelength; the two kinds of emission are simply different "colours" of electromagnetic radiation.

Clothing and building surfaces, and radiative transfer

Lighter colours and also whites and metallic substances absorb less illuminating light, and thus heat up less; but otherwise colour makes little difference as regards heat transfer between an object at everyday temperatures and its surroundings, since the dominant emitted wavelengths are nowhere near the visible spectrum, but rather in the far infrared. Emissivities at those wavelengths have little to do with visual emissivities (visible colours); in the far infrared, most objects have high emissivities. Thus, except in sunlight, the colour of clothing makes little difference as regards warmth; likewise, paint colour of houses makes little difference to warmth except when the painted part is sunlit. The main exception to this is shiny metal surfaces, which have low emissivities both in the visible wavelengths and in the far infrared. Such surfaces can be used to reduce heat transfer in both directions; an example of this is the multi-layer insulation used to insulate spacecraft. Low-emissivity windows in houses are a more complicated technology, since they must have low emissivity at thermal wavelengths while remaining transparent to visible light.

Newton's law of cooling

A related principle, **Newton's law of cooling**, states that *the rate of heat loss of a body is proportional to the difference in temperatures between the body and its surroundings, or environment*. The law is

$$\frac{dQ}{dt} = h \cdot A(T_{\text{env}} - T_0)$$

$Q =$ Thermal energy in joules

$h =$ Heat transfer coefficient

$A =$ Surface area of the heat being transferred

$T_0 =$ Temperature of the object's surface

$T_{\text{env}} =$ Temperature of the environment

This form of heat loss principle is sometimes not very precise; an accurate formulation may require analysis of heat flow, based on the (transient) heat transfer equation in a nonhomogeneous, or else poorly conductive, medium. An analog for continuous gradients is

Fourier's Law.

The following simplification (called *lumped system thermal analysis* and other similar terms) may be applied, so long as it is permitted by the Biot number, which relates surface conductance to interior thermal conductivity in a body. If this ratio permits, it shows that the body has relatively high internal conductivity, such that (to good approximation) the entire body is at the same uniform temperature throughout, even as this temperature changes as it is cooled from the outside, by the environment. If this is the case, these conditions give the behavior of exponential decay with time, of temperature of a body.

In such cases, the entire body is treated as lumped capacitance heat reservoir, with total heat content which is proportional to simple total heat capacity **C** , and **T**, the temperature of the body, or **Q = C T.** From the definition of heat capacity **C** comes the relation **C = *dQ/dT*.** Differentiating this equation with regard to time gives the identity (valid so long as temperatures in the object are uniform at any given time): ***dQ/dt* = C (*dT/dt*)**. This expression may be used to replace ***dQ/dt*** in the first equation which begins this section, above. Then, if **T(t)** is the temperature of such a body at time **t** , and $\mathbf{T_{env}}$ is the temperature of the environment around the body:

$$\frac{dT(t)}{dt} = -r(T - T_{\mathrm{env}})$$

where ***r*** **= hA/C** is a positive constant characteristic of the system, which must be in units of **1/time**, and is therefore sometimes expressed in terms of a characteristic time constant $\mathbf{t_0}$ given by: ***r*** **=** $\mathbf{1/t_0}$ **= ΔT/[*dT/dt*]** . Thus, in thermal systems, $\mathbf{t_0}$ **= C/hA.** (The total heat capacity **C** of a system may be further represented by its mass-specific heat capacity $\mathbf{c_p}$ multiplied by its mass **m**, so that the time constant $\mathbf{t_0}$ is also given by $\mathbf{mc_p/hA}$).

The solution of this differential equation, by standard methods of integration and substitution of boundary conditions, gives:

$$T(t) = T_{\mathrm{env}} + (T(0) - T_{\mathrm{env}})\ e^{-rt}.$$

Here, ***T***(***t***) is the temperature at time ***t***, and **T(0)** is the initial temperature at zero time, or ***t*** = 0.

If:

$\Delta T(t)$ is defined as : $T(t) - T_{\mathrm{env}}$,where $\Delta T(0)$ is the initial temperature difference at time 0,

then the Newtonian solution is written as:

$$\Delta T(t) = \Delta T(0)\ e^{-rt} = \Delta T(0)\ e^{-t/t_0}.$$

Uses: For example, simplified climate models may use Newtonian cooling instead of a full (and computationally expensive) radiation code to maintain atmospheric temperatures.

One dimensional application, using thermal circuits

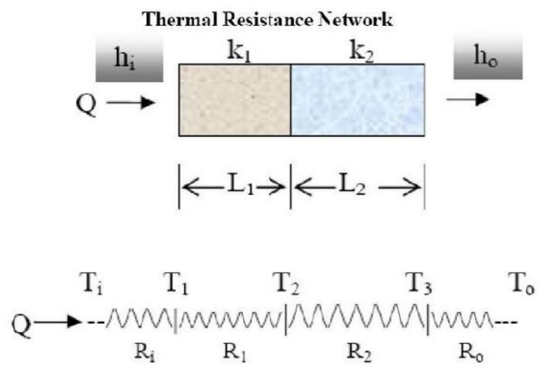
A very useful concept used in heat transfer applications is the representation of thermal transfer by what is known as thermal circuits. A thermal circuit is the representation of the resistance to heat flow as though it were an electric resistor. The heat transferred is analogous to the current and the thermal resistance is analogous to the electric resistor. The value of the thermal resistance for the different modes of heat transfer are calculated as the denominators of the developed equations. The thermal resistances of the different modes of heat transfer are used in analyzing combined modes of heat transfer. The

equations describing the three heat transfer modes and their thermal resistances, as discussed previously are summarized in the table below:

Transfer mode	Amount of heat transferred	Thermal Resistance
Conduction	$Q = \frac{T_1 - T_2}{L/kA}$	L/kA
Convection	$Q = \frac{T_{surf} - T_{env}}{1/h_{conv} A_{surf}}$	$\frac{1}{h_{conv} A_{surf}}$
Radiation	$Q = \frac{T_{surf} - T_{surr}}{1/h_r A_{surf}}$	$\frac{1}{h_r A}$ $h_r = \varepsilon\sigma A_{surf}(T_{surf} + T_{surr})(T_{surf}^2 + T_{surr}^2)$

Table 1 Equations for different heat transfer modes and their thermal resistances

In cases where there is heat transfer through different media (for example through a composite), the equivalent resistance is the sum of the resistances of the components that make up the composite. Likely, in cases where there are different heat transfer modes, the total resistance is the sum of the resistances of the different modes. Using the thermal circuit concept, the amount of heat transferred through any medium is the quotient of the temperature change and the total thermal resistance of the medium. As an example, consider a composite wall of cross- sectional area A. The composite is made of an L_1 long cement plaster with a thermal coefficient k_1 and L_2 long paper faced fiber glass, with thermal coefficient k_2. The left surface of the wall is at T_i and exposed to air with a convective coefficient of h_i. The Right surface of the wall is at T_o and exposed to air with convective coefficient h_o.



T_1 through T_3 are the temperatures at the surfaces of the parts of the composite.

Figure 1 Representation of heat flow diagram as a thermal circuit

Using the thermal resistance concept heat flow through the composite is as follows:

$$Q = \frac{T_i - T_o}{R_i + R_1 + R_2 + R_o} = \frac{T_i - T_1}{R_i} = \frac{T_i - T_2}{R_i + R_1} = \frac{T_i - T_3}{R_i + R_1 + R_2} = \frac{T_1 - T_2}{R_1} = \frac{T_3 - T_o}{R_o}$$

where

$$R_i = \frac{1}{h_i A}, \quad R_o = \frac{1}{h_o A}, \quad R_1 = \frac{L_1}{k_1 A}, \quad R_2 = \frac{L_2}{k_2 A}$$

Insulation and radiant barriers

Thermal insulators are materials specifically designed to reduce the flow of heat by limiting conduction, convection, or both. Radiant barriers are materials which reflect radiation and therefore reduce the flow of heat from radiation sources. Good insulators are not necessarily good radiant barriers, and vice versa. Metal, for instance, is an excellent reflector and poor insulator.

The effectiveness of an insulator is indicated by its **R-** (resistance) **value**. The R-value of a material is the inverse of the conduction coefficient (*k*) multiplied by the thickness (*d*) of the insulator. The units of resistance value are in SI units: ($K{\cdot}m^2/W$)

$$R = \frac{r}{k}$$

$$C = \frac{Q}{m\Delta T}$$

Rigid fiberglass, a common insulation material, has an R-value of 4 per inch, while poured concrete, a poor insulator, has an R-value of 0.08 per inch.[7]

The effectiveness of a radiant barrier is indicated by its **reflectivity**, which is the fraction of radiation reflected. A material with a high reflectivity (at a given wavelength) has a low emissivity (at that same wavelength), and vice versa (at any specific wavelength, **reflectivity** = 1 - **emissivity**). An ideal radiant barrier would have a reflectivity of 1 and would therefore reflect 100% of incoming radiation. Vacuum bottles (Dewars) are 'silvered' to approach this. In space vacuum, satellites use multi-layer insulation which consists of many layers of aluminized (shiny) mylar to greatly reduce radiation heat transfer and control satellite temperature.

Critical insulation thickness

To reduce the rate of heat transfer, one would add insulating materials i.e with low thermal conductivity (*k*). The smaller the *k* value, the larger the corresponding thermal resistance (*R*) value.
The units of thermal conductivity(k) are $W{\cdot}m^{-1}{\cdot}K^{-1}$ (watts per meter per kelvin), therefore increasing width of insulation (*x* meters) decreases the *k* term and as discussed increases resistance.

This follows logic as increased resistance would be created with increased conduction path (*x*).

However, adding this layer of insulation also has the potential of increasing the surface area and hence thermal convection area (*A*).

An obvious example is a cylindrical pipe:

- As insulation gets thicker, outer radius increases and therefore surface area increases.
- The point where the added resistance of increasing insulation width becomes overshadowed by the effects of surface are is called the **critical insulation thickness**. In simple cylindrical pipes:[8]

$$R_{critical} = \frac{k}{h}$$

For a graph of this phenomenon in a cylidrical pipe example see: External Link: Critical Insulation Thickness diagram [9] as at 26/03/09

Heat exchangers

A *heat exchanger* is a device built for efficient heat transfer from one fluid to another, whether the fluids are separated by a solid wall so that they never mix, or the fluids are directly contacted. Heat exchangers are widely used in refrigeration, air conditioning, space heating, power generation, and chemical processing. One common example of a heat exchanger is the radiator in a car, in which the hot radiator fluid is cooled by the flow of air over the radiator surface.

Common types of heat exchanger flows include parallel flow, counter flow, and cross flow. In parallel flow, both fluids move in the same direction while transferring heat; in counter flow, the fluids move in opposite directions and in cross flow the fluids move at right angles to each other. The common constructions for heat exchanger include shell and tube, double pipe, extruded finned pipe, spiral fin pipe, u-tube, and stacked plate. More information on heat exchanger flows and arrangements can be found in the heat exchanger article.

When engineers calculate the theoretical heat transfer in a heat exchanger, they must contend with the fact that the driving temperature difference between the two fluids varies with position. To account for this in simple systems, the log mean temperature difference (LMTD) is often used as an 'average' temperature. In more complex systems, direct knowledge of the LMTD is not available and the number of transfer units (NTU) method can be used instead.

Boiling heat transfer

Heat transfer in boiling fluids is complex but of considerable technical importance. It is characterised by an s-shaped curve relating heat flux to surface temperature difference (see say Kay & Nedderman 'Fluid Mechanics & Transfer Processes', CUP, 1985, p. 529).

At low driving temperatures, no boiling occurs and the heat transfer rate is controlled by the usual single-phase mechanisms. As the surface temperature is increased, local boiling occurs and vapour bubbles nucleate, grow into the surrounding cooler fluid, and collapse. This is sub-cooled nucleate boiling and is a very efficient heat transfer mechanism. At high bubble generation rates the bubbles begin to interfere and the heat flux no longer increases rapidly with surface temperature (this is the departure from nucleate boiling DNB). At higher temperatures still, a maximum in the heat flux is reached (the critical heat flux). The regime of falling heat transfer which follows is not easy to study but is believed to be characterised by alternate periods of nucleate and film boiling. Nukleate boiling slowing the heat transfer due to gas phase {bubbles} creation on the heater surface, as mentioned, gas phase thermal conductivity is much lower than liquid phase thermal conductivity, so the outcome is a kind of "gas thermal barrier".

At higher temperatures still, the hydrodynamically quieter regime of film boiling is reached. Heat fluxes across the stable vapour layers are low, but rise slowly with temperature. Any contact between fluid and the surface which may be seen probably leads to the extremely rapid nucleation of a fresh vapour layer ('spontaneous nucleation').

Condensation heat transfer

Condensation occurs when a vapor is cooled and changes its phase to a liquid. Condensation heat transfer, like boiling, is of great significance in industry. During condensation, the latent heat of vaporization must be released. The amount of the heat is the same as that absorbed during vaporization at the same fluid pressure.

There are several modes of condensation:

- Homogeneous condensation (as during a formation of fog).
- Condensation in direct contact with subcooled liquid.
- Condensation on direct contact with a cooling wall of a heat exchanger-this is the most common mode used in industry:
  - Filmwise condensation (when a liquid film is formed on the subcooled surface, usually occurs when the liquid wets the surface).
  - Dropwise condensation (when liquid drops are formed on the subcooled surface, usually occurs when the liquid does not wet the surface). Dropwise condensation is difficult to sustain reliably; therefore, industrial equipment is normally designed to operate in filmwise condensation mode.

Heat transfer in education

Heat transfer is typically studied as part of a general chemical engineering or → mechanical engineering curriculum. Typically, thermodynamics is a prerequisite to undertaking a course in heat transfer, as the laws of thermodynamics are essential in understanding the mechanism of heat transfer. Other courses related to heat transfer include energy conversion, thermofluids and → mass transfer.

Heat transfer methodologies are used in the following disciplines, among others:

- Automotive engineering
- Thermal management of electronic devices and systems
- HVAC
- Insulation
- Materials processing
- Power plant engineering

See also

- Heat
- Thermal contact conductance
- Thermal insulation
- Thermal physics
- → Thermal science
- Heat exchanger

Further reading

- Class notes of Dr. Rong-Yaw Chen, Department of Mechanical Engineering, NJIT [10]

Related journals

- *Heat Transfer Engineering* [11]
- *Experimental Heat Transfer* [12]
- *International Journal of Heat and Mass Transfer* [13]
- *ASME Journal of Heat Transfer* [14]
- *Numerical Heat Transfer Part A* [15]
- *Numerical Heat Transfer Part B* [16]
- *Nanoscale and Microscale Thermophysical Engineering* [17]
- *Journal of Enhanced Heat Transfer* [18]

External links

- Heat Transfer [19]
- **Heat Transfer Tutorial** [20] Modes of heat transfer (conduction, convection, radiation) within or between media are explained, together with calculations and other issues such as heat transfer barriers - Spirax Sarco
- Heat Transfer Podcast - Arun Majumdar - Department of Mechanical Engineering - University of California, Berkeley [21]
- Heat Transfer Basics [22] - Overview
- A Heat Transfer Textbook [23] - Downloadable textbook (free)
- Thermal Resistance Circuits [24] - Overview
- Hyperphysics Article on Heat Transfer [25] - Overview
- Interseasonal Heat Transfer [26] - a practical example of how heat transfer is used to heat buildings without burning fossil fuels.
- Heat transfer fundamentals [27]
- Principles of Enhanced Heat Transfer - Book [28]

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[9] http://www.cheresources.com/insulationzz.shtmlexample.com
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Mechanical Engineering Heritage (Japan)

The **Mechanical Engineering Heritage (Japan)** (機械遺産 *kikaiisan*) is a list of sites, landmarks, machines, and documents that made significant contributions to the development of mechanical engineering in Japan. Items in the list are certified by the Japan Society of Mechanical Engineers (JSME).

(Myriad year Japanese clock, Heritage No. 22

Overview

The Mechanical Engineering Heritage program was inaugurated in June 2007 in connection with the 110th anniversary of the founding of the JSME. The program recognizes machines, related systems, factories, specification documents, textbooks, and other items that had a significant impact on the development of mechanical engineering. When a certified item can no longer be maintained by its current owner, the JSME acts to prevent its loss by arranging a transfer to the National Science Museum of Japan or to a local government institution.

The JSME plans to certify approximately 100 items of high heritage value over 10 years.

Categories

Items in the Mechanical Engineering Heritage (Japan) are classified into four categories.

1. Sites: Historical sites that contain heritage items.
2. Landmarks: Representative buildings, structures, and machinery.
3. Collections: Collections of machinery, or individual machines.
4. Documents: Machinery-related documents of historical significance.

Each item is assigned a Mechanical Engineering Heritage number.

Items certified in 2007

Sites

- No. 1: Steam engines and hauling machinery at the Kosuge Ship Repair Dock, (built in 1868), Nagasaki Prefecture

Landmarks

- No. 2: Memorial workshop and machine tools at Kumamoto University, (built in 1908), Kumamoto Prefecture

Collections

- No. 3: Forged iron → treadle lathe (made in 1875 by Kaheiji Ito), Aichi Prefecture
- No. 4: Industrial steam turbine (Parsons steam turbine), (made in 1908), Nagasaki Prefecture
- No. 5: 10A rotary engine (made in 1967), Hiroshima Prefecture
- No. 6: Honda CVCC engine (first engine to meet emission standards of Clean Air Act (1970)), Tochigi Prefecture
- No. 7: FJR710 jet engine (made in 1971), Tokyo
- No. 8: Yanmar small horizontal diesel engine, Model HB (made in 1933), Shiga Prefecture
- No. 9: Prof. Inokuchi's centrifugal pump, (made in 1912), Aichi Prefecture
- No. 10: High frequency generator (made in 1929 by German AEG), Aichi Prefecture
- No. 11: 0-Series Tōkaidō Shinkansen electric multiple units (operated 1964–1978), Osaka Prefecture
- No. 12: Class 230 No.233 2-4-2 steam tank locomotive (made 1902–1909), Osaka Prefecture
- No. 13: YS11 passenger airplane (flown 1964–1998), Tokyo
- No. 14: Cub Type F, Honda bicycle engine (1952), Tochigi Prefecture
- No. 15: Chain stitch sewing machine for the production of straw hats (made in 1928), Aichi Prefecture
- No. 16: Non-stop shuttle change automatic loom, Toyoda Type G (made in 1924), Aichi Prefecture
- No. 17: Hand operated letterpress printing machine (made in 1885), Tokyo
- No. 18: Komatsu bulldozer G40 (made in 1943), Shizuoka Prefecture
- No. 19: Olympus gastrocamera GT-I (made in 1950), Tokyo
- No. 20: Buckton[1] universal testing machine (installed in 1908), Hyōgo Prefecture
- No. 21: Mutoh Drafter manual drafting machine, MH-I (made in 1953), Tokyo

- No. 22: Myriad year clock, (made in 1851), Tokyo
- No. 23: The Chikugo River Lift Bridge (opened in 1935), Fukuoka and Saga Prefectures

Documents

- No. 24: JSME publications from the early days of the society, (published in 1897, 1901 and 1934), Tokyo
- No. 25: "→ Hydraulics and Hydraulic Machinery", lecture notes by Professors Bunji Mano and Ariya Inokuty at Imperial University of Tokyo (1905), Tokyo

Items certified in 2008

Sites

- No. 26: Sankyozawa hydroelectric power station and related objects, (operating since 1888), Miyagi Prefecture
- No. 27: Hydraulic lock (made in United Kingdom, operating since 1908) and floating steam crane (operated 1905–2008), Miike Port, Fukuoka Prefecture

Collections

- No. 28: “Entaro” bus (Ford TT type), (1923, adapted from chassis imported from United States), Saitama Prefecture
- No. 29: Mechanical telecommunication devices (made in 1947 by Shinko Seisakusho Co.), Iwate Prefecture
- No. 30: Mechanical calculator, (Yazu Arithmometer, patented in 1903), [2] Fukuoka Prefecture
- No. 31: Induction motor and design sheet (made in 1910, in the earliest days of the Japanese electrical machinery industry), Ibaraki Prefecture

Items certified in 2009

Sites

- No. 32: Mechanical Device of Sapporo Clock Tower, (clock mechanism imported/installed from E. Howard & Co. in 1881, moved in 1906), Hokkaidō

Landmarks

- No. 33: Minegishi Watermill, (installed in 1808, in operation till 1965), Tokyo

Collections

- No. 34: The Master Worm Wheel of the Hobbing Machine HRS-500, (machining by Hobbing machine of Rhein-Neckar from Germany in 1943), Shizuoka Prefecture
- No. 35: Locomobile, The Oldest Private Steam Automobile in JAPAN, (one of eight imported from Locomobile Company of America in 1902, failured in 1908, discovered in 1978 then only boiler was replaced and operable in 1980), Hokkaidō
- No. 36: Arrow-Gou, The Oldest Japanese-made Car, (one of Japanese fundamental vehicle technology made in 1916), Fukuoka Prefecture

- No. 37: British-made 50ft Turn Table, (imported from Ransomes & Rapier made in 1897, but installed location was unknown before moved in 1941 then further moved to Ōigawa Railway in 1980, in operation. Two others are deemed also imported and still in operation in other locations, these historical details is not known), Shizuoka Prefecture

See also

- List of historic mechanical engineering landmarks

External links

- The Japan Society of Mechanical Engineers, JSME [3]
- The Mechanical Engineering Heritage (Japan) list [4] Official site, in Japanese with English titles.

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Hirth joint

A **Hirth joint** or **Hirth coupling** is a type of mechanical connection named after its developer Hellmuth Hirth. It is used to connect two pieces of a shaft together and is characterized by teeth that mesh together on the end faces of each half shaft.

Construction

Hirth joints consist of radial grooves milled or ground (or both) into the end face of a cylindrical feature of a part. Grooves are made one by one into the part tilted by the bottom angle of the grooves, and rotated from groove to groove until the serration is complete.

Usually the grooves mesh together within a ring, because the load bearing capacity of teeth is rapidly decreasing at smaller diameters. For instance a shaft of 60 mm diameter can be toothed in a 12 mm wide ring only (inner diameter is 36 mm) without jeopardizing the load bearing capacity of the shaft.

Theoretically a number of kinds of matching serrations can be made on the end faces of shafts. Only symmetric serrations are used in practice: the profile of a tooth is a symmetric triangle, and the tooth's head and bottom angle is the same too. Even the profile angles are not arbitrary: angles of 60 and 90 degrees are used.

The coupling is defined by the number of grooves, the outer diameter of the cylindrical feature, the bottom angle of the grooves (to the axis of the cylindrical feature), and the depth of grooves.

Finally, an axially oriented bolt holds the two parts together.

Advantages

- Very high loads can be transferred in a small enclosure of only a few parts (two serrated faces and a bolt fixing them together).
- There is no lag in the joint.
- The joint is self centering (because of this the Hirth coupling is used in very high RPM gas turbines).
- If there is some fretting wear resulting in looseness, tightening the axial thread can regain tightness.

Disadvantages

- The manufacturing process is complex and time consuming -- i.e. expensive.

Uses

Hirth joints were first used in gasoline engine crankshafts[1] and are now used in jet engine shafts, in accessories for surgical operating tables, in agricultural machines for fixing tools etc, and in bikes parts/frames such as Campagnolo's "Ultra-Torque" bicycle crankset, and in Bicycle Torque Couplings.

References

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Hydraulic manifold

A **hydraulic manifold** is a component which regulates fluid flow between pumps and actuators and other components in a hydraulic system. It is like a switchboard in an electrical circuit because it lets the operator control how much fluid flows between which components of a hydraulic machinery. For example, in a backhoe loader a manifold turns on or shuts off or diverts flow to the telescopic arms of the front bucket and the back bucket. The manifold is connected to the levers in the operator's cabin which the operator uses to achieve the desired manifold behaviour.

A manifold is composed of assorted hydraulic valves connected to each other. It is the various combinations of states of these valves that allow complex control behaviour in a manifold.

See also

- → Block and bleed manifold

Hydraulics

For the mechanical technology, see hydraulic machinery and hydraulic cylinder

Hydraulics is a topic in applied science and engineering dealing with the mechanical properties of liquids. Fluid mechanics provides the theoretical foundation for hydraulics, which focuses on the engineering uses of fluid properties. In fluid power, hydraulics is used for the generation, control, and transmission of power by the use of pressurized liquids. Hydraulic topics range through most science and engineering disciplines, and cover concepts such as pipe flow, dam design, fluidics and fluid control circuitry, pumps, turbines, hydropower, computational fluid dynamics, flow measurement, river channel behavior and erosion.

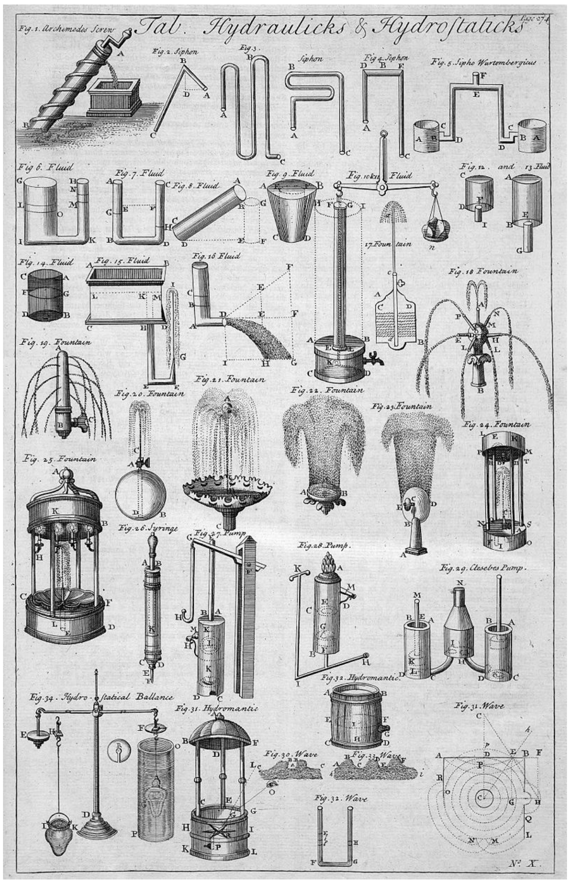


Table of Hydraulics and Hydrostatics, from the 1728 *Cyclopaedia*.

Free surface hydraulics is the branch of hydraulics dealing with free surface flow, such as occurring in rivers, canals, lakes, estuaries and seas. Its sub-field **open channel flow** studies the flow in open channels.

The word "hydraulics" originates from the Greek word *ὑδραυλικός* (*hydraulikos*) which in turn originates from *ὕδραυλος* (*hydraulos*) meaning water organ which in turn comes from *ὕδωρ* (*hydor*, Greek for water) and *αὐλός* (*aulos*, meaning pipe).

Ancient and medieval era

Hellenistic world

The earliest masters of hydraulics in the Greek-Hellenized West were Ctesibius (flourished c. 270 BC) and Hero of Alexandria (c. 10–80 AD). Hero describes a number of working machines using hydraulic power, such as the force pump, which is known from many Roman sites as having been used for raising water and in fire engines, for example.

China

In ancient China there was Sunshu Ao (6th century BC), Ximen Bao (5th century BC), Du Shi (circa 31 AD), Zhang Heng (78 - 139 AD), and Ma Jun (200 - 265 AD), while medieval China had Su Song (1020 - 1101 AD) and Shen Kuo (1031 - 1095). Du Shi employed a waterwheel to power the bellows of a blast furnace producing cast iron. Zhang Heng was the first to employ hydraulics to provide motive power in rotating an armillary sphere for

astronomical observation.

Sri Lanka

In ancient Sri Lanka, the Sri Lankan people used hydraulics in many applications, in the ancient kingdoms of Anuradhapura and Polonnaruwa. The discovery of the principle of the valve tower, or valve pit, for regulating the escape of water is credited to ingenuity more than 2,000 years ago. By the first century A.D, several large-scale irrigation works had been completed. Macro- and micro-hydraulics to provide for domestic horticultural and agricultural needs, surface drainage and erosion control, ornamental and recreational water courses and retaining structures and also cooling systems were in place in Sigiriya, Sri Lanka. The citadel on the massive rock at the site includes cisterns for collecting water. Special note is made on the pioneer Hydraulic Engineer, King Pandukabhaya (474-407BC) and Parākramabāhu the Great on the hydraulic history of Sri Lanka.

Moat and gardens at Sigirya.

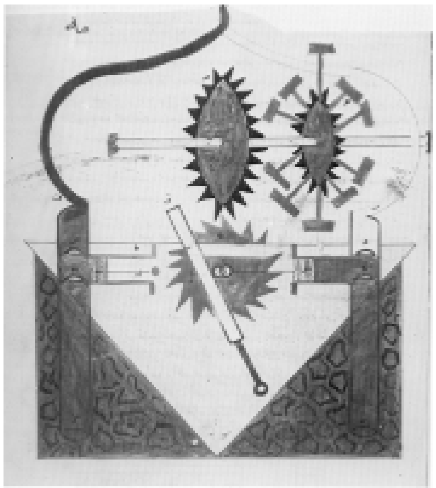
Innovations in Ancient Rome

In Ancient Rome many different hydraulic applications were developed, including public water supplies, innumerable aqueducts, power using watermills and hydraulic mining. They were among the first to make use of the siphon to carry water across valleys, and used hushing on a large scale to prospect for and then extract metal ores. They used lead widely in plumbing systems for domestic and public supply, such as feeding thermae.

Aqueduct of Segovia

While there is great public awareness of their highly visible aqueducts, less is known about their use of hydropower, although extant remains suggest that it was much more widespread than appreciated. The use of hydraulic mining methods is at its most spectacular in the gold-fields of northern Spain, which was conquered by Augustus in 25 BC. The alluvial gold-mine of Las Medulas for example must be one of the largest of their mines and even today rivals modern mines in sheer size. It was worked by at least 7 long aqueducts, and the water streams were used to erode the soft deposits, and then wash the tailings for the valuable gold content.

Innovations in the Islamic world



The double-action → reciprocating suction piston pump with a valve and crankshaft-connecting rod mechanism, from a manuscript of Al-Jazari in 1206.

In the medieval Islamic world, the advances in in fluid mechanics by Muslim physicists such as Abū Rayhān al-Bīrūnī (973-1048)[1] and Al-Khazini (who invented the hydrostatic balance in 1121),[2] led to innovations in hydraulics by Arabic engineers and inventors. The Arab Empire had advanced domestic water systems such as water cleaning systems and advanced water transportation systems resulting in better agriculture, something that helped in issues related to Islamic hygienical jurisprudence.[3]

Muslim engineers made a number of innovative uses of watermills between the 8th and 13th centuries, including: the bridge mill, a unique type of mill that was built as part of the superstructure of a bridge;[4] geared gristmill[5] with trip hammers;[6] hydropowered forge and finery forge;[4] milling dam, used to provide additional power for milling;[7] paper mill;[8] shipmill, powered by water wheels mounted on the sides of large ships moored in midstream;[6] spiral scoop-wheel, a device which raises large quantities of water to ground level with a high degree of efficiency;[9] sugar refinery;[4] the situation of watermills in the underground irrigation tunnels of a qanat and on the main canals of valley-floor irrigation systems;[4] and the water turbine.[6] The first factory milling installations were also built by Muslim engineers throughout every city and urban community in the Islamic world. For example, the factory milling complex in 10th century Baghdad could produce 10 tonnes of flour every day.[7]

In the 9th century, the Banū Mūsā brothers introduced the use of differential pressures in their hydraulic devices.[10] They also invented "the earliest known mechanical musical instrument", in this case a hydropowered organ which played interchangeable cylinders automatically. According to Charles B. Fowler, this "cylinder with raised pins on the surface remained the basic device to produce and reproduce music mechanically until the second half of the nineteenth century."[11] They also invented an automatic water-powered flute player which may have been the first programmable machine.[12] [13] Al-Jazari (1136-1206) created the first recorded designs of programmable humanoid robots, which were driven by hydraulics and were part of a boat with four automatic musicians that floated on a lake to entertain guests at royal drinking parties.[12] According to Charles B. Fowler, the automata were a "robot band" which performed "more than fifty facial and body actions during each musical selection."[14] He also invented a hand washing automaton incorporating a flush mechanism now used in modern flush toilets. It features a female humanoid automaton standing by a basin filled with water. When the user pulls the lever, the water drains and the female automaton refills the basin.[15] His "peacock fountain" was a more sophisticated hand washing device featuring humanoid automata as servants which offer soap and towels, dirven by advanced hydraulic-powered mechanisms.[16]

The mechanical → flywheel, used to smooth out the delivery of power from a driving device to a driven machine, was invented by Ibn Bassal (fl. 1038-1075) of Islamic Spain for use in

the chain pump (saqiya) and noria.[17] Al-Jazari invented a variety of machines for raising water in 1206,[18] as well as water mills and water wheels with → cams on their axle used to operate automata in the late 12th century.[7] He employed the crankshaft and connecting rod mechanism in his water-raising machines,[19] which included crank-driven and hydropowered saqiya chain pumps, and the first double-action suction piston pump with → reciprocating motion.[20] The concept of minimizing intermittency is also first implied in one of al-Jazari's saqiya chain pumps.[7]

The monumental water clocks constructed by medieval Muslim engineers employed complex gear trains, arrays of automata, and weight-drives, while the escapement mechanism was present in the hydraulic controls they used to make heavy floats descend at a slow and steady rate.[21] The on/off switch, an important feedback control principle, was invented by Muslim engineers between the 9th and 12th centuries, and it was employed in a variety of water-powered automata and water clocks.[22] In 1206, Al-Jazari invented monumental water-powered astronomical clocks such as the "castle clock", a hydraulics-powered programmable analog computer, which could re-program the length of day and night every day,[23] display moving models of the Sun, Moon, and stars, and had a pointer which travelled across the top of a gateway and caused automatic doors to open every hour.[6] His hydraulics-powered elephant clock was the first to feature an automaton, flow regulator, and closed-loop system.[24] The float regulator was later employed in domestic water systems during the Industrial Revolution.[25]

Modern era (c. 1600–1870)

Benedetto Castelli

In 1619 Benedetto Castelli (1576 - 1578–1643), a student of Galileo Galilei, published the book *Della Misura dell'Acque Correnti* or "On the Measurement of Running Waters", one of the foundations of modern hydrodynamics. He served as a chief consultant to the Pope on hydraulic projects, i.e., management of rivers in the Papal States, beginning in 1626.[26]

Blaise Pascal

Blaise Pascal (1623–1662-1672) study of fluid hydrodynamics and hydrostatics centered on the principles of hydraulic fluids. His inventions include the hydraulic press, which multiplied a smaller force acting on a larger area into the application of a larger force totaled over a smaller area, transmitted through the same pressure (or same change of pressure) at both locations. Pascal's law or principle states that for an incompressible fluid at rest, the difference in pressure is proportional to the difference in height and this difference remains the same whether or not the overall pressure of the fluid is changed by applying an external force. This implies that by increasing the pressure at any point in a confined fluid, there is an equal increase at every other point in the container, i.e., any change in pressure applied at any point of the fluid is transmitted undiminished throughout the fluids.

Jean Louis Marie Poiseuille

A French physician, Poiseuille researched the flow of blood through the body and discovered an important law governing the rate of flow with the diameter of the tube in which flow occurred.

See also

- Affinity laws
- Hydraulic engineering
- Hydraulic mining
- Pneumatics
- International Association of Hydraulic Engineering and Research

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External links

- International Association of Hydraulic Engineering and Research (IAHR) [27]
- National Fluid Power Association (NFPA) [28]
- Pascal's Principle and Hydraulics [29]
- The principle of hydraulics [30]
- IAHR media library Web resource of photos, animation & video [31]

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> "Using a whole body of mathematical methods (not only those inherited from the antique theory of ratios and infinitesimal techniques, but also the methods of the contemporary algebra and fine calculation techniques), Arabic scientists raised statics to a new, higher level. The classical results of Archimedes in the theory of the centre of gravity were generalized and applied to three-dimensional bodies, the theory of ponderable lever was founded and the 'science of gravity' was created and later further developed in medieval Europe. The phenomena of statics were studied by using the dynamic apporach so that two trends - statics and dynamics - turned out to be inter-related withina single science, mechanics. The combination of the dynamic apporach with Archimedean hydrostatics gave birth to a direction in science which may be called medieval hydrodynamics. [...] Numerous fine experimental methods were developed for determining the specific weight, which were based, in particular, on the theory of balances and weighing. The classical works of al-Biruni and al-Khazini can by right be considered as the beginning of the application of experimental methods in medieval science."

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Idler

An **idler** is a mechanical device such as an idler pulley or idler wheel that is secondary to the main transfer of power in a mechanical system.

See also

- Gear ratio
- The Idler magazines and an essay collection entitled *The Idler*
- wiktionary:idler

Idler-wheel

An **idler-wheel** drive is a system used to transmit the rotation of the main shaft of a motor to another rotating device. For example the platter of a record-reproducing turntable or the crankshaft-to-camshaft gear train of an automobile.

An idler gear is a gear wheel that is inserted between two or more other gear wheels.

The purpose of an idler gear can be two-fold. Firstly, the idler gear will change the direction of rotation of the output shaft. Secondly, an idler gear can assist to reduce the size of the input/output gears whilst maintaining the spacing of the shafts.

An idler gear does not affect the gear ratio between the input and output shafts.

Note that in a sequence of gears chained together, the ratio depends only on the number of teeth on the first and last gear. The intermediate gears, regardless of their size, do not alter the overall gear ratio of the chain. But, of course, the addition of each intermediate gear reverses the direction of rotation of the final gear.

An intermediate gear which doesn't drive a shaft to perform any work is called an idler gear. Sometimes, a single idler gear is used to reverse the direction, in which case it may be referred to as a reverse idler. For instance, the typical automobile manual transmission engages reverse gear by means of inserting a reverse idler between two gears.

Idler gears can also transmit rotation among distant shafts in situations where it would be impractical to simply make the distant gears larger to bring them together. Not only do larger gears occupy more space, but the mass and rotational inertia (moment of inertia) of a gear is quadratic in the length of its radius. Instead of idler gears, of course, a toothed belt or chain can be used to transmit torque over distance.

A gear wheel placed between two other gears to transmit motion from one to the other. It does not alter the speed of the output, but it does alter the direction it turns. It is used to ensure that the rotation of two gears is the same. An idler gear is placed between two gears. The idler gear rotates in the opposite direction as the driver gear, and the follower gear rotates in the opposite direction of the idler, the same direction of the driver. It is also used to change the spacing between the input and output axles. It does not change the gear ratio between the input and output gears. All the gears and wheels that turn inside the treads of a battle tank are all idler gears that transfer power from the input gear to the output gear to move the tread and move the tank forward. The power take off mechanism includes a gear train with an input idler gear, a first intermediate idler gear, a second intermediate idler gear and an output gear. The input idler gear receives a rotary input and

the first intermediate idler gear meshes with the input gear and the second intermediate idler gear. The output gears transmit rotary power to one of the first and second axles.

Index of mechanical engineering articles

This is an alphabetical list of articles pertaining specifically to → mechanical engineering. For a broad overview of engineering, please see List of engineering topics. For biographies please see List of engineers.

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C

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See also

Indexing (motion)

Indexing in reference to motion is moving (or being moved) into a new position or location quickly and easily but also precisely. After a machine part has been indexed, its location is known to within a few hundredths of a millimeter (thousandths of an inch), or often even to within a few thousandths of a millimeter (ten-thousandths of an inch), despite the fact that no elaborate measuring or layout was needed to establish that location. Indexing is a necessary kind of motion in many areas of → mechanical engineering and machining. A part that **indexes**, or can be **indexed**, is said to be **indexable**.

Usually when the word *indexing* is used, it refers specifically to rotation. That is, indexing is most often the quick and easy but precise rotation of a machine part through a certain known number of degrees. However, the swapping of one part for another, or other controlled movements, are also sometimes referred to as *indexing*, even if rotation is not the focus.

Examples from everyday life

There are various examples of indexing that laypersons (non-engineers and non-machinists) can find in everyday life. These motions are not always called by the name *indexing*, but the idea is essentially similar:

- The motion of pins inside a pin tumbler lock, which the correct key can move quickly and easily but also rather precisely into the correct position to allow the lock's cylinder to turn
- Indexable driver bits for screwdrivers
- The motion of a retractable utility knife blade, which often will have well-defined discrete positions (fully retracted, ¼-exposed, ½-exposed, ¾-exposed, fully exposed)
- The indexing of a revolver's cylinder with each shot

Manufacturing applications

Indexing is vital in manufacturing, especially mass production, where a well-defined cycle of motions must be repeated quickly and easily—but precisely—for each interchangeable part that is made. Without indexing capability, all manufacturing would have to be done on a craft basis, and interchangeable parts would have very high unit cost because of the time and skill needed to produce each unit. In fact, the evolution of modern technologies depended on the shift in methods from crafts (in which toolpath is controlled via operator skill) to indexing-capable toolpath control.

How indexing is achieved in manufacturing

Indexing capability is provided in two fundamental ways: with or without IT.

Non-IT-assisted physical guidance

Non-IT-assisted physical guidance was the first means of providing indexing capability, via purely mechanical means. It allowed the Industrial Revolution to progress into the Machine Age. It is achieved by jigs, fixtures, and machine tool parts and accessories, which control toolpath by the very nature of their shape, physically limiting the path for motion. Some archetypal examples, developed to perfection before the advent of the IT era, are drill jigs, the turrets on manual turret lathes, and indexing heads for manual milling machines. Purely mechanical indexing is still a vital part of current technology, even as it has been extended to newer uses, such as the indexing of CNC milling machine toolholders or of indexable cutter inserts, whose precisely controlled size and shape allows them to be rotated or replaced quickly and easily without changing overall tool geometry.

IT-assisted physical guidance

IT-assisted physical guidance (for example, via NC, CNC, or robotics) has been developed since the World War II era and uses electromechanical and electrohydraulic servomechanisms to translate digital information into position control. These systems also ultimately physically limit the path for motion, as jigs and other purely mechanical means do; but they do it not simply through their own shape, but rather using changeable information.

Industrial Refrigeration Consortium

The **Industrial Refrigeration Consortium (IRC)** is a research and technology center formed through a collaborative effort between the University of Wisconsin-Madison and industry. This non-profit technology center headquartered in the College of Engineering at the UW-Madison has a simple mission: *to improve the safety, reliability, efficiency, and productivity of industrial refrigeration systems*.

The IRC pursues its mission by conducting applied research, delivering knowledge transfer, and providing technical assistance. Although their efforts are focused on industrial refrigeration systems that utilize anhydrous ammonia, they also work with systems that use other refrigerants.

Injector

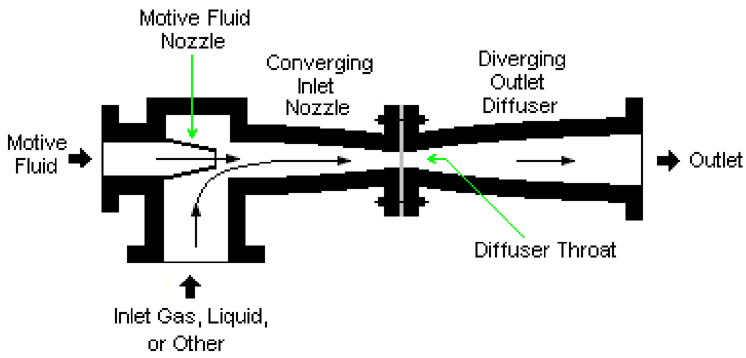


Diagram of a typical modern ejector.

An **injector**, **ejector**, **steam ejector** or **steam injector** is a pump-like device that uses the Venturi effect of a converging-diverging nozzle to convert the pressure energy of a motive fluid to velocity energy which creates a low pressure zone that draws in and entrains a suction fluid. After passing through the throat of the injector, the mixed fluid expands and the velocity is reduced which results in recompressing the mixed fluids by converting velocity energy back into pressure energy. The motive fluid may be a liquid, steam or any other gas. The entrained suction fluid may be a gas, a liquid, a slurry, or a dust-laden gas stream.[1] [2]

The adjacent diagram depicts a typical modern ejector. It consists of a motive fluid inlet nozzle and a converging-diverging outlet nozzle. Water, air, steam, or any other fluid at high pressure provides the motive force at the inlet.

An injector is a more complex device containing at least three cones. That used for delivering water to a steam locomotive boiler takes advantage of the release of the energy contained within the latent heat of evaporation to increase the pressure to above that within the boiler.

The Venturi effect, a particular case of Bernoulli's principle, applies to the operation of this device. Fluid under high pressure is converted into a high-velocity jet at the throat of the convergent-divergent nozzle which creates a low pressure at that point. The low pressure draws the suction fluid into the convergent-divergent nozzle where it mixes with the motive fluid.

In essence, the pressure energy of the inlet motive fluid is converted to kinetic energy in the form of velocity head at the throat of the convergent-divergent nozzle. As the mixed

fluid then expands in the divergent diffuser, the kinetic energy is converted back to pressure energy at the diffuser outlet in accordance with Bernoulli's principle.

Depending on the specific application, an injector is commonly also called an *Eductor-jet pump, a water eductor*, a *vacuum ejector*, a *steam-jet ejector*, or an *aspirator*.

Key design parameters

The compression ratio of the injector, P_2/P_1, is defined as ratio of the injectors's outlet pressure P_2 to the inlet pressure of the suction fluid P_1.

The entrainment ratio of the injector, W_s/W_v, is defined as the amount of motive fluid W_s (in kg/hr) required to entrain and compress a given amount W_v (in kg/hr) of suction fluid.. The compression ratio and the entrainment ratio are key parameters in designing an injector or ejector.

History

The injector was invented by a Frenchman, Henri Giffard in 1858[3] and patented in the United Kingdom by Messrs Sharp Stewart & Co. of Glasgow. Motive force was provided at the inlet by a suitable high-pressure fluid.

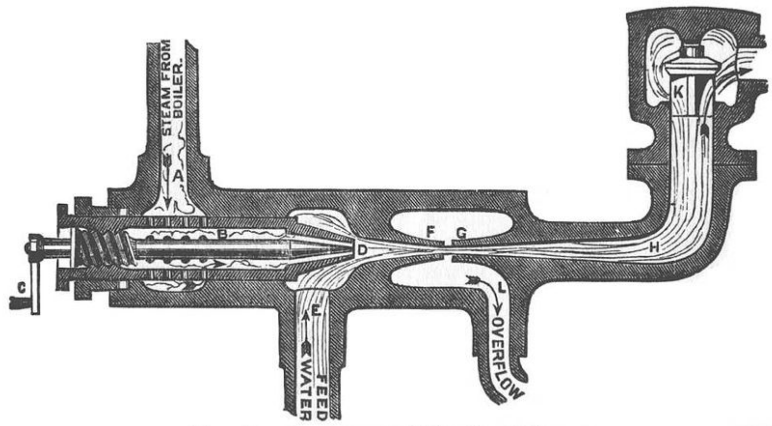
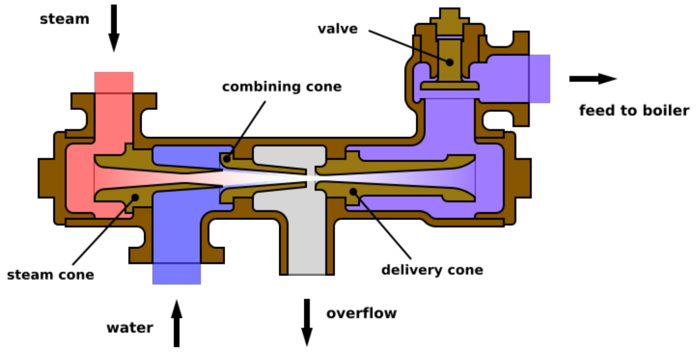


FIG. 6.– *Section of Giffard's Injector.*

A- Steam from boiler, B- Needle valve, C- Needle valve handle, D- Steam and water combine, E- Water feed, F- Combining cone, G- Delivery nozzle and cone, H- delivery chamber and pipe, K- Check valve

The injector was originally used in the boilers of steam locomotives for injecting or pumping the boiler feedwater to and from the boiler. The injector consisted of a body containing a series of three or more nozzles, "cones" or "tubes". The motive steam passed through a nozzle that reduced its pressure below atmospheric and increased the steam velocity. Fresh water was entrained by the steam jet, and both steam and water entered a convergent "combining cone" which mixed them thoroughly so that the water condensed the steam. The condensate mixture then entered a divergent "delivery

cone" which slowed down the jet, and thus built up the pressure to above that of the boiler. An overflow was required for excess steam or water to discharge, especially during starting. There was at least one check valve between the exit of the injector and the boiler to prevent back flow, and usually a valve to prevent air being sucked in at the overflow.



A more modern drawing of the injector used in steam locomotives.

After some initial skepticism resulting from the unfamiliar and superficially paradoxical mode of operation, the injector was widely adopted as an alternative to mechanical pumps in steam-driven locomotives. The injectors were simple and reliable, and they were thermally efficient.


Steam injector of a steam locomotive boiler.

Efficiency was further improved by the development of a multi-stage injector which was powered not by live steam from the boiler but by exhaust steam from the cylinders, thereby making use of the residual energy in the exhaust steam which would otherwise have gone to waste.

Steam locomotives dominated rail transport from the mid 19th century until the mid 20th century, after which they were superseded by diesel and electric locomotives.

Uses

The use of injectors (or ejectors) in various industrial applications has become quite common due to their relative simplicity and adaptability. For example:

- To inject chemicals into the boiler drums of small, stationary, low pressure boilers. In large, high-pressure modern boilers, usage of injectors for chemical dosing is not possible due to their limited outlet pressures.
- In thermal power stations, they are used for the removal of the boiler bottom ash, the removal of fly ash from the hoppers of the electrostatic precipitators used to remove that ash from the boiler flue gas, and for creating a vacuum pressure in steam turbine exhaust condensers.

- For use in producing a vacuum pressure in steam jet cooling systems.
- For the bulk handling of grains or other granular or powdered materials.
- The construction industry uses them for pumping turbid water and slurries.
- Some aircraft (mostly earlier designs) use an ejector attached to the fuselage to provide vacuum for gyroscopic instruments such as an attitude indicator.

Similar devices called aspirators based on the same operating principle are used in laboratories to create a partial vacuum and for medical use in suction of mucus or bodily fluids.

Multi-stage steam ejectors

In practice, for suction pressure below 100 mbar absolute, more than one ejector will be used, usually with condensors between the ejector stages. Condensing of motive steam greatly improves ejector set efficiency. Both barometric and shell-and-tube surface condensers are used for this purpose.

Construction materials

Injectors or ejectors are fabricated in carbon steel, Stainless steel, titanium, PTFE, carbon and other materials.

See also

- Aspirator
- De Laval nozzle
- Diffusion pump
- Nozzle
- Surface condenser
- Venturi effect

Additional reading

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- J.T. Hodgson and C.S. Lake (1954). *Locomotive Management* (Tenth Edition ed.). Tothill Press.

External links

- Ejector Pumps and Theory [4]
- Ejectors [5]
- Use of Eductor for Lifting Water [6]
- 1908 Lunkenheimer Injector Catalog [7]

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Inspirator

An **inspirator** is a device, similar to a venturi tube and an → orifice plate, which mixes a fuel gas with atmospheric air in a precise ratio to regulate burn characteristics. Only the pressure of the fuel gas is used to draw in and mix the air. They are the most simple and common type of mixing device for gas stoves and furnaces. Burners using an inspirator are considered to be naturally aspirated.

In an inspirator there are 2 tubes. The first is a fuel gas pipe with an orifice at the end where the gas comes out. Then in front of this there is another section of tubing with a larger diameter that the gas blows into. Usually (but not always) this second piece of tubing is tapered so that it starts getting narrower downstream from the orifice. Then, at a certain point, it stops getting narrower and either straightens out or starts getting larger again. This gives the fuel and air time to mix. The fuel/air ratio is determined by the ratio of the diameter of the orifice to the diameter of the mixing tube.

Institution of Mechanical Engineers

The **Institution of Mechanical Engineers** (IMechE) is the British engineering society concerned with → mechanical engineering. It is licensed by the Engineering Council UK to assess candidates for inclusion on ECUK's Register of professional Engineers. It was founded in 1847 and received a Royal Charter in 1930. The head office is located at 1 Birdcage Walk, Westminster, London, SW1H 9JJ.

Overview

Vision statement: "*Improving the World through Engineering*". Its Purpose is "*To lead and promote professional engineering*"

Membership Grades and Post-nominals

The following are membership grades with post-nominals :

- *Affiliate*: (no post-nominal) The grade for students, apprentices and those interested in or involved in mechanical engineering who do not meet the requirements for the following grades.
- **AMIMechE**: *Associate Member of the Institution of Mechanical Engineers*: this is the grade for graduates (of acceptable degrees or equivalents in engineering, mathematics or science) who have not yet met the requirements for full membership.
- **MIMechE**: *Member of the Institution of Mechanical Engineers*. For those who meet the educational and professional requirements for registration as a Chartered Engineer (CEng) or Incorporated Engineer (IEng) or Engineering Technician in Mechanical Engineering .
- **FIMechE**: *Fellow of the Institution of Mechanical Engineers*. This is the highest class of elected membership, and is awarded to individuals who have demonstrated exceptional commitment to and innovation in mechanical engineering.

Origins

In 1818 the Institution of Civil Engineers was founded. At that time the word "civil" was used to distinguish them from Military engineers and included all the fields of engineering, not just construction as it does today. The Institution of Mechanical Engineers was founded on January 27, 1847 in the Queen's Hotel next to Curzon Street railway station in Birmingham by the railway pioneer George Stephenson and others[1] . It operated from premises in Birmingham until 1877, when it moved to London, taking up its present headquarters in 1898[2] .

The beginning

The events that led to the formation of the IMechE began in the early autumn of 1846. A discussion between six or seven men, not all of whom were engineers, ended with the decision to try to gain support for an institution for "mechanics and engineers". Exactly where this discussion took place is open to debate. At the opening of the present headquarters in Birdcage Walk, London in 1899 a commemorative pamphlet was issued to members stating that the meeting took place in a house in Cecil Street, Manchester.

Namely the house of a Charles Beyer, the manager of Sharp Brothers' locomotive works. Although Beyer was very much involved in the formation of the IMechE, it is more likely that the meeting was no more than a conversation among friends.

More probably, the venue of the discussion that led to the first meeting was the Lickey Incline near Bromsgrove on the Bristol and Birmingham railway. James McConnell was, until 1846, locomotive superintendent of this line, known earlier as the Birmingham and Gloucester railway. It appears that McConnell had invited several engineers to view locomotive trials at Lickey, where there is a 1 in 37 gradient. It remains one of the steepest parts of the British railway network today.

In one account of the event a shower of rain sent the party running for cover. They found shelter in a trackside platelayers' hut, and it was in this hut that the discussion may have turned to the formation of an institution for mechanical engineers. It is quite probable that both the rain and the hut are a myth. It is more likely that the engineers returned to McConnell's house at Blackwell, less than half a mile away where the discussion began.

More than a decade later Samuel Smiles, in his biography of George Stephenson suggested that the IMechE was formed out of a sense of justifiable rage. Smiles wrote that the engineers present at the Lickey Incline were angry that Stephenson, the most famous mechanical engineer of the age had been refused membership to the Institution of Civil Engineers, unless he sent in "a probationary essay as proof of his capacity as an engineer". According to Smiles, Stephenson declined to submit to this indignity and as such the other engineers decided to form their own institution, that would not only include Stephenson, but put him at their head.


George Stephenson

It took over a century to expose Smiles's account as a complete myth, or at least an exaggeration. In the 1950s after the centennial of the IMechE had made the story public, engineers at the Institution of Civil Engineers checked their records and found that although there had been a definite coolness between Stephenson and some prominent members of the ICE (Stephenson retained a distaste for London-based consulting engineers compared to "practical Northerners") there is no evidence that he ever applied for membership or that if he did, it was refused. The story appears to have been invented by Smiles some years after Stephenson's death perhaps as an illustration of the hardships faced by the early engineering establishment or to provide some drama to his work.

As well as McConnel and Beyer, Richard Peacock, superintendent of the Manchester and Sheffied railway and later a member of parliament was present at the meeting at Lickey along with George Selby and Archibald Slate from the Birmingham tube company and Charles Geach, a Birmingham Banker. The result of the meeting was a letter that was sent to all the prominent engineers across Britain. It read:

> "To enable Mechanics and Engineers engaged in the different Manufactories, Railways and other Establishments in the Kingdom, to meet and correspond, and by mutual interchange of the ideas respecting improvements in the various branches of

> Mechanical Science to increase their knowledge, and give an impulse to inventions likely to be useful to the world. We hope to have the pleasure of seeing you at a Meeting of Promoters of the above on Wednesday 7th October at 2pm at the Queens Hotel, Birmingham"

The letter was signed by McConnell, Beyer and Slate and also by Edward Humphreys of the firm Rennie's in London. Although not present at the meeting the use of his name gave the endorsement of a London Engineer, to add to the Birmingham and Manchester men, and Rennie's was an illustrious name to attach to the new institution.

On the 7th of October the meeting was held. The preliminaries appear not to have taken too long. The four signatories of the letter, plus Peacock, William Buckle from Boulton and Watt, John Edward Clift and Edward Cowper were elected to form the committee and draft the rules, with McConnell as Chairman and Slate as honorary Secretary. The meeting however was followed by a dinner. The list of toasts, beginning with Queen Victoria and the Prince consort and including a toast to the Institution of Civil Engineers, to the memory of James Watt, to George Stephenson and his son Robert, to Brunel and the health of McConnell and Slate as well as others suggest that the evening slid into genial, less than sober, sentimentality.[3]

Presidents

As of 2006[4], there has been 122 presidents of the Institution, who since 1922 have been elected annually for one year. The first president was George Stephenson, followed by his son Robert. Joseph Whitworth, John Penn and William Armstrong are the only persons to have served two terms. Pamela Liversidge in 1997-98 was the first – and so far only – woman president.

Past presidents include:

No.	Years	Name	Sphere of Influence
1	1847–1848	George Stephenson	railway engineer
2	1849–1853	Robert Stephenson	railway engineer, MP
3	1854–1855	William Fairbairn	manufacturer, trader, ironmaster, bridge, mill wheels, ships, later made baronet.
4	1856–1857	Joseph Whitworth (*First term*)	pioneer of machine tools, precision engineering
5	1858–1859	John Penn (*First term*)	Marine Steam engines
6	1860	James Kennedy	Marine engines and locomotives
7	1861–1862	William George Armstrong (*First term*)	Industrialist and inventor, primarily of armaments. Pioneer of domestic electricity
8	1863–1865	Robert Napier	Ship building and Marine engines
4	1865–1866	Joseph Whitworth (*Second term*)	pioneer of machine tools, precision engineering
5	1866–1868	John Penn (*Second term*)	Marine Steam Engines
7	1868–1869	William George Armstrong (*Second term*)	Industrialist and inventor, primarily of armaments. Pioneer of domestic electricity
9	1870–1871	John Ramsbottom	railway engineer
10	1872–1873	Sir William Siemens	Metallurgist and electrical engineer
11	1874–1875	Sir Frederick Joseph Bramwell	Steam engines and boilers

12	1876–1877	Thomas Hawksley	water and gas engineer
13	1878–1879	John Robinson	Steam Engines
14	1880–1881	Edward Alfred Cowper	Metallurgist, inventor of Cowper pot
15	1882–1883	Percy Graham Buchanan Westmacott	Hydraulic machinery
16	1884	Sir Isaac Lowthian Bell	Iron master
17	1885–1886	Jeremiah Head	Steam powered agricultural machinrey
18	1887–1888	Edward Hamer Carbutt	Iron and steel making
19	1889	Charles Cochrane	Iron and steel making
20	1890–1891	Joseph Tomlinson	Locomotive Superintendent
21	1892–1893	Sir William Anderson	Bridges and factories
22	1894–1895	Prof. Alexander Blackie William Kennedy	Professor of engineering, University College London
23	1896–1897	Edward Windsor Richards	Iron master
24	1898	Samuel W. Johnson	Chief Mechanical Engineer, Midland Railway
25	1899–1900	Sir William Henry White	Naval architect
26	1901–1902	William Henry Maw	Editor, *Engineering*
27	1903–1904	Joseph Hartley Wicksteed	Testing machines and machine tools
28	1905–1906	Edward Pritchard Martin	Iron and steel making
29	1907–1908	Tom Hurry Riches	Chief engineer, Taff Vale Railway
30	1909–1910	Sir John Audley Frederick Aspinall	Chief Mechanical Engineer, Lancashire and Yorkshire Railway
31	1911–1912	Edward Bayzard Ellington	Hydraulic machinery
32	1913–1914	Sir Hay Frederick Donaldson	Royal Ordnance
33	1915–1916	William Cawthorne Unwin	oil engine research
34	1917–1918	Michael Longridge	Chief Engineer
35	1919	Edward Hopkinson	Electric Traction. Died during year of office
36	1920–1921	Cpt Matthew Henry Phineas Riall Sankey	Military engineering, oil engines and wireless telegraphy
37	1922	Dr Henry Selby Hele-Shaw	Prof. Mechanical Engineering at Liverpool University
38	1923	Sir John Dewrance	Inventor
39	1924	William Henry Patchell	Electricity supply
40	1925	Sir Vincent Raven	Chief Mechanical Engineer, North Eastern Railway
41	1926	Sir William Reavell	Compressor manufacturer
42	1927	Sir Henry Fowler	Chief Mechanical Engineer, Midland Railway and London Midland and Scottish Railway
43	1928	Richard William Allen	Pumps and Marine equipment
44	1929	Daniel Adamson	Gears, cranes and cutting tools
45	1930	Loughnan St Lawrence Pendred	Editor of *The Engineer*
46	1931	Edwin Kitson Clark	Locomotive Engineer
47	1932	William Taylor	Lens Manufacturing

48	1933	Alan Ernest Leofric Chorlton	Pumps and Diesel engines, MP
49	1934	Charles Day	Steam and diesel engines
50	1935	Major-General Alexander Elliott Davidson	Mechanised military transport
51	1936	Sir Nigel Gresley	Chief Mechanical Engineer, London and North Eastern Railway
52	1937	Sir John Edward Thornycroft	Ship building and motor vehicle design
53	1938	David E Roberts	Iron and steel manufacture
54	1939	E. Bruce Ball	Motor Vehicles and hydraulic valves
55	1940	Asa Binns	Engineer
56	1941	Sir William Stanier	Chief Mechanical Engineer, London, Midland and Scottish Railway
57	1942	Col Stephen Joseph Thompson	Boilers
58	1943	Frederick Charles Lea	Engineering Professor at Birmingham and Sheffield Universities
59	1944	Sir Harry Ralph Ricardo	Automotive engineer. Founder, Ricardo Consulting
60	1945	Andrew Robertson	Prof. Mechanical engineering at Bristol University
61	1946	Oliver Vaughan Snell Bulleid	Chief Mechanical Engineer, Southern Railway
62	1947	Lord Dudley Gordon	Refrigeration engineering
63	1948	E. William Gregson	Marine engines
64	1949	Herbert John Gough	Engineering Research
65	1950	Stanley Fabes Dorey	Chief Engineer Surveyor
66	1951	Arthur Clifford Hartley	Chief engineer, Anglo-Iranian Oil Co. Inventor, Pluto and Fido
67	1952	Sir David Randall Pye	Air Ministry research engineer
68	1953	Alfred Roebuck	Engineering metallurgy
69	1954	Richard William Bailey	High temperature steel and materials research
70	1955	Percy Lewis Jones	Marine engines and ship building
71	1956	Thomas Arkle Crowe	Marine Engines
72	1957	George Nelson	Chairman English Electric
73	1958	Air Marshal Sir Robert Owen Jones	Aircraft Engineer
74	1959	Herbert Desmond Carter	Diesel Engines
75	1960	Sir Owen Alfred Saunders	Prof. Mechanical Engineering Imperial College
76	1961	Sir Charles Hague	Chairman, Babcock & Wilcox
77	1962	John Hereward Pitchford	Internal Combustion engines
78	1963	Roland Curling Bond	Chief Mechanical Engineer, British Railways [5]
79	1964	Vice-Admiral Sir Frank Mason	Engineer in chief, Royal Navy
80	1965	Harold Norman Gwynne Allen	Power Transmission
81	1966	Lord Christopher Hinton of Bankside	Pioneer of nuclear power

82	1967	Hugh Graham Conway	Aero-engines and gas turbines
83	1968	Sir Arnold Lewis George Lindley	Chairman of GEC
84	1969	Donald Frederick Galloway	Manufacturing and machine tool engineer
85	1970	John Lamb Murray Morrison	Prof. Mechanical engineering Bristol University
86	1971	Robert Lank Lickley	Aircraft engineer
87	1972	Lord Donald Gresham Stokes	Chief executive, British Leyland
88	1973	Sir John William Atwell	Steel industry and pump manufacture
89	1974	Sir St John de Hold Elstub	Metals
90	1975	Paul Thomas Fletcher	Process plan and nuclear power plant
91	1976	Ewen McEwen	Chief engineer, Lucas
92	1977	Sir Hugh Ford	Professor of mechanical engineering, Imperial College London
93	1978	Diarmuid Downs	Internal combustion engines
94	1979	James Gordon Dawson	Chief Engineer, Shell
95	1980	Bryan Hildrew	Managing Director, Lloyd's Register of Shipping
96	1981	Francis David Penny	Director, National Engineering Laboratory
97	1982	Victor John Osola/Vaino Junani Osola	Process engineer, safety glass
98	1983	George Fritz Werner Adler	Research Director, British Hydromechanical Research Association
99	1984	Waheeb Rizk	Gas turbines at GEC
100	1985	Sir Philip Foreman	Aerospace engineer
101	1986	Sir Bernard Crossland	Prof. Mechanical Engineering, Queen's University Belfast
102	1987	Oscar Roith	Chief Engineer, Department of Industry
103	1988	Cecil Charles John French	Internal combustion engines
104	1989	Roy Ernest James Roberts	Director, GKN
105	1990	Michael John Neale	Tribology
106	1991	Duncan Dowson	Prof of Fluid Mechanics, Leeds University
107	1992	Tom D. Patten	Offshore engineering
108	1993	Anthony Albert Denton	Offshore engineering
109	1994	Brian Hamilton Kent	Design and engineering management
110	1995	Frank Christopher Price	Technical director
111	1996	Robert William Ernest Shannon	Inspection engineering
112	1997	Pamela Liversidge	Powder metallurgy
113	1998	John Spence	
114	1999	James McKnight	
115	2000	Denis E. Filer	
116	2001	Tony Roche	
117	2002	John McDougall	
117	2003	Chris Taylor	Tribology

119	2004	William Edgar[6]	
120	2005	Andrew Ives[7]	
121	2006	W Alec Osborn MBE[8] [9]	
122	2007	John Baxter	
123	2008	William M. Banks [10]	

Divisions

The Institution of Mechanical Engineers has a number of divisions to promote different industry sectors. The Engineering in Medicine and Health Division[11] aims to bring together key workers from both medicine and engineering to discuss the latest advances and issues, to enable networking among different industry leaders, and to promote the field of Medical Engineering, also known as Bioengineering or Biomedical Engineering, to government, healthcare professionals and the wider public.

The Engineering in Medicine and Health Division offer:

- seminars, lectures and conferences every year[12] ;
- the high-profile Journal of Engineering in Medicine[13] ;
- a quarterly Medical Newsletter[14] ;
- the highly successful annual Student Project Competition.

See also

- Mechanical Engineering
- Engineering
- Engineering Council (UK)
- James Watt International Medal
- Chartered Engineer
- Incorporated Engineer
- Engineering Technician

References

[1] Cragg, Roger (1997). *Civil Engineering Heritage: Wales and West Central England: Wales and West Central England, 2nd Edition*. Thomas Telford. p. 194. ISBN 0727725769.
[2] IMechE history website (http://heritage.imeche.org/historyimeche/birdcagewalk/1877to1898.htm)
[3] John Pullin. "Progress through Mechanical Engineering (1847-1997)". Quiller Press.
[4] http://en.wikipedia.org/wiki/Institution_of_mechanical_engineers
[5] Bond R.C. "A Lifetime With Locomotives", Goose & Son 1980
[6] http://www.imeche.org.uk/about/pdf/Biography%20of%20William%20Edgar%20CBE.pdf Biography pdf
[7] http://www.imeche.org.uk/about/pdf/Andrew_Ives_%20Biography.pdf Biography pdf
[8] http://www.imeche.org.uk/about/pdf/alec_osborn_presidential_address_2006.pdf Presidential Address pdf
[9] http://www.imeche.org.uk/about/pdf/Alec%20Osborn%20Biography.pdf Biography
[10] http://www.imeche.org/NR/rdonlyres/33BFDD58-7B4D-4376-9FBC-C2106421DEA0/0/BBTempBiog.pdf Biography pdf
[11] http://www.imeche.org/industries/medical/
[12] http://www.imeche.org/industries/medical/events.htm
[13] http://journals.pepublishing.com/content/119779
[14] http://www.medmatters.org

External links

- IMechE Official website (http://www.imeche.org)
- IMechE Heritage website, giving the history of mechanical engineering and the Institution (http://heritage.imeche.org/)
- Professional Engineering magazine website (http://www.profeng.com)

Interference fit

An **interference fit**, also known as a **press fit**, is a fastening between two parts which is achieved by friction after the parts are pushed together, rather than by any other means of fastening. For metal parts in particular, the friction that holds the parts together is often greatly increased by compression of one part against the other, which relies on the tensile and compressive strengths of the materials the parts are made from. Typical examples of interference fits are the press fitting of shafts into bearings or bearings into their housings and the attachment of watertight connectors to cables. An interference fit also results when pipe fittings are assembled and tightened.

Introducing interference between parts

An interference fit is generally achieved by shaping the two mating parts so that one or the other (or both) slightly deviate in size from the nominal dimension. The word *interference* refers to the fact that one part slightly interferes with the space that the other is taking up. For example: A shaft may be ground slightly oversize, and the hole in the bearing (through which it is going to pass with an interference fit) may be ground slightly undersized. When the shaft is pressed into the bearing, the two parts interfere with each others occupation of space; the result is that they elastically deform slightly, each being compressed, and the interface between them is one of extremely high friction—so high that even large amounts of torque cannot turn one of them relative to the other; they are locked together and they turn in unison.

Tightness of fit is controlled by amount of interference ("allowance")

Formulas exist to compute the "allowance" (planned difference from nominal size) that will result in various strengths of fit such as loose fit, light interference fit, and interference fit. The value of the allowance depends on which material is being used, how big the parts are, and what degree of tightness is desired. Such values have already been worked out in the past for many standard applications, and they are available to engineers in the form of tables, obviating the need for re-derivation. Thus if a loose fit is desired for a 10 mm (0.394 in) shaft made of 303 stainless steel, the engineer can look up the needed allowance in a reference book or computer program, rather than "reinventing the wheel" by using a formula to calculate it.

Assembling an oversize shaft into an undersized hole

There are two basic methods for assembly, sometimes used in combination: Force, and changing the size of the parts by heating.

Force

This is achieved with presses that can press the parts together with very large amounts of force. (Hence the term *press fit.*) The presses are generally hydraulic, although small hand-operated presses (such as arbor presses) may operate by means of the mechanical advantage supplied by a screw jack. The amount of force applied may be anything from a few pounds for the tiniest parts to hundreds of tons for the largest parts.

Often the edges of shafts and holes are chamfered (beveled). The chamfer forms a guide for the pressing movement, helping (a) to distribute the force evenly around the circumference of the hole, and (b) to allow the compression to occur gradually instead of all at once, thus helping the pressing operation to be smoother, to be more easily controlled, and to require less power (less force at any one instant of time).

Heating to temporarily remove the interference

Most materials expand when heated and shrink when cooled. Enveloping parts are heated (e.g., with torches or gas ovens) and assembled into position while hot, then allowed to cool and contract back to their former size, except for the compression that results from each interfering with the other. Railroad axles, wheels, and tires are typically assembled in this way. Alternatively, the enveloped part may be cooled before assembly such that it slides easily into its mating part. Upon warming, it expands and interferes. Cooling is often preferable as it is less likely than heating to change material properties, e.g. assembling a hardened gear onto a shaft, where heating the gear would alter its hardness.

External links

- Diagram of an interference fit [1]
- Interference fitting [2] - formulae for calculating clearance reductions when using interference fits for bearings on shafts and in housings
- Interference fit watertight cable connector [3]

References

[1] http://claymore.engineer.gvsu.edu/~jackh/eod/manufact/manufact-155.html
[2] http://www.eminebea.com/content/html/en/engineering/bearings/fitting.shtml
[3] http://www.amerace.com/NewFiles/interfit5.html

JIC fitting

JIC fittings, or SAE J514, or MIL-F-18866, are a type of flare fitting having 37-degree flare seating surfaces and are widely used in → hydraulic applications. The SAE J514 standard replaces the MS16142 mil-spec standard; some tooling is still listed under the old mil-spec name. JIC fittings are similar in size and threading to AN fittings. 45-degree flare SAE fittings are similar in thread, but not angle and are not interchangeable.

JIC fitting systems have three components that make a tubing assembly: body, nut, and sleeve, and depend upon metal-to-metal contact between the finished surface of the fitting nose and the inside diameter of the flared tubing to make a seal. Common materials of construction include stainless steel, forging brass, machining brass, Monel, and nickel-copper alloys.

As the fitting nose is installed on the flared tubing, they are held together by the fitting sleeve, which distributes the compressing load from the nut as it is threaded onto the fitting body. The sleeve extends to the back of the nut, which provides additional support for the tubing, and reduces longitudinal load on the fitting nose.

References

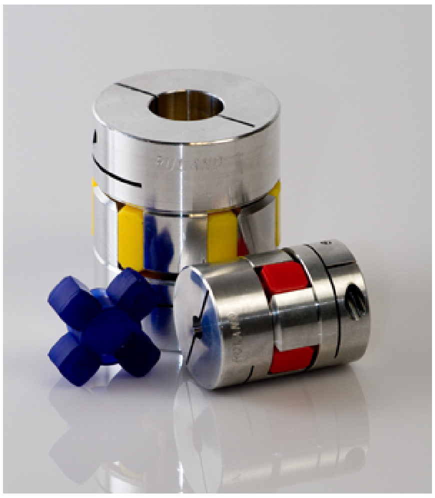
- World Wide Metric [1]
- IHS [2]
- Parker.com [3]

References

[1] http://www.worldwidemetric.com/PDFs/CAST_SAE_J514.pdf
[2] http://aero-defense.ihs.com/document/abstract/FSCNGBAAAAAAAAAA
[3] http://www.parker.com/tfd/fittingsolutions/undercuts.pdf

Jaw coupling

A **jaw coupling** is a type of motion control (servo) coupling designed to transmit torque (by connecting two shafts) while damping system vibrations, which protects other components from damage. Jaw couplings are composed of three parts: two metallic hubs and an elastomer insert called an element, but commonly referred to as a "spider". The three parts press fit together with a jaw from each hub fitted alternately with the lobes of the spider. The curved jaws of the hubs reduce deformation of the spider to maintain the zero backlash fit.



Curved Jaw Couplings - spiders are made in different hardnesses to allow the coupling to absorb more or less vibration.

Computer drawing of a curved jaw coupling

The elastomer of the spider can be made in different hardnesses, which allows the user to customize the coupling so that it absorbs more or less vibration. The more damping ability the coupling has, the less torsional strength it possesses. Jaw couplings are best suited for applications that rely on a stop-and-go type of movement, where accuracy needs to take place upon stopping in order to perform any number of precision tasks, such as taking a high resolution picture (machine vision system). Absorbing vibrations decreases the settling time the system needs, which increases through-put. The jaw coupling is less suited for applications that rely on a constant scanning type of motion, where accuracy is required *during* movement, which requires a torsionally stronger coupling.

The drawback of the jaw coupling is the lack of misalignment capability. Too much axial motion will cause the coupling to come apart, while too much angular or parallel misalignment will result in bearing loads that are higher than most other servo/motion control couplings. Jaw couplings are also considered fail-safe. If the spider fails, the jaws of the two hubs will mate, much like teeth on two gears, and continue to transmit torque. This may or may not be desirable to the user depending on the application.

Jaw couplings are well balanced and able to tolerate high RPM. With its damping capability and interchangeable spiders, jaw couplings make a great solution for shock absorption.

Keyseating

Keyseating is a method of joining two parts to transfer a rotational force, used where a shaft fits into a hole.

Matching lengthwise slots are cut into the outside of the shaft and the inside of the hole, so that when the two slots are lined up a square piece called a **key** can be inserted. This square piece locks the parts in relation to one another so that when one is turned the other does as well.

Kinematic determinacy

Kinematic determinacy is a term used in structural mechanics to describe a structure where material compatibility conditions alone can be used to calculate deflections.

A kinematically determinate structure can be defined as a structure where, if it is possible to find nodal displacements compatible with member extensions, those nodal displacements are unique. The structure has no possible mechanisms, i.e. nodal displacements, compatible with zero member extensions, at least to a first-order approximation. Mathematically, the mass matrix of the structure must have full rank.

Kinematic determinacy can be loosely used to classify an arrangement of structural members as a *structure* (stable) instead of a *mechanism* (unstable).

The principles of kinematic determinacy are used to design precision devices such as mirror mounts for optics, and precision linear motion bearings.

See also

- → Statical determinacy
- → Precision engineering
- Kinematic coupling

Kolsky's bar

Kolsky's bar (also called Kolsky bar or **split-Hopkinson pressure bar**, **SHPB** technique) is a concept in experimental mechanics for the studies of properties of materials undergoing high strain rates.

Concept

This experimental technique consists in using two equal elastic bars with a disk-shaped material sample inserted between their ends so as to make an elastic wave (pressure, torsion) travel along the apparatus. This wave is generally generated by a shock at one of the free ends of the rig. By measuring the difference of vibrations at the extremities of the structure, the sample's mechanical impedance can be deduced.

This concept has been proposed by Herbert Kolsky in 1949 [1] .

External links

- SYMPOSIUM ON EXPERIMENTAL INVESTIGATION OF THE BEHAVIOR OF MATERIALS AT HIGH STRAIN RATES « KOLSKY BAR -- FIFTY YEARS LATER » [2]
- Kolsky Bar-News from NIST [3]

References

[1] Kolsky, H. (1949). *An Investigation of the Mechanical Properties of Materials at Very High Rates of Loading*. Proc. Phys. Soc. London, B62, p.676..
[2] http://www.esm.vt.edu/mmconf/kolsky.htm
[3] http://www.nist.gov/public_affairs/newsfromnist_kolskybar.htm

Laser shaft alignment

When two machines are connected together through a shaft → Coupling, every effort must be made to eliminate misalignment of those shafts which can lead to damage or wasteful loss of energy. Lasers are highly accurate and easy to use in aligning objects. Using laser shaft alignment techniques can reduce the amount of time in the alignment process.

Precise laser coupling alignment is used to reduce bearing and seal damage, minimize energy loss, and reduce production downtime. Performing coupling alignment on a scheduled basis will make machinery last longer and perform more efficiently.

There are several methods used to align couplings including 'eyeing' it, dial calibration and laser alignment. Each method varies in its degree of accuracy and dial calibration can be a very time consuming process.

Utilizing a state-of-the-art laser measurement system, a technician will measure and align couplings, universal joints and belts. This alignment allows conveyor systems and manufacturing machines to run in a straight line. A factory line that makes masking tape is a good example of the need for precision alignment. In order for the tape to spool neatly and at a high rate of speed, the take up reel shaft must be exactly perpendicular to the incoming tape. Any deviation will decrease the quality of the end product.

To control the co-linearity and angle of two shafts at the coupling, where the power is transmitted - laser shaft alignment technology can help to perform the measurement easily. The Laser "shoots" onto a position sensitive detector, during continuously rotating the shafts the detector collects all changes and can calculate the gap & offset at the coupling position.

In addition the shaft alignment device can check whether the alignment is in within OEM tolerances or not.

See also

- → Coupling
- Alignment

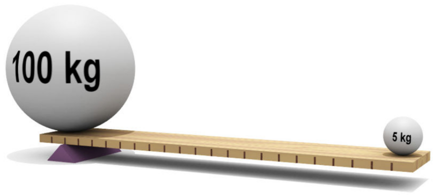
External links

- Express Alignment by Fixturlaser [1]
- PRUFTECHNIK - The inventors of laser shaft alignment [2]
- Shaft Coupling Glossary [3]
- Professional Laser Shaft Alignment measurement devices [3]
- Laser Measurement Systems for Shaft & Machinery Alignment [5]

References

[1] http://www.vibralign.com
[2] http://www.pruftechnik.com/en/alignment-systems.html
[3] http://www.ludeca.com

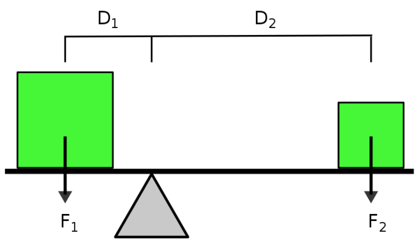
Lever



Levers can be used to exert a large force over a small distance at one end by exerting only a small force over a greater distance at the other.

In physics, a **lever** (from French *lever*, "to raise", c.f. a *levant*) is a rigid object that is used with an appropriate fulcrum or pivot point to multiply the mechanical force that can be applied to another object. This **leverage** is also termed → mechanical advantage, and is one example of the principle of moments. A lever is one of the six → simple machines. Archimedes once said, "Give me a lever long enough and a fulcrum on which to place it, and I shall move the world." First class levers are similar but not the same as second or third class levers, in which the fulcrum, resistance, and effort are in different locations.

Theory of operation



The principle of the lever tells us that the above is in static equilibrium, with all forces balancing, if $F_1D_1 = F_2D_2$.

The principle of **leverage** can be derived using Newton's laws of motion, and modern statics. It is important to note that the amount of work done is given by force times distance. To use a lever to lift a certain unit of weight with a force of half a unit, the distance from the fulcrum to the spot where force is applied must be exactly twice that of the distance between the weight and the fulcrum. For example, to cut in half the force required to lift a weight resting 1 meter from the fulcrum, we would need to apply force 2 meters from the other side of the fulcrum. The amount of work done is always the same and independent of the dimensions of the lever (in an ideal lever). The lever only allows to trade force for distance.

The point where you apply the force is called the effort. The effect of applying this force is called the load. The load arm and the effort arm are the names given to the distances from the fulcrum to the load and effort, respectively. Using these definitions, the Law of the Lever is:

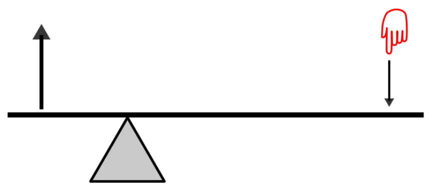
Load arm X load force = effort arm X effort force. If, for example, a 1 gram feather were balanced by a one kilogram rock, the feather would be 1000 times further from the fulcrum than the rock; if a 1 kilogram rock were balanced by another 1 kilogram rock, the fulcrum would be in the middle.

The three classes of levers

There are three classes of levers which represent variations in the location of the fulcrum and the input and output forces.

First-class levers

A first-class lever is a lever in which the fulcrum is located between the input effort and the output load. In operation, a force is applied (by pulling or pushing) to a section of the bar, which causes the lever to swing about the fulcrum, overcoming the resistance force on the opposite side. The fulcrum may be at the center point of the lever as in a seesaw or at any point between the input and output. This supports the effort arm.



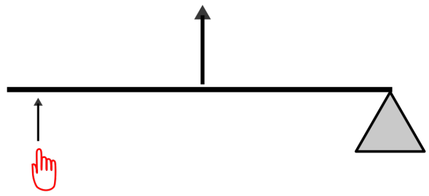
First class lever

Examples:

1. Seesaw (also known as a teeter-totter)
2. Trebuchet
3. Crowbar (curved end of it)
4. Hammer Claw, when pulling a nail with the hammer's claw
5. Hand trucks are L-shaped but work on the same principle, with the axis as a fulcrum
6. Pliers (double lever)
7. Scissors (double lever)
8. Shoehorn
9. Spud bar (moving heavy objects)
10. Beam engine although here the aim is just to change the direction in which the applied force acts, since the fulcrum is normally in the center of the beam (i.e. D1 = D2)
11. Wheel and axle because the wheel's motions follows the fulcrum, load arm, and effort arm principle.
12. Chopsticks with hand the middle finger acts as a pivot. The whole system is a double lever.

Second-class levers

In a second class lever the input effort is located at the end of the bar and the fulcrum is located at the other end of the bar, opposite to the input, with the output load at a point between these two forces. Examples:



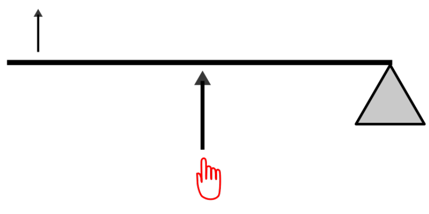
Second class lever

1. Dental elevator
2. Nutcracker
3. Paddle
4. Curb bit
5. Wheelbarrow
6. Wrench
7. Bottle opener
8. Diving Board (spring board)

9. Crowbar (flat end)
10. Push-up
11. Doorknob(could be a wheel and axle also)
12. Oars (the object is to move the boat, not the water).
13. Tennis racket
14. Nail clippers, the main body handle exerts the incoming force
15. torsion spring, the main body handle exerts the incoming force

Third-class levers

For this class of levers, the input effort is higher than the output load, which is different from second-class levers and some first-class levers. However, the distance moved by the resistance (load) is greater than the distance moved by the effort. Since this motion occurs in the same length of time, the resistance necessarily moves faster than the effort. Thus, a third-class lever still has its uses in making certain tasks easier to do. In third class levers, effort is applied between the output load on one end and the fulcrum on the opposite end.



Third class lever. For the lever in this diagram to work correctly, one must assume that the fulcrum is attached to the bar or acting in opposition to the other two forces.

Examples

1. Baseball bat
2. Boat paddle
3. Broom
4. Electric Gates
5. Fishing rod
6. Hockey stick
7. Mandible
8. Mousetrap (Spring-loaded bar type)
9. Shovel (the action of picking or lifting up sand or dirt)
10. Stapler
11. Tongs
12. Tweezers
13. Hammer

See also

- Engineering mechanics
- Engineering vehicles
- Linkage (mechanical)
- Switch
- Archimedes

External links

- Lever [1] at Diracdelta science and engineering encyclopedia
- *A Simple Lever* [2] by Stephen Wolfram, Wolfram Demonstrations Project.
- Levers: Simple Machines [3] at EnchantedLearning.com

References

[1] http://www.diracdelta.co.uk/science/source/l/e/lever/source.html
[2] http://demonstrations.wolfram.com/ASimpleLever/
[3] http://www.enchantedlearning.com/physics/machines/Levers.shtml

Light Aid Detachment

A **Light Aid Detachment** is an attached independent minor unit of the Royal Electrical and Mechanical Engineers or Detachment of Royal Canadian Electrical and Mechanical Engineers operating as a sub-unit of the supported unit. These units provide dedicated logistic support to every field unit of the British Army or Canadian Army.

REME and RCEME were created in October 1942 out of elements of the Royal Army Ordnance Corps, Royal Engineers, Royal Corps of Signals, Royal Army Service Corps and Royal Canadian Ordnance Corps who previously handled functions such as the repair of weapons, optics and vehicles.[1]

In the RCEME LADs were divisions of larger units known as Workshops.[2] In the British Army the title Workshop (Wksp) is used both for major REME units and for those minor units which provide some 2nd Line support to the parent regiment. The term LAD is therefore restricted to only those minor REME units which solely provide 1st Line support, typically this is Armour and Infantry units. REME minor units supporting RA, R Signals, RE, RLC etc. are normally titled as Wksp as they also provide some degree of 2nd line support to the parent unit.

Typically composed of around 60-80 personnel they are attached to a host battalion. Typical field deployment would split the LAD/Wksp into a regimental "B Echelon" contingent of about 30 men and 4 "fitter sections" of about 7-8 men, each of which is attached to a company. The fitter sections are part of the A Echelon HQ of the company. This average configuration does, of course, vary widely dependent on the parent unit and their equipment.

References

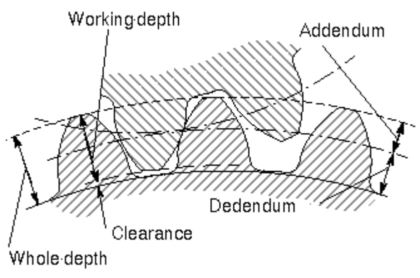
[1] RCEME article (http://www.canadiansoldiers.com/mediawiki-1.5.5/index.php?title=RCEME)
[2] Ibid

List of gear nomenclature

Gears have a wide range of unique terminology known as **gear nomenclature**. Many of the terms defined cite the same reference work.[1]

Addendum

The **addendum** is the height by which a tooth of a gear projects beyond (outside for external, or inside for internal) the standard pitch circle or pitch line; also, the radial distance between the pitch circle and the addendum circle.[1]



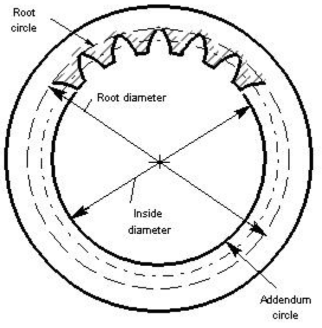
Principal dimensions

Addendum angle

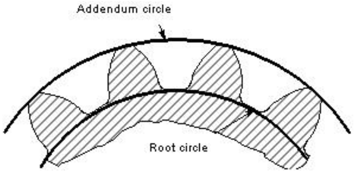
Addendum angle in a bevel gear, is the angle between elements of the face cone and pitch cone.[1]

Addendum circle

The **addendum circle** coincides with the tops of the teeth of a gear and is concentric with the standard (reference) pitch circle and radially distant from it by the amount of the addendum. For external gears, the addendum circle lies on the outside cylinder while on internal gears the addendum circle lies on the internal cylinder.[1]



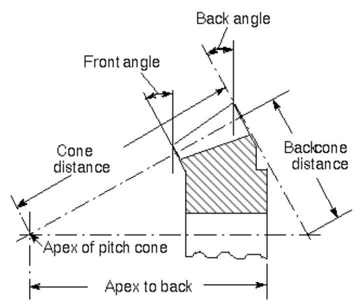
Diameters, internal gear



Root circle

Apex to back

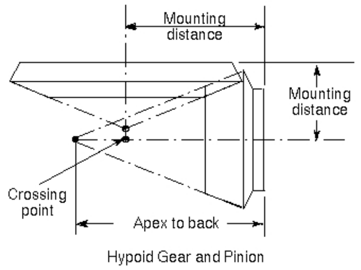
Apex to back, in a bevel gear or hypoid gear, is the distance in the direction of the axis from the apex of the pitch cone to a locating surface at the back of the blank.[1]



Apex to back

Back angle

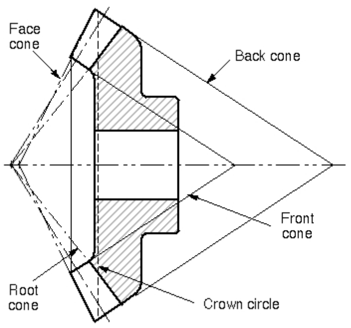
The **back angle** of a bevel gear is the angle between an element of the back cone and a plane of rotation, and usually is equal to the pitch angle.[1]



Mounting distance

Back cone

The **back cone** of a bevel or hypoid gear is an imaginary cone tangent to the outer ends of the teeth, with its elements perpendicular to those of the pitch cone. The surface of the gear blank at the outer ends of the teeth is customarily formed to such a back cone.[1]



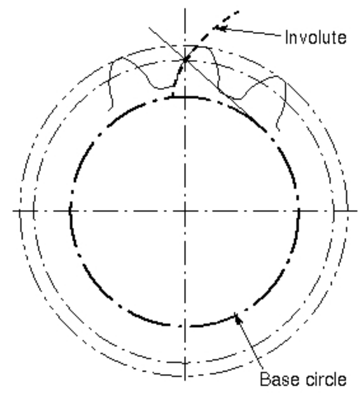
Principal dimensions

Back cone distance

Back cone distance in a bevel gear is the distance along an element of the back cone from its apex to the pitch cone.[1]

Base circle

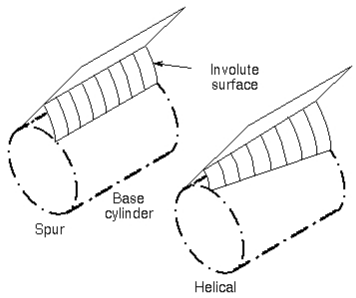
The **base circle** of an involute gear is the circle from which involute tooth profiles are derived.[1]



Involute teeth

Base cylinder

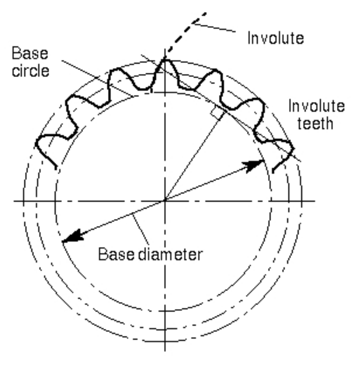
The **base cylinder** corresponds to the base circle, and is the cylinder from which involute tooth surfaces are developed.[1]



Base cylinder

Base diameter

The **base diameter** of an involute gear is the diameter of the base circle.[1]



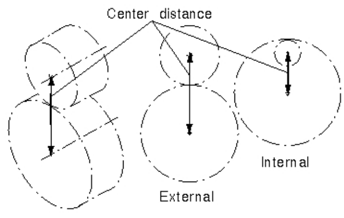
Base diameter

Bull gear

The term **bull gear** is used to refer to the larger of two spur gears that are in engagement in any machine. The smaller gear is usually referred to as a pinion.

Center distance

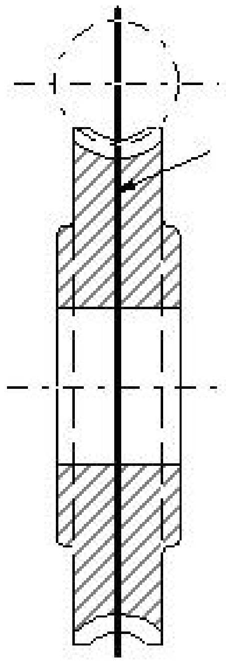
Center distance (operating) is the shortest distance between non-intersecting axes. It is measured along the mutual perpendicular to the axes, called the line of centers. It applies to spur gears, parallel axis or crossed axis helical gears, and worm gearing.[1]



Center distance

Central plane

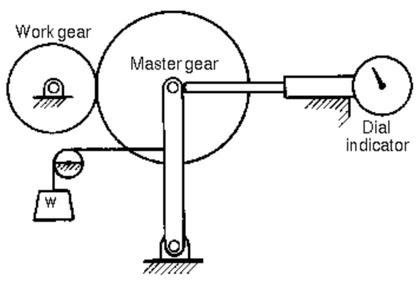
The **central plane** of a worm gear is perpendicular to the gear axis and contains the common perpendicular of the gear and worm axes. In the usual case with axes at right angles, it contains the worm axis.[1]



Central plane

Composite action test

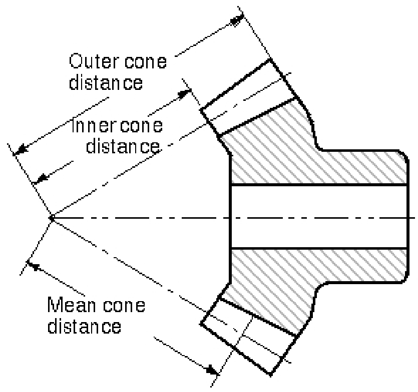
The **composite action test** (double flank) is a method of inspection in which the work gear is rolled in tight double flank contact with a master gear or a specified gear, in order to determine (radial) composite variations (deviations). The composite action test must be made on a variable center distance composite action test device.[1]



Schematic of the composite action test

Cone distance

Cone distance in a bevel gear is the general term for the distance along an element of the pitch cone from the apex to any given position in the teeth.[1]



Cone distance

Outer cone distance in bevel gears is the distance from the apex of the pitch cone to the outer ends of the teeth. When not otherwise specified, the short term cone distance is understood to be outer cone distance.

Mean cone distance in bevel gears is the distance from the apex of the pitch cone to the middle of the face width.

Inner cone distance in bevel gears is the distance from the apex of the pitch cone to the inner ends of the teeth.

Conjugate gears

Conjugate gears transmit uniform rotary motion from one shaft to another by means of gear teeth. The normals to the profiles of these teeth, at all points of contact, must pass through a fixed point in the common centerline of the two shafts.[1]

Crossed helical gear

A **crossed helical gear** is a gear that operate on non-intersecting, non-parallel axes.

The term crossed helical gears has superseded the term *spiral gears*. There is theoretically point contact between the teeth at any instant. They have teeth of the same or different helix angles, of the same or opposite hand. A combination of spur and helical or other types can operate on crossed axes.[1]

Crossing point

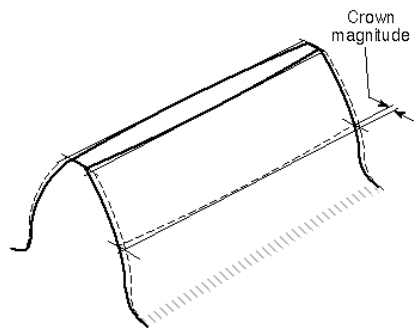
The **crossing point** is the point of intersection of bevel gear axes; also the apparent point of intersection of the axes in hypoid gears, crossed helical gears, worm gears, and offset face gears, when projected to a plane parallel to both axes.[1]

Crown circle

The **crown circle** in a bevel or hypoid gear is the circle of intersection of the back cone and face cone.[1]

Crowned teeth

Crowned teeth have surfaces modified in the lengthwise direction to produce localized contact or to prevent contact at their ends.[1]



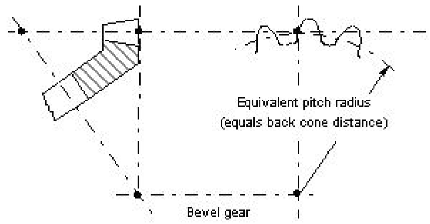
Crowned Gear, *ANSI/AGMA 1012-G05*

Dedendum angle

Dedendum angle in a bevel gear, is the angle between elements of the root cone and pitch cone.[1]

Equivalent pitch radius

Equivalent pitch radius is the radius of the pitch circle in a cross section of gear teeth in any plane other than a plane of rotation. It is properly the radius of curvature of the pitch surface in the given cross section. Examples of such sections are the transverse section of bevel gear teeth and the normal section of helical teeth.



Back cone equivalent

Face (tip) angle

Face (tip) angle in a bevel or hypoid gear, is the angle between an element of the face cone and its axis.[1]

Face cone

The **face cone**, also known as the **tip cone** is the imaginary surface that coincides with the tops of the teeth of a bevel or hypoid gear.[1]

Face gear

A **face gear** set consists of a face gear in combination with a spur, helical, or conical pinion. A face gear has a planar pitch surface and a planar root surface, both of which are perpendicular to the axis of rotation.[1]

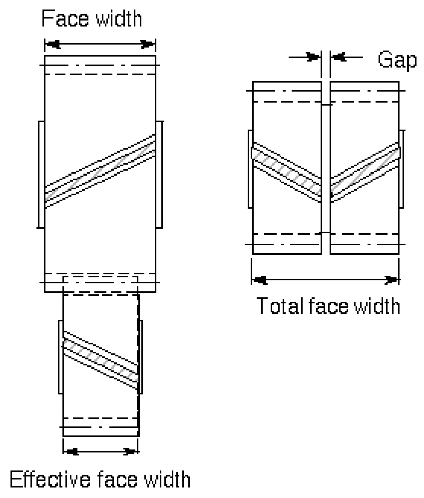
Face width

The **face width** of a gear is the length of teeth in an axial plane. For double helical, it does not include the gap.[1]

Total face width is the actual dimension of a gear blank including the portion that exceeds the effective face width, or as in double helical gears where the total face width includes any distance or gap separating right hand and left hand helices.

For a cylindrical gear, effective face width is the portion that contacts the mating teeth. One member of a pair of gears may engage only a portion of its mate.

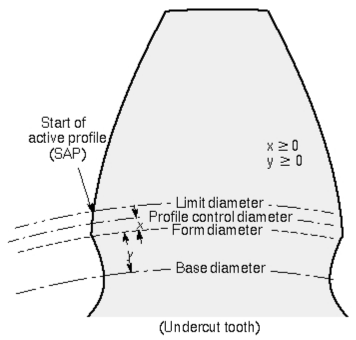
For a bevel gear, different definitions for effective face width are applicable.



Face width

Form diameter

Form diameter is the diameter of a circle at which the trochoid (fillet curve) produced by the tooling intersects, or joins, the involute or specified profile. Although these terms are not preferred, it is also known as the true involute form diameter (TIF), start of involute diameter (SOI), or when undercut exists, as the undercut diameter. This diameter cannot be less than the base circle diameter.[1]



Form diameter

Front angle

The **front angle**, in a bevel gear, denotes the angle between an element of the front cone and a plane of rotation, and usually equals the pitch angle.[1]

Front cone

The **front cone** of a hypoid or bevel gear is an imaginary cone tangent to the inner ends of the teeth, with its elements perpendicular to those of the pitch cone. The surface of the gear blank at the inner ends of the teeth is customarily formed to such a front cone, but sometimes may be a plane on a pinion or a cylinder in a nearly flat gear.[1]

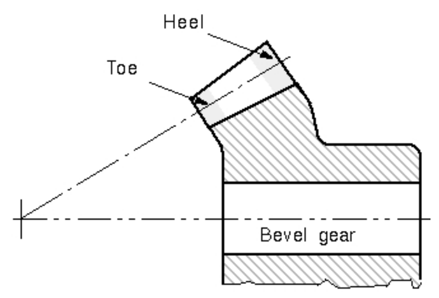
Gear center

A **gear center** is the center of the pitch circle.[1]

Heel

The **heel** of a tooth on a bevel gear or pinion is the portion of the tooth surface near its outer end.

The **toe** of a tooth on a bevel gear or pinion is the portion of the tooth surface near its inner end.[1]



Heel and toe

Helical rack

A **helical rack** has a planar pitch surface and teeth that are oblique to the direction of motion.[1]

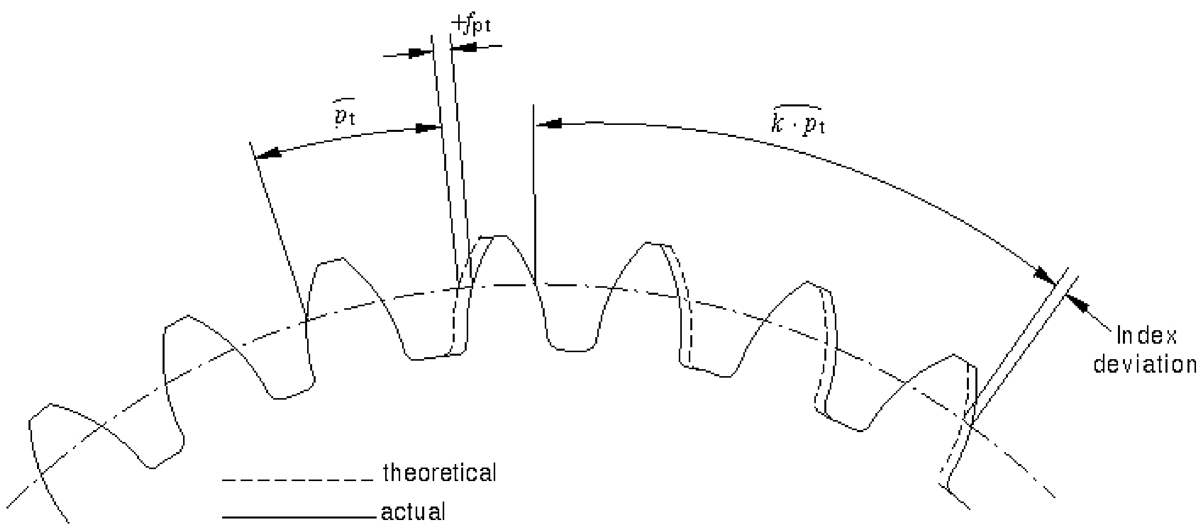
Herringbone gear

Index deviation

The displacement of any tooth flank from its theoretical position, relative to a datum tooth flank.

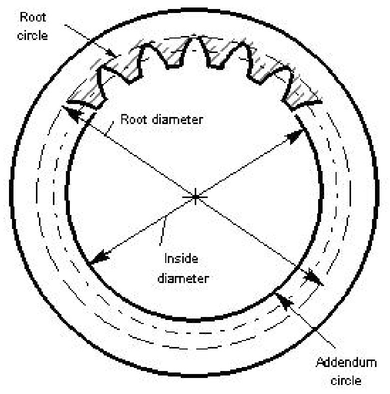
Distinction is made as to the direction and algebraic sign of this reading. A condition wherein the actual tooth flank position was nearer to the datum tooth flank, in the specified measuring path direction (clockwise or counterclockwise), than the theoretical position would be considered a minus (-) deviation. A condition wherein the actual tooth flank position was farther from the datum tooth flank, in the specified measuring path direction, than the theoretical position would be considered a plus (+) deviation.

The direction of tolerancing for index deviation along the arc of the tolerance diameter circle within the transverse plane.[1]



Inside cylinder

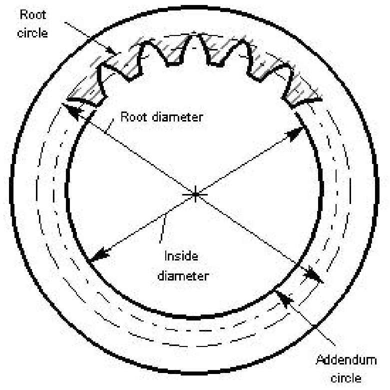
The **inside cylinder** is the surface that coincides with the tops of the teeth of an internal cylindrical gear.[1]



Diameters, Internal Gear

Inside diameter

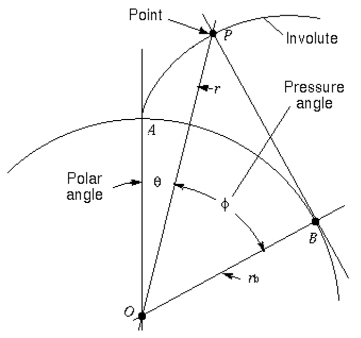
Inside diameter is the diameter of the addendum circle of an internal gear.[1]



Diameters, Internal Gear, *AGMA*

Involute polar angle

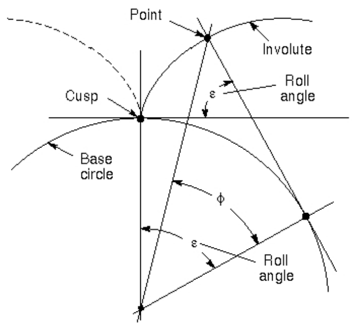
Expressed as θ, the **involute polar angle** is the angle between a radius vector to a point, *P*, on an involute curve and a radial line to the intersection, *A*, of the curve with the base circle.[1]



Involute polar angle

Involute roll angle

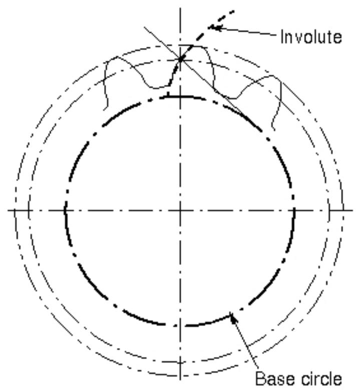
Expressed as ε, the **involute roll angle** is the angle whose arc on the base circle of radius unity equals the tangent of the pressure angle at a selected point on the involute.[1]



Involute roll angle

Involute teeth

Involute teeth of spur gears, helical gears, and worms are those in which the profile in a transverse plane (exclusive of the fillet curve) is the involute of a circle.[1]



Involute teeth

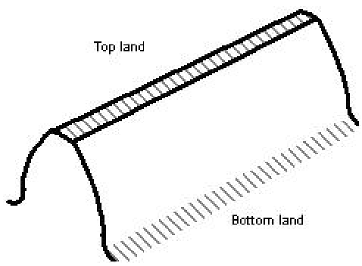
Lands

Bottom land

The **bottom land** is the surface at the bottom of a gear tooth space adjoining the fillet.[1]

Top land

Top land is the (sometimes flat) surface of the top of a gear tooth.[1]

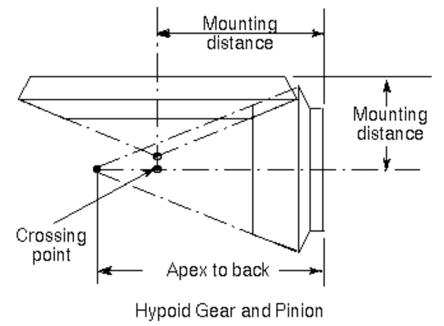


Top and bottom lands

Line of centers

The **line of centers** connects the centers of the pitch circles of two engaging gears; it is also the common perpendicular of the axes in crossed helical gears and wormgears. When one of the gears is a rack, the line of centers is perpendicular to its pitch line.[1]

Mounting distance



Mounting Distance, *ANSI/AGMA 1012-G05*

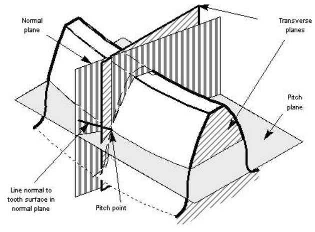
Mounting distance, for assembling bevel gears or hypoid gears, is the distance from the crossing point of the axes to a locating surface of a gear, which may be at either back or front.[1]

Normal module

Normal module is the value of the module in a normal plane of a helical gear or worm.[1]

$$m_n = m_t \cos \beta$$

Normal plane



Planes at a pitch point on a helical tooth

A **normal plane** is normal to a tooth surface at a pitch point, and perpendicular to the pitch plane. In a helical rack, a normal plane is normal to all the teeth it intersects. In a helical gear, however, a plane can be normal to only one tooth at a point lying in the plane surface. At such a point, the normal plane contains the line normal to the tooth surface.

Important positions of a normal plane in tooth measurement and tool design of helical teeth and worm threads are:

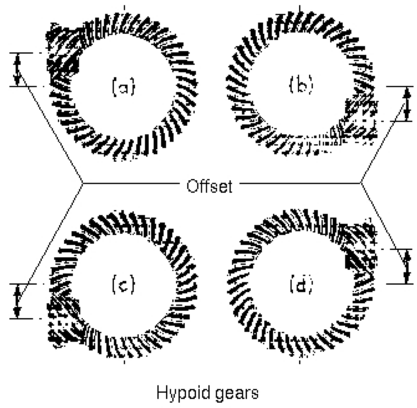
1. the plane normal to the pitch helix at side of tooth;
2. the plane normal to the pitch helix at center of tooth;
3. the plane normal to the pitch helix at center of space between two teeth

In a spiral bevel gear, one of the positions of a normal plane is at a mean point and the plane is normal to the tooth trace.[1]

Offset

Offset is the perpendicular distance between the axes of hypoid gears or offset face gears.[1]

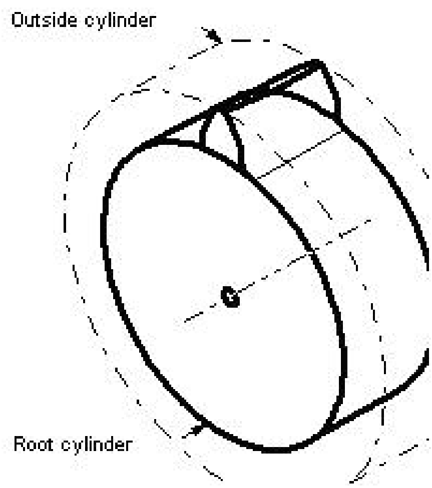
In the diagram to the right, (a) and (b) are referred to as having an offset *below center*, while those in (c) and (d) have an offset *above center*. In determining the direction of offset, it is customary to look at the gear with the pinion at the right. For below center offset the pinion has a left hand spiral, and for above center offset the pinion has a right hand spiral.



Offset

Outside cylinder

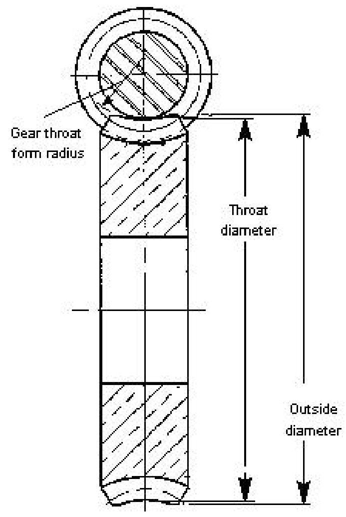
The **outside** (tip or addendum) **cylinder** is the surface that coincides with the tops of the teeth of an external cylindrical gear.[1]



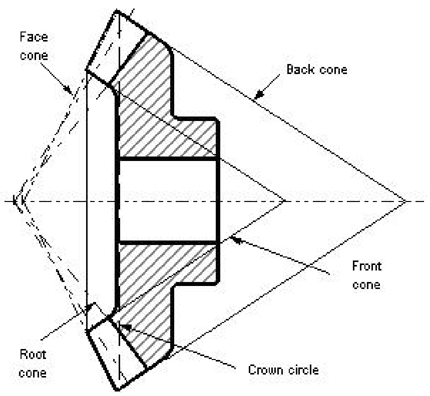
Cylindrical surfaces

Outside diameter

The **outside diameter** of a gear is the diameter of the addendum (tip) circle. In a bevel gear it is the diameter of the crown circle. In a throated wormgear it is the maximum diameter of the blank. The term applies to external gears.[1]

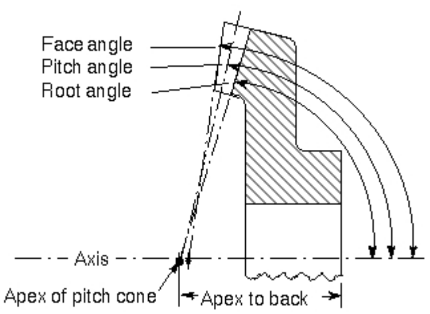


Wormgear diameters



Conical surfaces

Pitch angle



Angle Relationships, *ANSI/AGMA 1012-G05*

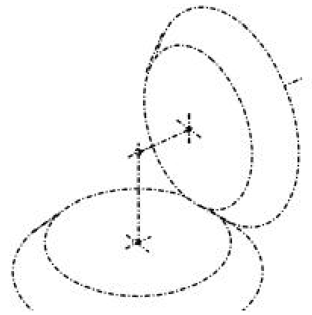
Pitch angle in bevel gears, is the angle between an element of a pitch cone and its axis. In external and internal bevel gears, the pitch angles are respectively less than and greater than 90 degrees.[1]

Pitch circle

A **pitch circle** (operating) is the curve of intersection of a pitch surface of revolution and a plane of rotation. It is the imaginary circle that rolls without slipping with a pitch circle of a mating gear.[1]

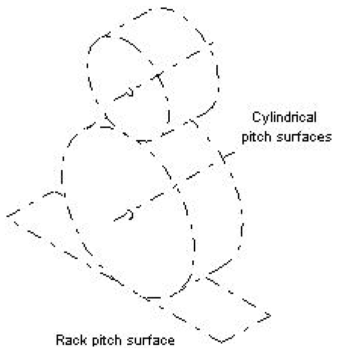
Pitch cone

A **pitch cone** is the imaginary cone in a bevel gear that rolls without slipping on a pitch surface of another gear.[1]


Pitch cones

Pitch cylinder

A **pitch cylinder** is the imaginary cylinder in a spur or helical gear that rolls without slipping on a pitch plane or pitch cylinder of another gear.[1]



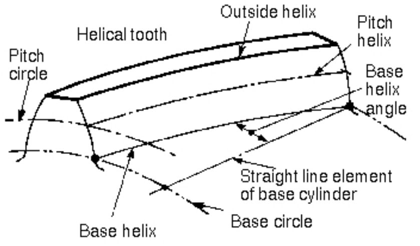
Pitch cylinder

Pitch helix

The **pitch helix** is the intersection of the tooth surface and the pitch cylinder of a helical gear or cylindrical worm.[1]

Base helix

The **base helix** of a helical, involute gear or involute worm lies on its base cylinder.



Tooth Helix, *ANSI/AGMA 1012-G05*

Base helix angle

Base helix angle is the helix angle on the base cylinder of involute helical teeth or threads.

Base lead angle

Base lead angle is the lead angle on the base cylinder. It is the complement of the base helix angle.

Outside helix

The **outside** (tip or addendum) **helix** is the intersection of the tooth surface and the outside cylinder of a helical gear or cylindrical worm.

Outside helix angle

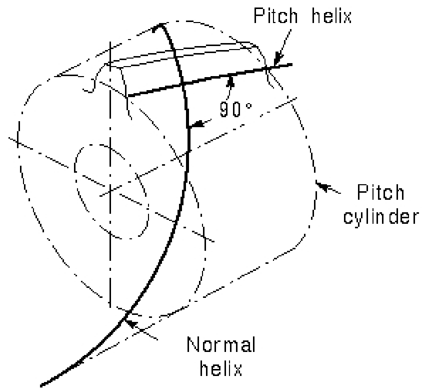
Outside helix angle is the helix angle on the outside cylinder.

Outside lead angle

Outside lead angle is the lead angle on the outside cylinder. It is the complement of the outside helix angle.

Normal helix

A **normal helix** is a helix on the pitch cylinder, normal to the pitch helix.



Normal Helix, *ANSI/AGMA 1012-G05*

Pitch line

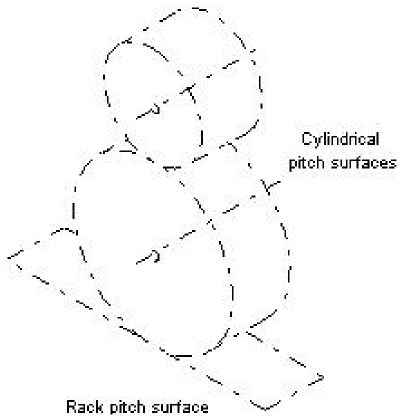
The **pitch line** corresponds, in the cross section of a rack, to the pitch circle (operating) in the cross section of a gear.[1]

Pitch point

The **pitch point** is the point of tangency of two pitch circles (or of a pitch circle and pitch line) and is on the line of centers.[1]

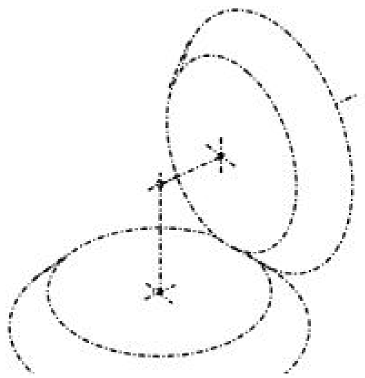
Pitch surfaces

Pitch surfaces are the imaginary planes, cylinders, or cones that roll together without slipping. For a constant velocity ratio, the pitch cylinders and pitch cones are circular.[1]



Pitch Surfaces, *AGMA*

Planes

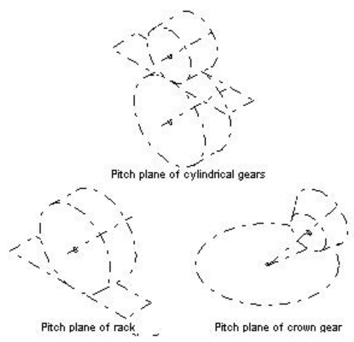

Pitch Cones, *AGMA*

Axial plane

Pitch plane

The **pitch plane** of a pair of gears is the plane perpendicular to the axial plane and tangent to the pitch surfaces. A pitch plane in an individual gear may be any plane tangent to its pitch surface.

The pitch plane of a rack or in a crown gear is the imaginary planar surface that rolls without slipping with a pitch cylinder or pitch cone of another gear. The pitch plane of a rack or crown gear is also the pitch surface.[1]



Pitch planes

Transverse plane

The **transverse plane** is perpendicular to the axial plane and to the pitch plane. In gears with parallel axes, the transverse and the plane of rotation coincide.[1]

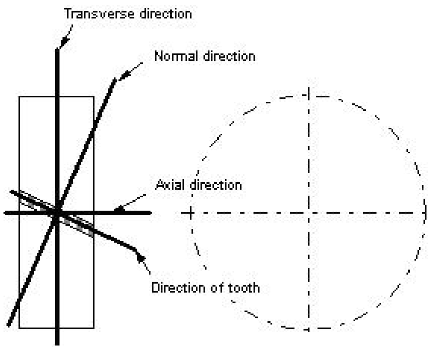
Principal directions

Principal directions are directions in the pitch plane, and correspond to the principal cross sections of a tooth.

The axial direction is a direction parallel to an axis.

The transverse direction is a direction within a transverse plane.

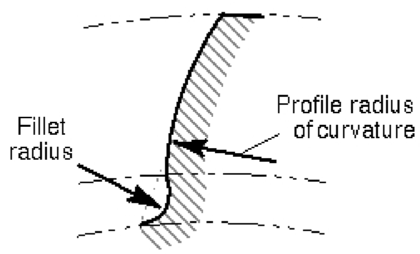
The normal direction is a direction within a normal plane.[1]



Principal Directions, *AGMA*

Profile radius of curvature

Profile radius of curvature is the radius of curvature of a tooth profile, usually at the pitch point or a point of contact. It varies continuously along the involute profile.[1]

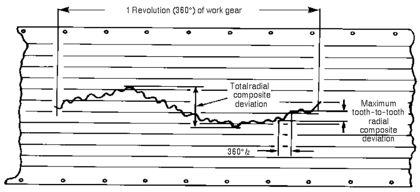


Fillet radius

Radial composite deviation

Tooth-to-tooth **radial composite deviation** (double flank) is the greatest change in center distance while the gear being tested is rotated through any angle of 360 degree/z during double flank composite action test.

Tooth-to-tooth radial composite tolerance (double flank) is the permissible amount of tooth-to-tooth radial composite deviation.



Total Composite Variation Trace

Total radial composite deviation (double flank) is the total change in center distance while the gear being tested is rotated one complete revolution during a double flank composite action test.

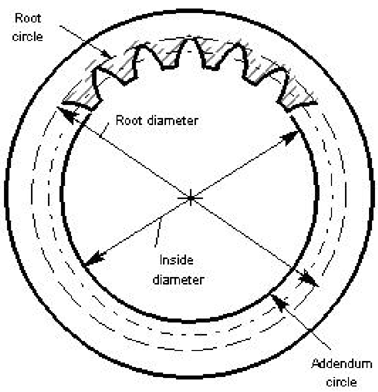
Total radial composite tolerance (double flank) is the permissible amount of total radial composite deviation.[1]

Root angle

Root angle in a bevel or hypoid gear, is the angle between an element of the root cone and its axis.[1]

Root circle

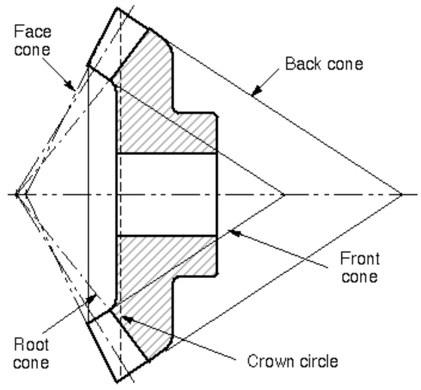
The **root circle** coincides with the bottoms of the tooth spaces.[1]



Diameters, Internal Gear

Root cone

The **root cone** is the imaginary surface that coincides with the bottoms of the tooth spaces in a bevel or hypoid gear.[1]



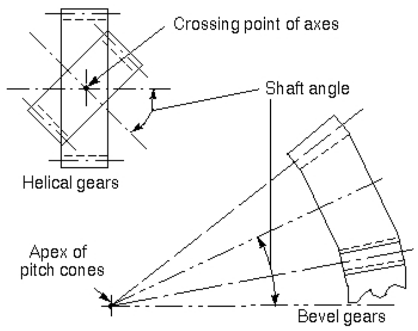
Principal Dimensions

Root cylinder

The **root cylinder** is the imaginary surface that coincides with the bottoms of the tooth spaces in a cylindrical gear.[1]

Shaft angle

A **shaft angle** is the angle between the axes of two non-parallel gear shafts. In a pair of crossed helical gears, the shaft angle lies between the oppositely rotating portions of two shafts. This applies also in the case of worm gearing. In bevel gears, the shaft angle is the sum of the two pitch angles. In hypoid gears, the shaft angle is given when starting a design, and it does not have a fixed relation to the pitch angles and spiral angles.[1]



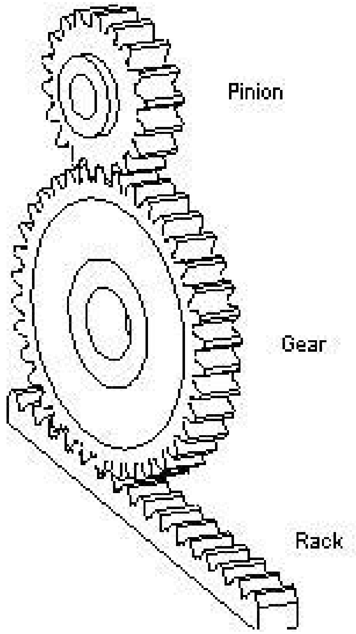
Shaft Angle, *ANSI/AGMA 1012-G05*

Spiral gear

See: Crossed helical gear.

Spur gear

A **spur gear** has a cylindrical pitch surface and teeth that are parallel to the axis.[1]



Spur gear

Spur rack

A **spur rack** has a planar pitch surface and straight teeth that are at right angles to the direction of motion.[1]

Standard pitch circle

The **standard pitch circle** is the circle which intersects the involute at the point where the pressure angle is equal to the profile angle of the basic rack.[1]

Standard pitch diameter

The **standard reference pitch diameter** is the diameter of the standard pitch circle. In spur and helical gears, unless otherwise specified, the standard pitch diameter is related to the number of teeth and the standard transverse pitch. The diameter can be roughly estimated by taking the average of the diameter measuring the tips of the gear teeth and the base of the gear teeth.[1]

The pitch diameter is useful in determining the spacing between gear centers because proper spacing of gears implies tangent pitch circles. The pitch diameters of two gears may be used to calculate the gear ratio in the same way the number of teeth is used.

$$d = \frac{N}{P_d} = \frac{pN}{\pi} \quad \text{Spur gears}$$

$$d = \frac{N}{P_{nd}\cos\psi} \quad \text{Helical gears}$$

Where N is the total number of teeth, p is the circular pitch, P_d is the diametrical pitch, and ψ is the helix angle for helical gears.

Standard reference pitch diameter

The **standard reference pitch diameter** is the diameter of the standard pitch circle. In spur and helical gears, unless otherwise specified, the standard pitch diameter is related to the number of teeth and the standard transverse pitch. It is obtained as:[1]

$$d = zm = \frac{zp}{\pi} = z\frac{m_n}{\cos\beta}$$

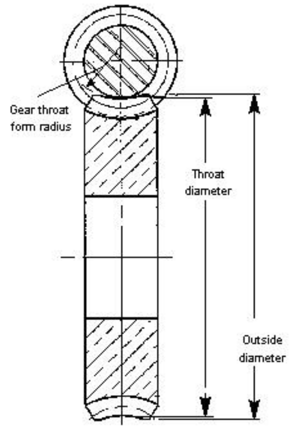
$$D = \frac{N}{P_d} = \frac{Np}{\pi} = \frac{N}{P_{nd}\cos\psi}$$

Test radius

The **test radius** (**R_r**) is a number used as an arithmetic convention established to simplify the determination of the proper test distance between a master and a work gear for a composite action test. It is used as a measure of the effective size of a gear. The test radius of the master, plus the test radius of the work gear is the set up center distance on a composite action test device. Test radius is not the same as the operating pitch radii of two tightly meshing gears unless both are perfect and to basic or standard tooth thickness.[1]

Throat diameter

The **throat diameter** is the diameter of the addendum circle at the central plane of a wormgear or of a double-enveloping wormgear.[1]



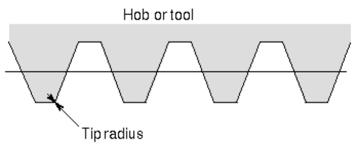
Wormgear diameters, *ANSI/AGMA 1012-G05*

Throat form radius

Throat form radius is the radius of the throat of an enveloping wormgear or of a double-enveloping worm, in an axial plane.[1] </ref>

Tip radius

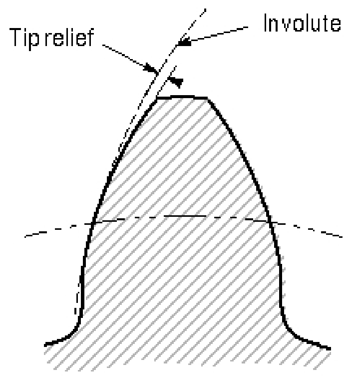
Tip radius is the radius of the circular arc used to join a side-cutting edge and an end-cutting edge in gear cutting tools. Edge radius is an alternate term.[1]



Tip radius

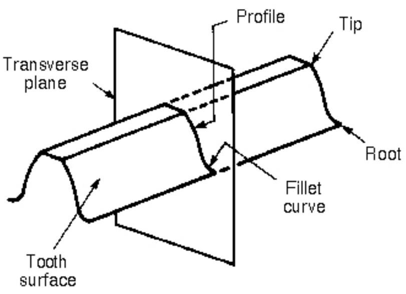
Tip relief

Tip relief is a modification of a tooth profile whereby a small amount of material is removed near the tip of the gear tooth.[1]

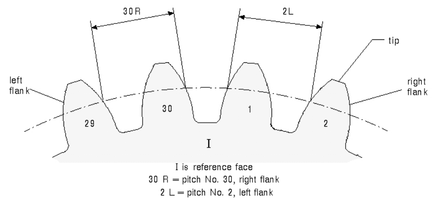


Tip relief

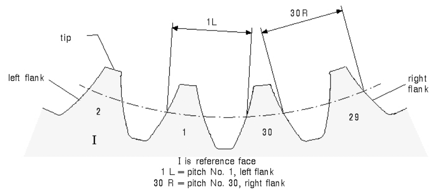
Tooth surface



Profile of a spur gear



Notation and numbering for an external gear



Notation and Numbering for an internal gear

The **tooth surface** (flank) forms the side of a gear tooth.[1]

It is convenient to choose one face of the gear as the reference face and to mark it with the letter “I”. The other non-reference face might be termed face “II”.

For an observer looking at the reference face, so that the tooth is seen with its tip uppermost, the right flank is on the right and the left flank is on the left. Right and left flanks are denoted by the letters “R” and “L” respectively.

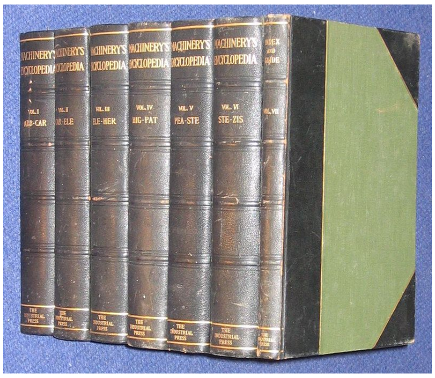
See also

- Gear ratio
- Gears

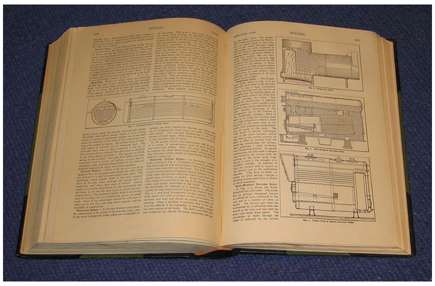
References

[1] *Gear Nomenclature, Definition of Terms with Symbols*. American Gear Manufacturers Association. ANSI/AGMA 1012-G05. ISBN 1-55589-846-7. OCLC 65562739 (http://worldcat.org/oclc/65562739).

Machinery's Handbook



Machinery's Encyclopedia, 1917



"Boiler", *Machinery's Encyclopedia*, 1917

Machinery's Handbook *for machine shop and drafting-room; a reference book on machine design and shop practice for the mechanical engineer, draftsman, toolmaker, and machinist* (the full title of the 1st edition) is a classic reference work in → mechanical engineering and practical workshop mechanics in one volume published by Industrial Press, New York, since 1914. The first edition was created by Erik Oberg (1881–1951) and Franklin D. Jones (1879–1967), who are still mentioned on the title page of the 28th edition (2008). Recent editions of the handbook contain chapters on mathematics, mechanics, materials, measuring, toolmaking, manufacturing, threading, gears, and machine elements, combined with excerpts from ANSI standards.

In 1917, Oberg and Jones also published *Machinery's Encyclopedia* in 7 volumes. The handbook and encyclopedia are named after the monthly magazine *Machinery* (Industrial Press, 1894–1973), where the two were consulting editors.

Today, the phrases "machinist's handbook" or "machinists' handbook" are almost always imprecise references to *Machinery's Handbook*. During the decades from World War I through World War II, these phrases could refer to either of two competing reference books: McGraw-Hill's → *American Machinists' Handbook* or Industrial Press's *Machinery's Handbook*. The former book ceased publication after the 8th edition (1945). (One short-lived spin-off appeared in 1955.) The latter book, *Machinery's Handbook*, is still regularly revised and updated, and it continues to be a "bible of the metalworking industries" today.

Machinery's Handbook is apparently the direct inspiration for similar works in other countries, such as Sweden's *Karlebo handbok* (1st ed. 1936).

See also

- Machinist Calculator
- (discussion page for a list of copyright dates)

External links

- Industrial Press [1]
- History of the Machinery's Handbook [2], from the publisher

References

[1] http://www.industrialpress.com/
[2] http://new.industrialpress.com/node/1003

Maintenance engineering

Maintenance Engineering is the discipline and profession of applying engineering concepts to the optimization of equipment, procedures, and departmental budgets to achieve better maintainability, reliability, and availability of equipment.

Maintenance, and hence maintenance engineering, is increasing important due to rising amounts of equipment, systems, machineries and infrastructures. Since the Industrial Revolution devices, equipment, machinery and structures have grown increasingly complex, requiring a host of personnel, vocations and related systems needed to maintain them.[1] Prior to 2006, the United States spent approximately US$300 billion annually on plant maintenance and operations alone.[1]

A person practising **Maintenance Engineering** is known as a **Maintenance Engineer**.

Maintenance Engineer's Essential Knowledge

A Maintenance Engineer shall possess significant knowledge of statistics, probability and logistics, and additionally in the fundamentals of the operation of the equipment and machinery he or she is responsible for.

A Maintenance Engineer shall also possess high interpersonal, communication and management skills.

Typical Maintenance Engineering Responsibilities

Typical responsibilities include:[2] - Assure optimization of the Maintenance Organization structure
- Analysis of repetitive equipment failures
- Estimation of maintenance costs and evaluation of alternatives
- Forecasting of spare parts
- Assessing the needs for equipment replacements and establish replacement programs when due
- Application of scheduling and project management principles to replacement programs
- Assessing required maintenance tools and skills required for efficient maintenance of equipment

- Assessing required skills required for maintenance personnel
- Reviewing personnel transfers to and from maintenance organizations
- Assessing and reporting safety hazards associated with maintenance of equipment

Maintenance Engineering Education

There are no dedicated Bachelor Degree programs for Maintenance Engineering. However, Maintenance Engineers usually hold a degree in Mechanical Engineering, Industrial Engineering, or other Engineering Disciplines.

See also

- Aircraft Maintenance Engineering
- Auto mechanic
- Civil engineer
- Computer repair technician
- Electrician
- Electrical Technologist
- Marine fuel management
- Mechanic
- Millwright (machinery maintenance)
- → Maintenance, repair and operations (MRO)
- Reliability centered maintenance (RCM)
- Reliability engineering
- Preventive maintenance
- Product lifecycle management
- Stationary engineer

External links

- MaintenanceOnline.org [3]

References

[1] Dhillon, Balbir S. (2006) Maintainability, Maintenance, and Reliability for Engineers (http://books.google.com/books?id=nxT-wxeVVIQC), CRC Press, 2006, ISBN 0849372437, ISBN 9780849372438;
[2] Mobley, Keith R. & Higgins, Lindley R. & Wikoff, Darrin J. (2008) Maintenance Engineering Handbook (http://books.google.ca/books?hl=en&id=O8Fcf-VIliwC&dq=maintenance+engineering+handbook&printsec=frontcover&source=web&ots=64-5OGeEgg&sig=hspdMJ5Oe5Hz4T0qyjdh0XUoYoE&sa=X&oi=book_result&resnum=1&ct=result), McGraw-Hill Professional, Seventh Edition, 2008, ISBN 0071546464, ISBN 9780071546461;
[3] http://www.maintenanceonline.org/maintenanceonline

Maintenance, repair and operations

Maintenance, repair and operations is fixing any sort of mechanical or electrical device should it become out of order or broken (known as repair, unscheduled or casualty maintenance) as well as performing the routine actions which keep the device in working order (known as scheduled maintenance) or prevent trouble from arising (preventive maintenance). MRO may be defined as, "All actions which have the objective of retaining or restoring an item in or to a state in which it can perform its required function. The actions include the combination of all technical and corresponding administrative, managerial, and supervision actions." [1]

MRO operations can be categorised by whether the product remains the property of the customer, i.e., a service is being offer or whether the product is brought by the reprocessing organisation and sold to any customer wishing to make the purchase. (Guadette, 2002)

The former of these represents a closed loop supply chain and usually has the scope of maintenance, repair or overhaul of the product. The latter of the categorisations is an open loop supply chain and is typified by refurbishment and remanufacture. The main characteristic of the closed loop system is that the demand for a product is matched with the supply of a used product. Neglecting asset write-offs and exceptional activities the total population of the product between the customer and the service provider remains constant

Engineering

In telecommunication, and engineering in general, the term maintenance has the following meanings:

1. Any activity – such as tests, measurements, replacements, adjustments and repairs — intended to retain or restore a functional unit in or to a specified state in which the unit can perform its required functions.[2]
2. For material — all action taken to retain material in a serviceable condition or to restore it to serviceability. It includes inspection, testing, servicing, classification as to serviceability, repair, rebuilding, and reclamation.[2]
3. For material — all supply and repair action taken to keep a force in condition to carry out its mission.[2]
4. For material — the routine recurring work required to keep a facility (plant, building, structure, ground facility, utility system, or other real property) in such condition that it may be continuously used, at its original or designed capacity and efficiency for its intended purpose.[2]

Manufacturers and Industrial Supply Companies often refer to MRO as opposed to Original Equipment Manufacture (OEM). OEM includes any activity related to the direct manufacture of goods, where MRO refers to any maintenance and repair activity to keep a manufacturing plant running.

Industrial supply companies can generally be sorted into two types:

- the ones who cater to the MRO market generally carry a broad range of items such as fasteners, conveyors, cleaning goods, plumbing, and tools to keep a plant running.
- OEM supply companies generally provide a smaller range of goods in much larger quantities with much lower prices, selling materials that will be regularly consumed in

the manufacturing process to create the finished item.

MRO software

In many organizations because of the number of devices or products that need to be maintained or the complexity of systems, there is a need to manage the information with software packages. This is particularly the case in aerospace (e.g. airline fleets), military installations, large plants (e.g. manufacturing, power generation, petrochemical) and ships.

These software tools help engineers and technicians in increasing the availability of systems and reducing costs and repair times as well as reducing material supply time and increasing material availability by improving supply chain communication.

As MRO involves working with an organization's products, resources, suppliers and customers, MRO packages have to interface with many enterprise business software systems (PLM, EAM, ERP, SCM, CRM).

One of the functions of such software is the configuration of bills of materials or BOMs, taking the component parts list from engineering (eBOM) and manufacturing (mBOM) and updating it from “as delivered” through “as maintained” to “as used”.

Another function is project planning logistics, for example identifying the critical path on the list of tasks to be carried out (inspection, diagnosis, locate/order parts and service) to calculate turnaround times (TAT).

Other tasks that software can perform:

- Planning operations,
- Managing execution of events,
- Management of assets (parts, tools and equipment inventories),
- Knowledge-base data on:
  - Maintenance service history,
  - Serial numbered parts,
  - Reliability data: MTBF, MTTB (mean time to breakdown), MTBR (mean time between removals),
  - Maintenance and repair documentation and best practices,
  - Warranty/guarantee documents.

Many of these tasks are addressed in Computerized Maintenance Management Systems (CMMS). Data standards have been developed around these activities, most notably EAMXML and MIMOSA

MRO goods

MRO goods are typically defined as any goods used in the creation of a product but not in the final product itself. Examples are: the machinery used to make a product, spare parts for the machinery that creates the product and items used to maintain the facility in which the product is made.

See also

- Auto mechanic
- Automobile repair shop
- Car maintenance
- User reengineering
- Preventive maintenance
- Plant Lifecycle Management
- Product Lifecycle Management
- Reliability engineering
- Reliability centered maintenance
- Refurbishment
- Scheduled maintenance
- Unscheduled maintenance

References

[1] European Federation of National Maintenance Societies (http://www.EFNMS.org)
[2] Federal Standard 1037C and from MIL-STD-188 and from the Department of Defense Dictionary of Military and Associated Terms

Marks' Standard Handbook for Mechanical Engineers

Marks' Standard Handbook for Mechanical Engineers is a comprehensive handbook for the field of → mechanical engineering. It was first published in 1916 by Lionel S. Marks. It is now in its 11th edition (2007), and is put out by McGraw-Hill.

Topics

In the 11th edition, there are 20 sections:

1. Mathematical Tables and Measuring Units
2. Mathematics
3. Mechanics of Solids and Fluids
4. Heat
5. Strength of Materials
6. Materials of Engineering
7. Fuels and Furnaces
8. Machine Elements
9. Power Generation
10. Materials Handling
11. Transportation
12. Building Construction and Equipment
13. Manufacturing Processes
14. Fans, Pumps, and Compressors
15. Electrical and Electronics Engineering
16. Instruments and Controls
17. Industrial Engineering
18. The Regulatory Environment
19. Refrigeration, Cyrogenics, and Optics
20. Emerging Technologies

References

- Avallone, Eugene A., Theodore Baumeister III, and Ali M. Sadegh, eds. (2007). *Marks' Standard Handbook for Mechanical Engineers*. 11th ed. New York: McGraw-Hill. ISBN 9780071428675.

External links

- Publisher's description [1]

References

[1] http://www.mhprofessional.com/product.php?isbn=0071428674

Mass transfer

Mass transfer is the transfer of mass from high concentration to low concentration. The phrase is commonly used in engineering for physical processes that involve molecular and convective transport of atoms and molecules within physical systems. Mass transfer includes both fluid flow and separation unit operations.

Examples

Some common examples of mass transfer processes are the evaporation of water from a pond to the atmosphere; the diffusion of chemical impurities in lakes, rivers, and oceans from natural or artificial point sources; mass transfer is also responsible for the separation of components in an apparatus such as a distillation column. In HVAC examples of a heat and mass exchangers are → cooling towers and evaporative coolers where evaporation of water cools that portion which remains as a liquid, as well as cooling and humidifying the air passing through.

The driving force for mass transfer is a difference in concentration; the random motion of molecules causes a net transfer of mass from an area of high concentration to an area of low concentration. The amount of mass transfer can be quantified through the calculation and application of mass transfer coefficients. Mass transfer finds extensive application in chemical engineering problems, where material balance on components is performed.

In astronomy, mass transfer is the process by which matter gravitationally bound to a body, usually a star, fills its Roche lobe and becomes gravitationally bound to a second body, usually a compact object (white dwarf, neutron star or black hole), and is eventually accreted onto it. It is a common phenomenon in binary systems, and may play an important role in some types of supernovae, and pulsars.

For separation processes, thermodynamics determines the extent of separation, while mass transfer determines the rate at which the separation will occur.

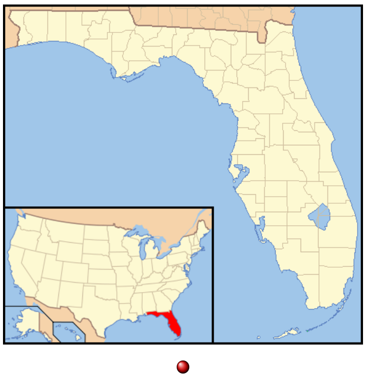
Analogies between heat, mass, and momentum transfer

It is important to note that in molecular transport, heat, or mass there are many similarities. The molecular diffusion equations of Newton for momentum, Fourier law for heat, and Fick for mass are very similar. Therefore there are many analogies among these three molecular transport processes. A great deal of effort has been devoted in the literature to developing analogies among these three transport processes for turbulent transfer so as to allow prediction of one from any of the others. Reynolds analogy assumes that the turbulent diffusivities are all equal and that the molecular diffusivities of momentum (μ/ρ) and mass (D_{AB}) are negligible compared to the turbulent diffusivities. When liquids are present and/or drag is present the analogy is not valid. Other analogies, such as von Karman's and Prandtl's, usually results in poor relations. The most successful and most widely used analogy is the Chilton and Colburn J-factor analogy. This analogy is based on experimental data for gases and liquids in both the laminar and turbulent regions. Although it is based on experimental data, it can be shown to satisfy the exact solution derived from laminar flow over a flat plate.

See also

- Crystal growth
- → Heat transfer
- Heat exchangers
- Fick's law
- Distillation column
- McCabe-Thiele method
- Vapor-Liquid Equilibrium
- Liquid-liquid extraction
- Separation process

McKinley Climatic Laboratory

McKinley Climatic Laboratory	
U.S. National Register of Historic Places	
 F-117 on ice at McKinley Climatic Laboratory	
	
Nearest city:	Fort Walton Beach, Florida
Coordinates:	30°28′33″N 86°30′27″W
Built/Founded:	1944
Architect:	US Army Air Corps of Engineers
Architectural style(s):	Late 19th And Early 20th Century American Movements, Other
Governing body:	US Air Force
Added to NRHP:	October 06, 1997
NRHP Reference#:	97001145[1]

The **McKinley Climatic Laboratory** is a both an active laboratory and a historic site located in Building 440 on Eglin Air Force Base, Florida. The laboratory is part of the 46th Test Wing. In addition to Air Force testing, it can be used by other US government agencies and private industry.[2]

On October 6, 1997, it was added to the U.S. National Register of Historic Places.[1] The laboratory was named a National Historic Mechanical Engineering Landmark by the → American Society of Mechanical Engineers in 1987.[3] [4]

History

In 1940, the US Army Air Force designated Ladd Field in Fairbanks, Alaska as a cold-weather testing facility. Because sufficiently cold weather was not predictible and often of short duration, Ashley McKinley suggested a refrigerated airplane hangar be built. The facilities were constructed at Eglin Field.[4]

The first tests started in May 1947. Airplanes that were tested included the B-29 Superfortress, C-82 Packet, P-47 Thunderbolt, P-51 Mustang, P-80 Shooting Star, and the Sikorsky H-5D helicopter.[4] More recently, it has tested the C-5 Galaxy,[4] the F-117,[5] and the F-22.[6]

In 1971, the hangar was dedicated at the McKinley Climatic Hangar in honor of Col. Ashley McKinley, who suggested the facility and served at Eglin during its construction.[4]

Buildings

The Building 440 is an insulated, refrigerated hangar. There is an office and instrumentation building, a cold-weather engine test cell, the refrigeration system, mechanical-draft cooling towers, and a steam-heating plant.[4]

The main chamber is 252 feet (77 m) wide, 201 feet (61 m) deep, and 70 feet (21 m) tall at the center of the hangar. It was constructed to hold aircraft as large a B-29, its size also fitting the larger Convair B-36 Peacemaker. In 1968, a 60 feet (18 m) by 85 feet (26 m) extension was added. It now has 55000 square feet (5100 m^2) working area. This allows it to test aircraft as large as a C-5A. Under hot conditions, it can achieve 165 °F (74 °C).[4] [7]

The All-Weather Room is 42 feet (13 m) by 22 feet (7 m). It has a temperature range from −80 °F (−62 °C) to 170 °F (77 °C). Rainfall can be as high as 15 inches (380 mm) per hour and the wind can be as high as 60 knots (31 m/s). Snow can be made in the chamber.[4]

The Temperature-Altitude Chamber is 13.5 feet (4.1 m) by 9.5 feet (2.9 m) with a height of 6.9 feet (2.1 m). Altitudes up to 80000 feet (24 km) can be simulated. The temperature range is −80 °F (−62 °C) to 140 °F (60 °C).[4]

The engine test cell was originally used for aircraft engines. It was about 130 feet (40 m) by 30 feet (9 m) with a height of 25 feet (8 m). It is now called the Equipment Test Chamber and is used mainly for tanks, trucks, and other equipment. The original building had small tests rooms for desert, hot, marine, and jungle conditions. These have been eliminated. [2] [4]

The original floor of the building was constructed of reinforced-concrete slabs that were 12 inches (30 cm) thick and 12.5 feet (3.8 m) square. The slabs rested on 13 inches (33 cm) of cellular glass blocks over reinforced concrete. In 1990, much of this floor was replaced with 25 feet (7.6 m) square slabs. The walls and door are insulated with 13 inches (33 cm) of glass-wool board sheathed in galvanized steel. To seal the doors, they are pulled against foam rubber seals. The ceiling insulation is on a corrugated steel deck, which is suspended from the roof trusses by chains.[4] [7]

Refrigeration system

The original coolant was R-12 refrigerant. Liquid refrigerant is held in a low-pressure surge tank. The pressure in this tank is maintained at the saturation pressure for the desired temperature for the cooling coils. Vapor from this tank is compressed to a gage pressure of 20 psi (138 kPa) by the first-stage compressor. The compressed vapor is expanded into an intermediate, desuperheater tank. Liquid condensed in this expansion is drained back the to the surge tank. The remaining vapor is compressed in a high-stage compressor to a gage pressure of about 150 psi (1 MPa). Heat is transferred from the hot vapor to cooling water. Any condensed liquid is returned to the intermediate tank, the surge tank, or the supply tank. Liquid refrigerant from the surge tank is pumped through the the cooling coils at sufficient pressure to avoid vaporization. Warmed liquid is returned to the surge tank. As its pressure is reduced, a portion of this liquid will flash into vapor.[4]

There are three such refrigeration systems. Each low-stage compressor is powered by a 1000 horsepower (746 kW) motor and each high-stage compressor is powered by a 1250 horsepower (932 kW) motor. The system was built by York Corporation. The original motors were Allis Chalmers induction motors. They have been replaced by variable frequency, synchronous motors manufactured by EMICC that operate between 350 and 1800 rpm.[4] Recent efforts have been made to change from ozone-depleting refrigerants.[7]

For engine tests, there is need for makeup air. The system originally could cool 200 pounds (91 kg) per second of humid air. In 1966, this was increased to 450 pounds (204 kg) per second. Air is also cooled by a two-stage heat exchanger. The first stage uses 110000 US gallons (416 m^3) of 20% calcium chloride brine pre-cooled to 24 °F (−4 °C). The second stage uses 137500 US gallons (520 m^3) of methylene chloride pre-cooled to −97 °F (−72 °C). This can cool 450 pounds (204 kg) per second of humid air from 80 °F (27 °C) to −65 °F (−54 °C) for 40 minutes.[4]

References

[1] " National Register Information System (http://www.nr.nps.gov/)". *National Register of Historic Places*. National Park Service. 2008-04-15. .

[2] " McKinley Climatic Laboratory (http://www.aiaa.org/tc/gt/facility_database/Climatic2008.pdf)". *46th Test Wing Fact Sheet*. US Air Force. . Retrieved 2009-01-16.

[3] " McKinley Climatic Laboratory (http://www.asme.org/Communities/History/Landmarks/McKinley_Climatic_Laboratory.cfm)". *Landmarks*. American Society of Mechanical Engineers. . Retrieved 2009-01-06.

[4] " McKinley Climatic Laboratory, Eglin Air Force Base, Florida (http://files.asme.org/ASMEORG/Communities/History/Landmarks/5590.pdf)" (PDF). *McKinley Climatic Laboratory brochure*. ASME. . Retrieved 2009-01-06.

[5] " F-117 on ice at McKinley Climatic Laboratory (http://www.eglin.af.mil/photos/media_search.asp?q=mckinley&page=1)". *Eglin Air Force Base Photos*. US Air Force. . Retrieved 2009-01-16.

[6] " F-22 endures 3-week, cold-weather test at Eielson (http://www.af.mil/news/story.asp?id=123077428)". *Air Force Link*. US Air Force. . Retrieved 2009-01-16.

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Mechanical advantage

In physics and engineering, **mechanical advantage** (**MA**) is the factor by which a mechanism multiplies the force or torque put into it. Generally, the mechanical advantage is calculated as follows:

$$MA = \frac{\text{distance over which effort is applied}}{\text{distance over which the load is moved}}$$

or more simply:

$$MA = \frac{\text{output force}}{\text{input force}}$$

The first equation shows that the force exerted IN to the machine multiplied by the distance moved IN will always be equal to the force exerted OUT of the machine multiplied by the distance moved OUT. For example, using a block and tackle with 6 ropes, and a 600 pound load, the operator would be required to pull the rope 6 feet, and exert 100 pounds of force to lift the 600 pound load 1 foot.

The second equation is a simplified formula based just on the forces in and out. Using the example above, 100 pounds of force IN results in 600 pounds of force OUT, an MA of 6. Both of these equations calculate only the ideal mechanical advantage (IMA) and ignore any losses due to friction. The actual mechanical advantage (AMA) includes those frictional losses. The difference between the two is the → mechanical efficiency of the system.

Types

There are two types of mechanical advantage: ideal mechanical advantage (IMA) and actual mechanical advantage (AMA).

Ideal mechanical advantage

The *ideal mechanical advantage* (IMA), or *theoretical mechanical advantage*, is the mechanical advantage of an ideal machine. It is usually calculated using physics principles because there is no ideal machine.

The IMA of a machine can be found with the following formula:

$$IMA = \frac{D_E}{D_R}$$

where

D_E equals the 'effort distance' (the distance from the fulcrum to where the effort is applied)

D_R equals the resistance distance (the distance from the fulcrum to where the resistance is applied)

Actual mechanical advantage

The *actual mechanical advantage* (AMA) is the mechanical advantage of a real → machine. Actual mechanical advantage takes into consideration real world factors such as energy lost in friction.

The AMA of a machine is calculated with the following formula:

$$AMA = \frac{R}{E_{\text{actual}}}$$

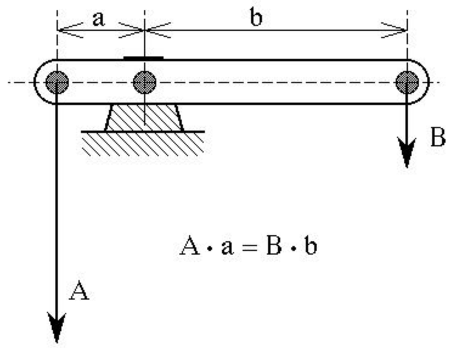
where

R = resistance force

E_{actual} = actual effort force

Simple machines

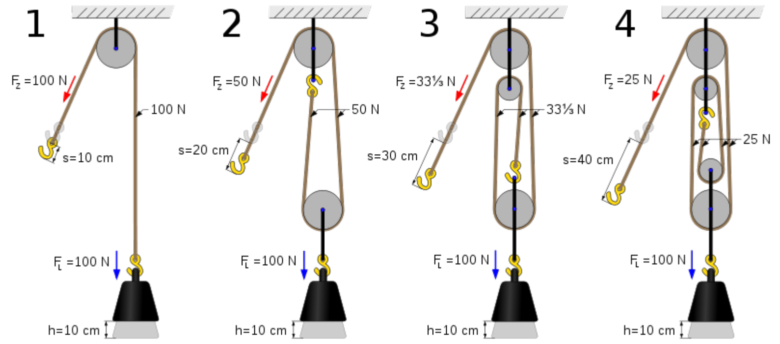
The following → simple machines exhibit a mechanical advantage:



Beam balanced around a fulcrum

- The beam shown is in static equilibrium around the fulcrum. This is due to the moment created by vector force "*A*" counterclockwise (moment *A**a) being in equilibrium with the moment created by vector force "*B*" clockwise (moment *B**b). The relatively low vector force "*B*" is translated in a relatively high vector force "*A*". The force is thus increased in the ratio of the forces *A : B*, which is equal to the ratio of the distances to the fulcrum *b : a*. This ratio is called the mechanical advantage. This idealised situation does not take into account friction. For more explanation, see also → lever.
- Wheel and axle motion (e.g. screwdrivers, doorknobs): A wheel is essentially a lever with one arm the distance between the axle and the outer point of the wheel, and the other the radius of the axle. Typically this is a fairly large difference, leading to a proportionately large mechanical advantage. This allows even simple wheels with wooden axles running in wooden blocks to still turn freely, because their friction is overwhelmed by the rotational force of the wheel multiplied by the mechanical advantage.
- Pulley: Pulleys change the direction of a tension force on a flexible material, e.g. a rope or cable. In addition, pulleys can be "added together" to create mechanical advantage, by having the flexible material looped over several pulleys in turn. Adding more loops and pulleys increases the mechanical advantage.
- Screw: A screw is essentially an inclined plane wrapped around a cylinder. The run over the rise of this inclined plane is the mechanical advantage of a screw.[1]

Pulleys



An example of a rope and pulley system illustrating mechanical advantage.

Consider lifting a weight with rope and pulleys. A rope looped through a pulley attached to a fixed spot, e.g. a barn roof rafter, and attached to the weight is called a *single pulley*. It has an MA = 1 (assuming frictionless bearings in the pulley), meaning no mechanical advantage (or disadvantage) however advantageous the change in direction may be.

A *single movable pulley* has an MA of 2 (assuming frictionless bearings in the pulley). Consider a pulley attached to a weight being lifted. A rope passes around it, with one end attached to a fixed point above, e.g. a barn roof rafter, and a pulling force is applied upward to the other end with the two lengths parallel. In this situation the distance the lifter must pull the rope becomes twice the distance the weight travels, allowing the force applied to be halved. Note: if an additional pulley is used to change the direction of the rope, e.g. the person doing the work wants to stand on the ground instead of on a rafter, the mechanical advantage is not increased.

By looping more ropes around more pulleys we can continue to increase the mechanical advantage. For example if we have two pulleys attached to the rafter, two pulleys attached to the weight, one end attached to the rafter, and someone standing on the rafter pulling the rope, we have a mechanical advantage of four. Again note: if we add another pulley so that someone may stand on the ground and pull down, we still have a mechanical advantage of four.

Here are examples where the fixed point is not obvious:

- A velcro strap on a shoe passes through a slot and folds over on itself. The slot is a movable pulley and the MA = 2.
- Two ropes laid down a ramp attached to a raised platform. A barrel is rolled onto the ropes and the ropes are passed over the barrel and handed to two workers at the top of the ramp. The workers pull the ropes together to get the barrel to the top. The barrel is a movable pulley and the MA = 2. If there is enough friction where the rope is pinched between the barrel and the ramp, the pinch point becomes the attachment point. This is considered a fixed attachment point because the rope above the barrel does not move relative to the ramp. Alternatively the ends of the rope can be attached to the platform.
- Block and tackle: MA = 3

Screws

The theoretical mechanical advantage for a screw can be calculated using the following equation:[2]

$$MA = \frac{\pi d_m}{l}$$

where

d_m = the mean diameter of the screw thread

l = the lead of the screw thread

Note that the actual mechanical advantage of a screw *system* is greater, as a screwdriver or other screw driving system has a mechanical advantage as well.

- Inclined plane: MA = length of slope ÷ height of slope

See also

- Balanced arm lamps
- Gear ratio

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External links

- Gears and pulleys [5]
- Mechanical engineering — pulleys [6]
- Mechanical advantage — video [7]

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[2] United States Bureau of Naval Personnel, p. 5-4.
[3] http://books.google.com/books?id=VuK7m3LU8rgC
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[5] http://www.technologystudent.com/gears1/geardex1.htm
[6] http://www.swe.org/iac/lp/pulley_03.html
[7] http://ca.youtube.com/watch?v=yfAdmRJDKIc

Mechanical efficiency

In physics, **mechanical efficiency** is the effectiveness of a machine and is defined as

$$\text{Mechanical Efficiency} = \frac{\text{Work output}}{\text{Work input}}$$

Mechanical Efficiency is the ratio of work input to work output. It is often expressed as a percentage. The efficiency of an ideal machine is 100 percent but an actual machine's efficiency will always be less than 100% because of the Second law of thermodynamics which states that the quality of energy will decay, eventually becoming heat. This means that some of the work put into the system is transformed (lost) into thermal energy (heat). In a mechanical system, friction is the most common cause of the work lost to heat.

The actual → Mechanical advantage of a system is always less than the ideal mechanical advantage due to these losses. Another way to express mechanical efficiency is it is the ratio of actual mechanical advantage to ideal mechanical advantage.

100 percent Mechanical Efficiency is also the core principal in creating a perpetual motion machine of the third kind. By "re-using" the Work Output to conserve the Work Input, a perpetual motion machine could maintain its movement forever. In controlled environments, low friction mechanisms can come close to the ideal efficiency. However, to maintain a perfectly ideal mechanism, the temperature output must be the absolute zero, which is impossible to reach due to the Third law of thermodynamics. Therefore, a perfect mechanical efficiency can never be achieved.

See also

- → Mechanical advantage
- → Thermal efficiency
- Electrical efficiency
- Internal combustion engine
- Electric motor

Mechanical engineering technology

Mechanical engineering technology is the application of physical principles and current technological developments to the creation of useful machinery and operation design. Technologies such as solid models may be used as the basis for finite element analysis (FEA) and / or computational fluid dynamics (CFD) of the design. Through the application of computer-aided manufacturing (CAM), the models may also be used directly by software to create "instructions" for the manufacture of objects represented by the models, through computer numerically-controlled (CNC) machining or other automated processes, without the need for intermediate drawings.

Mechanical engineering technologists are also expected to understand and be able to apply concepts from the chemistry and electrical engineering fields. Mechanical engineering technologists are expected to apply current technologies and principals to machine and product design, production, and manufacturing processes.

Mechanical Engineering Technology coursework

Fundamental subjects of mechanical engineering technology include:

- Dynamics
- Statics
- Strength of materials
- → Heat transfer
- Fluid mechanics/fluid dynamics
- Applied thermodynamics
- Machine design and kinematics
- Material science
- Manufacturing process
- Engineering drafting and standard familiarization classes
- Circuit and electrical analysis
- Instrumentation and measurement
- HVAC
- → Hydraulics and pneumatics
- Quality assurance
- Technical communications

See also

- Aerospace engineering
- Civil engineering
- Electrical engineering technology
- Industrial engineering
- → Mechanical engineering
- Nuclear engineering
- → Power engineering
- Systems engineering

External links

- List of Mechanical Engineering Technology Programs [1]

References

[1] http://www.abet.org/accredittac.asp

Mechanical singularity

In engineering, a **mechanical singularity** is a position or configuration of a mechanism or a machine where the subsequent behaviour cannot be predicted, or the forces or other physical quantities involved become infinite or nondeterministic.

When the underlying engineering equations of a mechanism or machine are evaluated at the singular configuration (if any exists), then those equations exhibit mathematical singularity.

Examples of mechanical singularities are gimbal lock, and the wobbly, chaotic motion of excessively tall flagpoles or chimneys right before collapse.

Modal analysis

Modal analysis is the study of the dynamic properties of structures under vibrational excitation.

Modal analysis, or more accurately experimental modal analysis, is the field of measuring and analysing the dynamic response of structures and or fluids when excited by an input. Examples would include measuring the vibration of a car's body when it is attached to an electromagnetic shaker, or the noise pattern in a room when excited by a loudspeaker.

Modern day modal testing systems are composed of transducers (typically accelerometers and load cells), an analog-to-digital converter frontend (to digitize analog instrumentation signals) and a host PC to view the data and analyze it.

Classically this was done with a SIMO (single-input, multiple-output) approach, that is, one excitation point, and then the response is measured at many other points. In the past a hammer survey, using a fixed accelerometer and a roving hammer as excitation, gave a MISO analysis, which is mathematically identical to SIMO, due to the principle of reciprocity. In recent years MIMO has become more practical, where partial coherence analysis identifies which part of the response comes from which excitation source.

Typical excitation signals can be classed as impulse, broadband, swept sine, chirp, and possibly others. Each has its own advantages and disadvantages.

The analysis of the signals typically relies on Fourier analysis. The resulting transfer function will show one or more resonances, whose characteristic mass, frequency and damping can be estimated from the measurements.

The animated display of the mode shape is very useful to NVH engineers.

The results can also be used to correlate with finite element analysis normal mode solutions.

References

- D. J. Ewins: *Modal Testing: Theory, Practice and Application*

See also

- Frequency analysis
- Modal analysis using FEM
- Mode shape
- Eigenanalysis
- Structural dynamics
- Vibration
- Modal testing
- Seismic performance analysis

External links

- A Brief Introduction to Modal Analysis [1]
- An Introduction on the Topic from The Society for Experimental Mechanics [2]
- International Modal Analysis Conference (IMAC) [3]
- NAFEMS - Modal Analysis in Virtual Prototyping and Product Validation [4]
- An Integrated Approach to the Dynamic Testing of Aerospace Structures [5]

References

[1] http://www.lmsintl.com/modal-analysis
[2] http://www.sem.org/ArtDownLoad/msma98.pdf
[3] http://www.sem.org/CONF-IMAC-TOP.asp
[4] http://www.nafems.org/events/nafems/2009/modal/
[5] http://www.lmsintl.com/dynamic-testing-aerospace-structures

Motion ratio

The **motion ratio** of a mechanism is the ratio of the displacement of the point of interest to that of another point.

The most common example is in a vehicle's suspension, where it is used to describe the displacement and forces in the springs and shock absorbers. The force in the spring is (roughly) the vertical force at the contact patch divided by the motion ratio, and the wheel rate is the spring rate divided by the motion ratio squared.

This is described as the Installation Ratio in the reference. Motion Ratio is the more common term in the industry, but sometimes is used to mean the inverse of the above definition.

References

- Milliken and Milliken "Race Car Vehicle Dynamics"

Non-synchronous transmission

Transmission types

Manual
• Sequential manual
→ Non-synchronous
Automatic
• Tiptronic
Semi-automatic
• Electrohydraulic manual transmission
• Twin-clutch gearbox
  • Direct-Shift Gearbox
  • Twin Clutch SST
• Saxomat
• Zeroshift

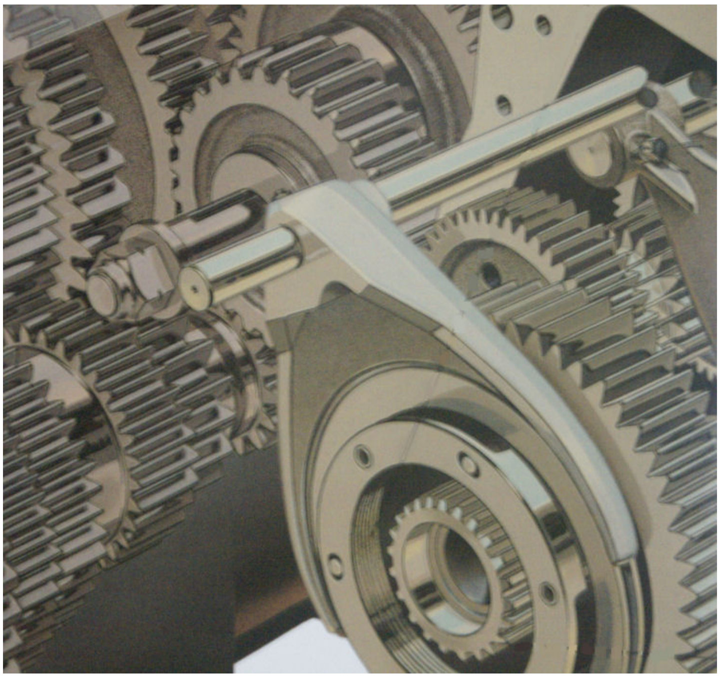
Continuously variable • Variomatic • multitronic
Bicycle gearing • Derailleur gears • Hub gears

A **non-synchronous transmission** is a form of transmission based on gears that do not use synchronizing mechanisms. They are found primarily in various types of agricultural, and commercial vehicles. Because the gear boxes are engineered without "cone and collar" synchronizing technology, the non-synchronous transmission type requires an understanding of gear range, torque, engine power, range selector,[1] multi-functional clutch, and shifter functions. Engineered to pull tremendous loads, often equal to or exceeding 40 tons, some vehicles may also use a combination of transmissions for different mechanisms. An example would be a PTO.[2]

History

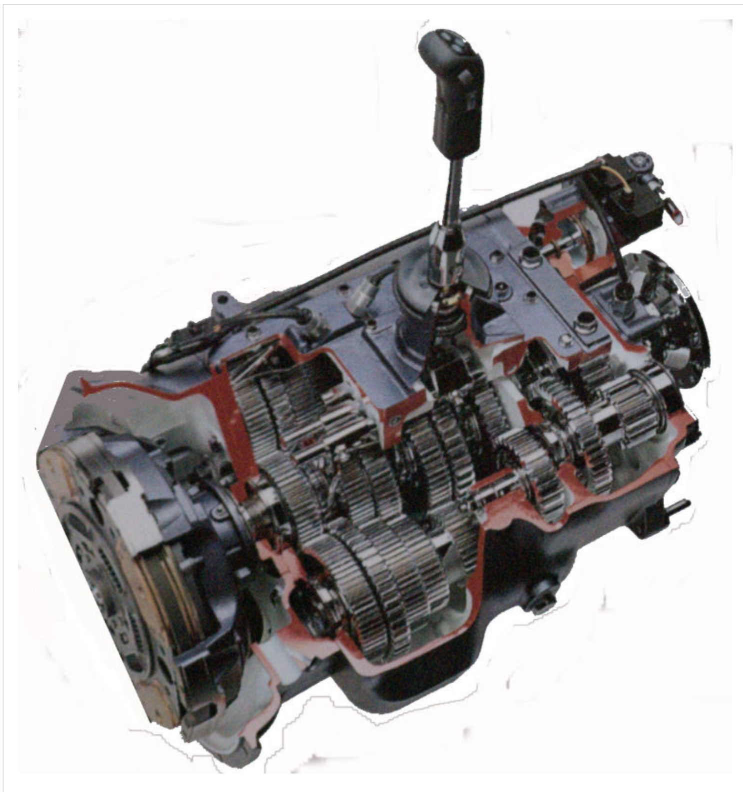
In 1842, the reversing lever was invented and patented as the Walschaerts valve gear in Belgium, and reversing lever descriptions exists in British, and American mechanic's diagrams.[3] In 1890, Panhard used a chain-drive with a Daimler engine in a horseless carriage. Industrial marketing has since then coined spectacular names for various vehicle parts. Changing from the Locomobile,[4] a 1906 race-car to what is now called the automobile, advertisers used design wording from the engineering departments to give new ideas a desirable appeal for sales promotions. From 1932, synchronizer mechanisms began to appear in automotive transmissions. The split off of automotive transmission types that has prevailed in engineering designs uses three major categories: *automatic*, *manual*, and *non-synchronous*. Some of the differences are improvements, including the continuously variable transmission installed in hybrid vehicles that are powered partly by an internal combustion engine, and partly by an electric motor. The concepts of transmission continue to employ methods for transferring the most conceivably efficient use of power.

How non-synchronization works



Non-synchronous transmissions are engineered[5] with the understanding that a trained operator will be shifting gears in a known coordination of timing. Commercial vehicle operators use a double-clutching technique that is taught in driver's trade schools. With payloads of cargo ranging in commercial freight of 80,000 lbs (40 tons) or more, some heavy haulers have over 24 gears that an operator will shift through before reaching a top cruising speed of 70 mph. Many low-low (creeper) gears are used in farm equipment to plow, till, or harvest. Also see Engineering vehicle. An inexperienced operator would suddenly find a piece of heavy equipment stuck in gear under full power, or even worse unable to shift into gear a runaway vehicle in neutral headed down a steep slope, unless he understood the synchronizing skill, and torque issues in non-synchronous transmissions. Many mountain roads require heavy equipment operators to remain in gear and not shift while passing down a steep grade. For more details about steep grade operation see either jake brake, or engine brake. Many other circumstances face operators of non-synchronous transmissions. Safety and operator skills need to be learned before operating any of these types of vehicles.

Double clutching (commercial motor vehicle)



Operators of 18-wheelers, farm equipment, tractors & other heavy equipment learn to float the transmission in & out of gear, beginning with dis-engaging the clutch by pressing the clutch pedal *only part way, enough* to pull the transmission out of gear, re-engaging the clutch in neutral (between gears by letting the clutch pedal all the way back out) to let the engine revolutions deccelerate enough for the idle sprockets to shift, and free gear shafts to slow their revolutions per minute (RPM), then dis-engage the clutch again (by pressing the clutch pedal *only part way to the floor*) a 2nd time, and float the higher gear into engaging the drive coupling & fly wheel and engaging the clutch plates. Professional operators of heavy equipment take extensive safety training before ever learning how to double-clutch. Once an operator is familiar with range, range selector, rpm, velocity, and torque of heavy equipment like an 18-wheeler, they can begin to anticipate when to shift gears. Operators become familiar with ranges of gears. They also learn not to leave their foot on the clutch while driving, because these types of transmissions use the clutch for several very different purposes. The depth the clutch is depressed to the floor will determine what the clutch will be doing as a synchronizing function.

Clutch brake

Unlike any other type of transmission, non-synchronous transmissions often have a mechanism for slowing down, or stopping an idle gear. In commercial motor vehicles, this mechanism is called the *clutch brake*, and is used by depressing the clutch all the way to the floor. This is useful in 18-wheelers that have just started their diesel engines, and are releasing parking locks, and engaging the transmission from a stop. The clutch brake not only slows or stops the idle gear axis, but can also prevent shifting into gear until the clutch is lifted a few inches off the floor. In order to shift into gear, the clutch must be half way off the floor, otherwise the clutch brake will prevent the transmission from being shifted into or out of gear. Mechanics must often repair or replace the *clutch brake* in a non-synchronous transmission when an inexperienced operator wears it out, it becomes inoperable, or has lost it's function.

Comparison of transmissions

Non-synchronous transmissions[6] are designed to depend upon an operator experienced in changing gears. These types of transmissions are known to heavy equipment operators as non-synchronous transmissions. The operators must understand how to shift these transmissions into and out of gear. Many learn how to do this in certifying schools.

All *automatic transmissions* have synchronizing mechanisms. Most manual transmissions also have synchronizers[7] . But, there are still other types of transmissions used mostly in commercial applications that are non-synchronous.

Fully synchronous,hydrau-pneumatic systems are designed to change gears based on engine performance, and other velocity indicators, delivering torque to drive wheels. These transmissions have synchronizing mechanisms (called cone & collar synchronizers) that are designed to keep gear dog-teeth from being broken off.

Heavy equipment for industrial, military, or farm use have different torque and load issues. They have unique stress from massive horsepower that would make converter faces shear. For the reasons of engineering a dependable, longer-life piece of equipment, these machines often use non-synchronous transmissions.

Any transmission that requires the operator to manually synchronize engine crank-shaft revolutions (RPM) with drive-shaft revolutions is non-synchronous.

See also

- → Mechanical engineering
- Gear ratio
- unsynchronized transmission

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[2] " 6-10 Bolt Mechanical Power Takeoff (http://news.thomasnet.com/fullstory/10489/1723)". . Retrieved 2007-07-16.
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- Core Transmissions (http://www.coresuppliers.com/transmission_core_supplier.htm)-for display only: this is not an endorsement
- ATA - American Trucking Association (http://www.truckline.com)- not a global reference
- PTDI acronym for Professional Truck Driver Institute - pertains to U.S. only
- Federal Motor Carrier Safety Administration (http://www.nh.gov/safety/divisions/dmv/documents/nhcdm.pdf)New Hampshire Dept. of Motor Vehicles 2005 Commercial Driver's License Manual, sec. 13.1.11 Section 13 page 13-3 says *Double clutch if vehicle is equipped with non-synchronized transmission*. (note: this file is a complete manual in Adobe Acrobat format with a file size of over 10 Megabytes).

Nutate

Verb meaning to rock, sway, or nod; usually involuntarily

In Engineering

In engineering, a nutating motion is a motion similar to a → swashplate. A → swashplate contains pistons or follower rods, however, which many nutating devices do not have. The motion is similar to the motions of coin or a tire wobbling on the ground after being dropped with the flat side down.

The nutating motion is widely employed in flowmeters and pumps. The displacement of volume for one revolution is first determined. The speed of the device in revolutions per unit time is measured. In the case of flowmeters, the product of the rotational speed and the displacement per revolution is then taken to find the flow rate.

In Popular Culture

This term was used by MIT physicist Peter Fisher on the television show Late Night with Conan O'Brien on February 8, 2008. Fisher used the term to describe the motion of a spinning ring as it began to slow down and wobble.

In Astronomy

See Nutation.

See also

→ swashplate

References

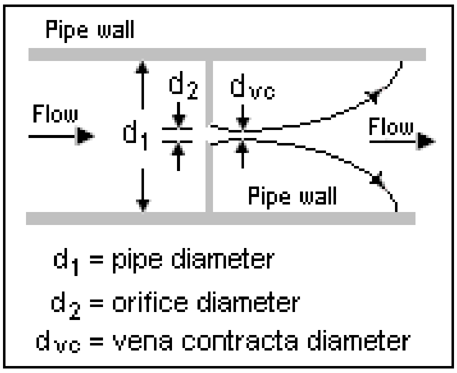
|Nutating Disk Displacement Flowmeter [1]

References

[1] http://www.engineersedge.com/instrumentation/nutating_disk_displacment_meter.htm

Orifice plate

An **orifice plate** is a device used to measure the rate of fluid flow. It uses the same principle as a Venturi nozzle, namely Bernoulli's principle which says that there is a relationship between the pressure of the fluid and the velocity of the fluid. When the velocity increases, the pressure decreases and vice versa.



Flat-plate, sharp-edge orifice

An orifice plate is basically a thin plate with a hole in the middle. It is usually placed in a pipe in which fluid flows. As fluid flows through the pipe, it has a certain velocity and a certain pressure. When the fluid reaches the orifice plate, with the hole in the middle, the fluid is forced to converge to go through the small hole; the point of maximum convergence actually occurs shortly downstream of the physical orifice, at the so-called vena contracta point (see drawing to the right). As it does so, the velocity and the pressure changes. Beyond the vena contracta, the fluid expands and the velocity and pressure change once again. By measuring the difference in fluid pressure between the normal pipe section and at the vena contracta, the volumetric and mass flow rates can be obtained from Bernoulli's equation.

Uses

Orifice plates are most commonly used for continuous measurement of fluid in pipes. They are also used in some small river systems to measure flow at locations where the river passes through a culvert or drain. Only a small number of rivers are appropriate for the use of the technology since the plate must remain completely immersed i.e the approach pipe must be full, and the river must be substantially free of debris.

In the natural environment large orifice plates are used to control onward flow in flood relief dams. in these structures a low dam is placed across a river and in normal operation the water flows through the orifice plate unimpeded as the orifice is substantially larger than the normal flow cross section. However, in floods, the flow rate rises and floods out the orifice plate which can then only pass a flow determined by the physical dimensions of the orifice. Flow is then held back behind the low dam in a temporary reservoir which is slowly discharged through the orifice when the flood subsides.

Incompressible flow through an orifice

By assuming steady-state, incompressible (constant fluid density), inviscid, laminar flow in a horizontal pipe (no change in elevation) with negligible frictional losses, Bernoulli's equation reduces to an equation relating the conservation of energy between two points on the same streamline:

$$P_1 + \frac{1}{2} \cdot \rho \cdot V_1^2 = P_2 + \frac{1}{2} \cdot \rho \cdot V_2^2$$

or:

$$P_1 - P_2 = \frac{1}{2} \cdot \rho \cdot V_2^2 - \frac{1}{2} \cdot \rho \cdot V_1^2$$

By continuity equation:

$Q = A_1 \cdot V_1 = A_2 \cdot V_2$ or $V_1 = Q/A_1$ and $V_2 = Q/A_2$:

$$P_1 - P_2 = \frac{1}{2} \cdot \rho \cdot \left(\frac{Q}{A_2}\right)^2 - \frac{1}{2} \cdot \rho \cdot \left(\frac{Q}{A_1}\right)^2$$

Solving for Q :

$$Q = A_2 \sqrt{\frac{2\;(P_1 - P_2)/\rho}{1 - (A_2/A_1)^2}}$$

and:

$$Q = A_2 \sqrt{\frac{1}{1 - (d_2/d_1)^4}} \sqrt{2\;(P_1 - P_2)/\rho}$$

The above expression for Q gives the theoretical volume flow rate. Introducing the beta factor $\beta = d_2/d_1$ as well as the coefficient of discharge C_d :

$$Q = C_d\; A_2 \sqrt{\frac{1}{1 - \beta^4}} \sqrt{2\;(P_1 - P_2)/\rho}$$

And finally introducing the meter coefficient C which is defined as $C = \frac{C_d}{\sqrt{1 - \beta^4}}$ to obtain the final equation for the volumetric flow of the fluid through the orifice:

$$(1) \qquad Q = C\; A_2 \sqrt{2\;(P_1 - P_2)/\rho}$$

Multiplying by the density of the fluid to obtain the equation for the mass flow rate at any section in the pipe:[1] [2] [3] [4]

$$(2) \qquad \dot{m} = \rho\, Q = C\; A_2 \sqrt{2\;\rho\;(P_1 - P_2)}$$

where:

Q	= volumetric flow rate (at any cross-section), m³/s
$\dot{m}$	= mass flow rate (at any cross-section), kg/s
C_d	= coefficient of discharge, dimensionless
C	= orifice flow coefficient, dimensionless
A_1	= cross-sectional area of the pipe, m²
A_2	= cross-sectional area of the orifice hole, m²
d_1	= diameter of the pipe, m
d_2	= diameter of the orifice hole, m

β	= ratio of orifice hole diameter to pipe diameter, dimensionless
V_1	= upstream fluid velocity, m/s
V_2	= fluid velocity through the orifice hole, m/s
P_1	= fluid upstream pressure, Pa with dimensions of kg/(m·s^2)
P_2	= fluid downstream pressure, Pa with dimensions of kg/(m·s^2)
ρ	= fluid density, kg/m^3

Deriving the above equations used the cross-section of the orifice opening and is not as realistic as using the minimum cross-section at the vena contracta. In addition, frictional losses may not be negligible and viscosity and turbulence effects may be present. For that reason, the coefficient of discharge C_d is introduced. Methods exist for determining the coefficient of discharge as a function of the Reynolds number.[2]

The parameter $\sqrt{1-\beta^4}$ is often referred to as the *velocity of approach factor*[1] and dividing the coefficient of discharge by that parameter (as was done above) produces the flow coefficient C . Methods also exist for determining the flow coefficient as a function of the beta function β and the location of the downstream pressure sensing tap. For rough approximations, the flow coefficient may be assumed to be between 0.60 and 0.75. For a first approximation, a flow coefficient of 0.62 can be used as this approximates to fully developed flow.

An orifice only works well when supplied with a fully developed flow profile. This is achieved by a long upstream length (20 to 40 pipe diameters, depending on Reynolds number) or the use of a flow conditioner. Orifice plates are small and inexpensive but do not recover the pressure drop as well as a venturi nozzle does. If space permits, a venturi meter is more efficient than a flowmeter.

Flow of gases through an orifice

In general, equation (2) is applicable only for incompressible flows. It can be modified by introducing the expansion factor Y to account for the compressibility of gases.

$$(3) \qquad \dot{m} = \rho_1\,Q = C\,Y\,A_2\,\sqrt{2\,\rho_1\,(P_1-P_2)}$$

Y is 1.0 for incompressible fluids and it can be calculated for compressible gases.[2]

Calculation of expansion factor

The expansion factor Y, which allows for the change in the density of an ideal gas as it expands isentropically, is given by:[2]

$$Y = \sqrt{r^{2/k}\left(\frac{k}{k-1}\right)\left(\frac{1-r^{(k-1)/k}}{1-r}\right)\left(\frac{1-\beta^4}{1-\beta^4\,r^{2/k}}\right)}$$

For values of β less than 0.25, β^4 approaches 0 and the last bracketed term in the above equation approaches 1. Thus, for the large majority of orifice plate installations:

$$(4) \qquad Y = \sqrt{r^{2/k}\left(\frac{k}{k-1}\right)\left(\frac{1-r^{(k-1)/k}}{1-r}\right)}$$

where:

Y	= Expansion factor, dimensionless

r	$= P_2/P_1$
k	= specific heat ratio (c_p/c_v), dimensionless

Substituting equation (4) into the mass flow rate equation (3):

$$\dot{m} = C\ A_2\ \sqrt{2\ \rho_1\ \left(\frac{k}{k-1}\right)\left[\frac{(P_2/P_1)^{2/k} - (P_2/P_1)^{(k+1)/k}}{1 - P_2/P_1}\right](P_1 - P_2)}$$

and:

$$\dot{m} = C\ A_2\ \sqrt{2\ \rho_1\ \left(\frac{k}{k-1}\right)\left[\frac{(P_2/P_1)^{2/k} - (P_2/P_1)^{(k+1)/k}}{(P_1 - P_2)/P_1}\right](P_1 - P_2)}$$

and thus, the final equation for the non-choked (i.e., sub-sonic) flow of ideal gases through an orifice for values of β less than 0.25:

$$(5) \qquad \dot{m} = C\ A_2\ \sqrt{2\ \rho_1\ P_1\ \left(\frac{k}{k-1}\right)\left[(P_2/P_1)^{2/k} - (P_2/P_1)^{(k+1)/k}\right]}$$

Using the ideal gas law and the compressibility factor (which corrects for non-ideal gases), a practical equation is obtained for the non-choked flow of real gases through an orifice for values of β less than 0.25:[3] [4] [5]

$$(6) \qquad \dot{m} = C\ A_2\ P_1\ \sqrt{\frac{2\ M}{Z\ R\ T_1}\left(\frac{k}{k-1}\right)\left[(P_2/P_1)^{2/k} - (P_2/P_1)^{(k+1)/k}\right]}$$

where:

k	= specific heat ratio (c_p/c_v), dimensionless
$\dot{m}$	= mass flow rate at any section, kg/s
C	= orifice flow coefficient, dimensionless
A_2	= cross-sectional area of the orifice hole, m²
ρ_1	= upstream real gas density, kg/m³
P_1	= upstream gas pressure, Pa with dimensions of kg/(m·s²)
P_2	= downstream pressure, Pa with dimensions of kg/(m·s²)
M	= the gas molecular mass, kg/mol (also known as the molecular weight)
R	= the Universal Gas Law Constant = 8.3145 J/(mol·K)
T_1	= absolute upstream gas temperature, K
Z	= the gas compressibility factor at P_1 and T_1, dimensionless

A detailed explanation of choked and non-choked flow of gases, as well as the equation for the choked flow of gases through restriction orifices, is available at Choked flow.

The flow of real gases through thin-plate orifices never becomes fully choked. The mass flow rate through the orifice continues to increase as the downstream pressure is lowered to a perfect vacuum, though the mass flow rate increases slowly as the downstream pressure is reduced below the critical pressure.[6] "Cunningham (1951) first drew attention to the fact that choked flow will not occur across a standard, thin, square-edged orifice."[7]

Permanent pressure drop for incompressible fluids

For a square-edge orifice plate with flange taps[8] :

$$\frac{\Delta P_p}{\Delta P_i} = 1 - 0.24\beta - 0.52\beta^2 - 0.16\beta^3$$

where:

ΔP_p = permanent pressure drop

ΔP_i = indicated pressure drop at the flange taps

$\beta = d_2/d_1$

And rearranging the formula near the top of this article:

$$\Delta P_i = P_1 - P_2 = \frac{Q^2\ \rho\ (1-\beta^4)}{2\ C_d^2\ A_2^2} = \frac{Q^2\ \rho\ (1-\beta^4)}{2\ C_d^2\ A_1^2\ \beta^4}$$

See also

- Accidental release source terms
- Choked flow
- Flowmeter
- De Laval nozzle
- Pitot tube
- Rocket engine nozzle
- Venturi effect

External links

- Orifice Flow Calculator [9]
- Engineering Tool Box (orifice theory) [10]
- Omega Engineering Flow Measurement Orientation [11]
- Online orifice gas-flow calculator [12] - Lenoxlaser.com

References

[1] Lecture, University of Sydney (http://www.aeromech.usyd.edu.au/aero/cvanalysis/node3.shtml#node43)

[2] Perry, Robert H. and Green, Don W. (1984). *Perry's Chemical Engineers' Handbook* (Sixth Edition ed.). McGraw Hill. ISBN 0-07-049479-7.

[3] *Handbook of Chemical Hazard Analysis Procedures*, Appendix B, Federal Emergency Management Agency, U.S. Dept. of Transportation, and U.S. Environmental Protection Agency, 1989. Handbook of Chemical Hazard Analysis, Appendix B (http://nepis.epa.gov/Exe/ZyNET.exe/10003MK5.TXT?ZyActionD=ZyDocument&Client=EPA&Index=1986+Thru+1990&Docs=&Query=&Time=&EndTime=&SearchMethod=1&TocRestrict=n&Toc=&TocEntry=&QField=pubnumber^"OSWERHCHAP"&QFieldYear=&QFieldMonth=&QFieldDay=&UseQField=pubnumber&IntQFieldOp=1&ExtQFieldOp=1&XmlQuery=&File=D:\zyfiles\Index Data\86thru90\TXT\00000003\10003MK5.TXT&User=ANONYMOUS&Password=anonymous&SortMethod=h|-&MaximumDocuments=10&FuzzyDegree=0&ImageQuality=r75g8/r75g8/x150y150g16/i425&Display=p|f&DefSeekPage=x&SearchBack=ZyActionL&Back=ZyActionS&BackDesc=Results page&MaximumPages=1&ZyEntry=1&SeekPage=x) Click on PDF icon, wait and then scroll down to page 391 of 520 PDF pages.

[4] *Risk Management Program Guidance For Offsite Consequence Analysis*, U.S. EPA publication EPA-550-B-99-009, April 1999. Guidance for Offsite Consequence Analysis (http://yosemite.epa.gov/oswer/ceppoweb.nsf/vwResourcesByFilename/oca-all.pdf/$file/oca-all.pdf?OpenElement)

[5] *Methods For The Calculation Of Physical Effects Due To Releases Of Hazardous Substances (Liquids and Gases)*, PGS2 CPR 14E, Chapter 2, The Netherlands Organization Of Applied Scientific Research, The Hague, 2005. PGS2 CPR 14E (http://vrom.nl/pagina.html?id=20725)

[6] Section 3 -- Choked Flow (http://www.engsoft.co.kr/download_e/steam_flow_e.htm)
[7] Forum post on 1 Apr 03 19:37 (http://www.eng-tips.com/viewthread.cfm?qid=51260)
[8] Catalog section by AVCO (http://www.avcovalve.com/products/pdfs/Orifice Plates.pdf)
[9] http://www.efunda.com/formulae/smc_fluids/calc_orifice_flowmeter.cfm
[10] http://www.engineeringtoolbox.com/orifice-nozzle-venturi-d_590.html
[11] http://www.omega.com/literature/transactions/volume4/T9904-06-FLOW.html#flow_1
[12] http://www.lenoxlaser.com/calculator/orifice.asp

Oscillating reciprocation

Oscillating reciprocation is an action where a body's displacement 'reciprocates' in a given axis or defined displacement vector and 'oscillates' along that axis usually perpendicular to the defined displacement. eg. the new Sabre Saw's on the market are reciprocating saw's which also oscillate the blade in an up and down fashion perpendicular to the cutting stroke.

See also

- Reciprocation
- Oscillation
- Reciprocating oscillation

Overspeed (engine)

Overspeed is a condition in which an engine is allowed or forced to turn beyond its design limit. The consequences of running an engine too fast vary by engine type and model and depend upon several factors, chief amongst them the duration of the overspeed and by the speed attained. With some engines even a momentary overspeed can result in greatly reduced engine life or even catastrophic failure. The speed of an engine is ordinarily measured in revolutions per minute (RPM).

Examples of overspeed

- In aircraft an engine overspeed will occur should the propeller - ordinarily connected directly to the engine - be forced to turn too fast by high speed airflow while the aircraft is in a dive.
- In jet aircraft an overspeed results when the → axial compressor exceeds its maximum operating RPM - this often leads to the mechanical failure of turbine blades, flameout and complete destruction of the engine.
- In vehicles an engine can be forced to turn too quickly by changing to an inappropriately low gear.
- Most unregulated engines will overspeed should there be no or little load while power is applied.

Overspeed protection

Sometimes a regulator or governor is fitted to make engine overspeed impossible or less likely. For example:

- Many steam engines use a centrifugal governor which centrifugally close a throttle to restrict steam flow as engine speed increases.
- In motor vehicles automatic gearboxes will change gear to prevent the engine from turning too quickly.
- Some aircraft have constant speed units which automatically change propeller pitch to keep the engine running at the optimum speed.

Large diesel engines are sometimes fitted with a secondary protection device [1] which operates if the governor fails. This consists of a flap valve in the air intake. If the engine overspeeds, the air flow through the intake will rise to an abnormal level. This causes the flap valve to snap shut, starving the engine of air and shutting it down.

See also

- Rev limiter
- Diesel engine runaway

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[1] AirTek Systems (http://www.airteksystems.com/pages/positive.html)

Parallel motion

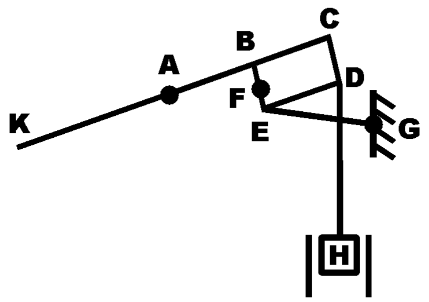
This article concerns parallel motion in mechanics. For parallel motion in music, see the article Contrary motion.

The **parallel motion** is a mechanical linkage invented by the Scottish engineer James Watt in 1784 for his double-acting steam engine.

In previous engines built by Newcomen and Watt, the piston pulled one end of the walking beam downwards during the power stroke using a chain, and the weight of the pump pulled the other end of the beam downwards during the recovery stroke using a second chain, the alternating forces producing the rocking motion of the beam. In Watt's new double-acting engine, the piston produced power on both the upward and downward strokes, so a chain could not be used to transmit the force to the beam. Watt designed the parallel motion to transmit force in both directions whilst keeping the piston rod vertical. He called it "parallel motion" because both the piston and the pump rod were required to move vertically, parallel to one another.

In a letter to his son in 1808, James Watt wrote "I am more proud of the parallel motion than of any other invention I have ever made."[1]

See the diagram on the right. **A** is the journal (bearing) of the walking beam **KAC**, which rocks up and down about **A**. **H** is the piston, which is required to move vertically but not horizontally. The heart of the design is the four-bar linkage consisting of **AB**, **BE** and **EG** and the base link is **AG**, both joints on the framework of the engine. As the beam rocks, point **F** (which is drawn to aid this explanation, but which is not visible on the machine itself) describes an elongated figure-of-eight in mid-air. Since the motion of the walking beam is constrained to a small angle, **F** describes only a short section of the figure-of-eight, which is quite close to a vertical straight line.

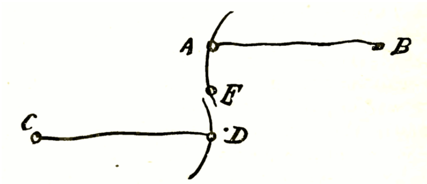


Schematic of Watt's parallel motion

It would have been possible to connect **F** directly to the piston rod, but this would have made the machine an awkward shape, with **G** a long way from the end of the walking beam. To avoid this, Watt added the parallelogram linkage BCDE to form a pantograph. This guarantees that **F** always lies on a straight line between **A** and **D**, and therefore that the motion of **D** is a magnified version of the motion of **F**. **D** is therefore the point to which the piston rod **DH** is attached.


Watt parallel motion on a pumping engine

As already noted, the path of **F** is not a perfect straight line, but merely an approximation. Watt's design produced a deviation of about one part in 4000 from a straight line. Later, in the 19th century, perfect straight-line linkages were invented, beginning with the Peaucellier-Lipkin linkage of 1864.



Hand-drawn diagram by James Watt (1808) in a letter to his son, describing how he arrived at the design.[1]

References

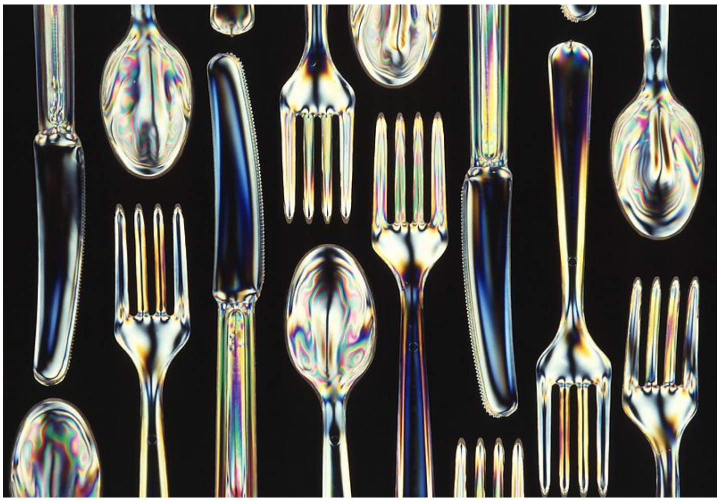
[1] Franz Reuleaux, *The Kinematics of Machinery* (1876), page 4.

- *Linkages* article in Encyclopedia Britannia, 1958.
- *Parallel Motion* article in Encyclopedia Britannia, 1911.
- Robert Stuart, *A Descriptive History of the Steam Engine*, London, J. Knight and H. Lacey, 1824.

See also

- How round is your circle? (http://www.howround.com/) Contains a chapter about James Watt's parallel motion mechanism

Photoelasticity


A picture of plastic utensils created using photoelasticity

Photoelasticity is an experimental method to determine stress distribution in a material. The method is mostly used in cases where mathematical methods become quite cumbersome. Unlike the analytical methods of stress determination, photoelasticity gives a fairly accurate picture of stress distribution even around abrupt discontinuities in a material. The method serves as an important tool for determining the critical stress points in a material and is often used for determining stress concentration factors in irregular geometries.

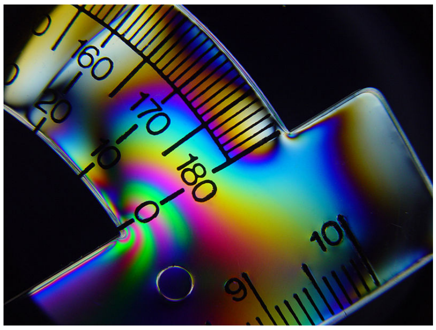
History

Photoelasticity developed at the beginning of the twentieth century with the works of E.G.Coker and L.N.G Filon of University of London. Their book *Treatise on Photoelasticity* published in 1930 by the Cambridge Press became a standard text on the subject. Between 1930 and 1940 many other books in Russian, German and French appeared on the subject.

At the same time lot of development was made in field. Great improvements were achieved in the technique and the equipment was simplified. With the improvement in technology the scope of photoelasticity was also extended to three dimensional state of stress. Many practical problems were solved using photoelasticity and it soon became very popular. A number of photoelastic laboratories were then setup in both educational institutions and industries.

With the advent of digital polariscope using LEDs, continuous monitoring of structures under load became possible. This led to the development of dynamic photoelasticity. Dynamic photoelasticity has contributed greatly to the study of complex phenomena of fracture of materials.

Principles



Tension lines in plastic protractor seen under cross polarized light.

The method is based on the property of birefringence, which is exhibited by certain transparent materials. Birefringence is a property by virtue of which a ray of light passing through a birefringent material experiences two refractive indices. The property of birefringence or double refraction is exhibited by many optical crystals. But photoelastic materials exhibit the property of birefringence only on the application of stress and the magnitude of the refractive indices at each point in the material is directly related to the state of stress at that point. Thus, the first task is to develop a model made out of such materials. The model has a similar geometry to that of the structure on which stress analysis is to be performed. This ensures that the state of the stress in the model is similar to the state of the stress in the structure.

When a ray of plane polarised light is passed through a photoelastic material, it gets resolved along the two principal stress directions and each of these components experiences different refractive indices. The difference in the refractive indices leads to a relative phase retardation between the two component waves. The magnitude of the relative retardation is given by the *stress optic law*:

where R is the induced retardation, C is the stress optic coefficient, t is the specimen thickness, σ_{11} is the first principal stress, and σ_{22} is the second principal stress.
The two waves are then brought together in a polariscope. The phenomena of optical interference takes place and we get a fringe pattern, which depends on relative retardation. Thus studying the fringe pattern one can determine the state of stress at various points in the material.

Isoclinics and isochromatics

Isoclinics are the locus of the points in the specimen along which the principal stresses are in the same direction.

Isochromatics are the locus of the points along which the difference in the first and second principal stress remains the same. Thus they are the lines which join the points with equal maximum shear stress magnitude.

Two-dimensional photoelasticity

Photoelasticity can be applied both to three dimensional and two dimensional state of stress. But the application of photoelasticty to the three dimensional state of stress is more involved as compared to the state of two dimensional / plane stress system. So the present section deals with application of photoelasticity in investigation of a plane stress system. This condition is achieved when the thickness of the prototype is much smaller as compared to dimensions in the plane. Thus one is only concerned with stresses acting parallel to the plane of the model, as other stress components are zero.

The experimental setup varies from experiment to experiment. The two basic kinds of setup used are plane polariscope and circular polariscope.

Plane polariscope

The setup consists of two linear polarizers and a light source. The light source can either emit monochromatic light or white light depending upon the experiment. First the light is passed through the first polarizer which converts the light into plane polarized light. The apparatus is set up in such a way that this plane polarized light then passes through the stressed specimen. This light then follows, at each point of the specimen, the direction of principal stress at that point. The light is then made to pass through the analyzer and we finally get the fringe pattern.

The fringe pattern in a plane polariscope setup consists of both the isochromatics and the isoclinics. The isoclinics change with the orientation of the polariscope while there is no change in the isochromatics.

Circular polariscope

In a circular polariscope setup two quarter-wave plates are added to the experimental setup of the plane polariscope. The first quarter-wave plate is placed in between the polariser and the specimen and the second quarter-wave plate is placed between the specimen and the analyser. The effect of adding the quarter-wave plates is that we get circularly polarised light.

The basic advantage of a circular polariscope over a plane polariscope is that in a circular polariscope setup we only get the isochromatics and not the isoclinics. This eliminates the problem of differentiating between the isoclinics and the isochromatics.

See also

- Acousto-optic modulator
- Photoelastic modulator

References

- *Photoelasticity*, Volume 1 by Max Mark Frocht
- University of Cambridge Page on Photoelasticity [1]
- Photograph of photoelastic stress pattern using plane-polarized white light. [2]

References

[1] http://www.doitpoms.ac.uk/tlplib/photoelasticity/history.php
[2] http://public.fotki.com/ROBERT1010/scitech/photoelasticstress4.html

Physical compression

Physical compression is the result of the subjection of a material to compressive stress, resulting in reduction of volume. The opposite of compression is rarefraction tension.

Explanation

By inducing compression, mechanical properties such as compressive strength or modulus of elasticity, can be measured. Scientists may utilize press machines to induce compression.

In engines

Internal combustion engine

In internal combustion engines it is a necessary condition of economy to compress the explosive mixture before it is ignited: in the Otto cycle, for instance, the second stroke of the piston effects the compression of the charge which has been drawn into the cylinder by the first forward stroke.

Steam engines

The term is applied to the arrangement by which the exhaust valve of a steam engine is made to close, shutting a portion of the exhaust steam in the cylinder, before the stroke of the piston is quite complete. This steam being compressed as the stroke is completed, a cushion is formed against which the piston does work while its velocity is being rapidly reduced, and thus the stresses in the mechanism due to the inertia of the reciprocating parts are lessened. This compression, moreover, obviates the shock which would otherwise be caused by the admission of the fresh steam for the return stroke.

See also

- Buckling
- Strength of materials
- Compression member
- Rarefaction

Pinch analysis

Pinch analysis is a methodology for minimising energy consumption of chemical processes by calculating thermodynamically feasible *energy targets* (or minimum energy consumption) and achieving them by optimising heat recovery systems, energy supply methods and process operating conditions. It is also known as → *process integration*, *heat integration*, *energy integration* or *pinch technology*.

The process data is represented as a set of energy flows, or streams, as a function of heat load (kW) against temperature (deg C). These data are combined for all the streams in the plant to give *composite curves*, one for all *hot streams* (releasing heat) and one for all *cold streams* (requiring heat). The point of closest approach between the hot and cold composite curves is the *pinch temperature* (*pinch point* or just *pinch*), and is where design is most constrained. Hence, by finding this point and starting design there, the energy targets can be achieved using heat exchangers to recover heat between hot and cold streams. In practice, during the pinch analysis, often cross-pinch exchanges of heat are found between a stream with its temperature above the pinch and one below the pinch. Removal of those exchanges by alternative matching makes the process reach its *energy target*.

History

The techniques were first developed in late 1978 by Ph.D. student Bodo Linnhoff from Imperial Chemical Industries (ICI) under the supervision of Professor John Flower from the University of Leeds [1] . He was recruited by then University of Manchester Institute of Technology (UMIST, present day University of Manchester) to continue the work. He then setup a consultation firm known as Linnhoff March International Ltd (later acquired by KBC Energy Services plc [2]).

Many refinements have been developed since and used in a wide range of industries, including non-process situations. Both detailed and simplified (spreadsheet) programs are now available to calculate the energy targets. A commonly used, free pinch analysis program is PinchLeni.

In recent years, pinch analysis has been extended beyond energy applications. It now includes:

- Mass Exchange Networks (El-Halwagi and Manousiouthakis, 1989)
- → Water Pinch (Wang and Smith, 1994; Hallale, 2002)
- Hydrogen Pinch (Hallale et al., 2003)

References

[1] Ebrahim, M (2000). "Pinch technology: an efficient tool for chemical-plant energy and capital-cost saving". *Applied Energy* **65**: 45. doi: 10.1016/S0306-2619(99)00057-4 (http://dx.doi.org/10.1016/S0306-2619(99)00057-4). edit (http://en.wikipedia.org/wiki/Template:cite_doi/10.1016.2fs0306-2619.2899.2900057-4)

[2] http://www.kbcenergyservices.com/default.energy.asp?id=1

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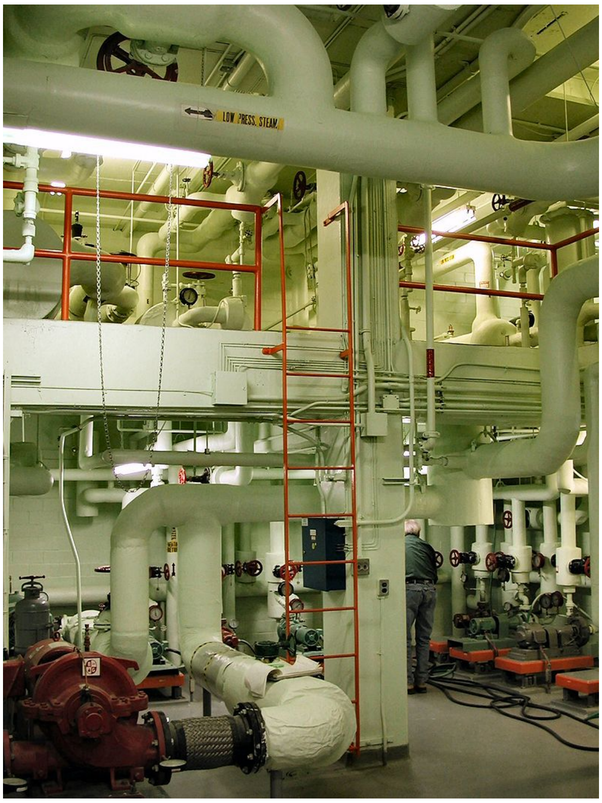
Piping

For other uses, see Piping (sewing), Bagpiping or Pipe.

Within industry, **piping** is a system of pipes used to convey fluids (liquids and gases) from one location to another. The engineering discipline of piping design studies the efficient transport of fluid.[1] [2]



Large-scale piping system in an HVAC mechanical room

Industrial process piping (and accompanying in-line components) can be manufactured from wood, fiberglass, glass, steel, aluminum, plastic, copper, and concrete. The in-line components, known as fittings, valves, and other devices, typically sense and control the pressure, flow rate and temperature of the transmitted fluid, and usually are included in the field of Piping Design (or Piping Engineering). Piping systems are documented in piping and instrumentation diagrams (P&IDs). If necessary, pipes can be cleaned by the tube cleaning process.

"Piping" sometimes refers to Piping Design or the performance of the actual layout of the physical piping within a process plant or commercial building. In earlier days, this was sometimes called Drafting, Technical drawing, Engineering Drawing, and Design but is commonly performed by Designers who have learned to used automated computer aided drawing/computer aided design (CAD) software.

Plumbing is a piping system that most people are familiar with, as it constitutes the form of fluid transportation that is used to provide potable water and fuels to their homes and business. Plumbing pipes also remove waste in the form of sewage, and allow venting of sewage gases to the outdoors. Fire sprinkler systems also use piping, and may transport potable or nonpotable water, or other fire-suppression fluids.

Piping also has many other industrial applications, which are crucial for moving raw and semi-processed fluids for refining into more useful products. Some of the more exotic materials of construction are Inconel, Titanium, chrome-moly and various other steel alloys.

Pipe stress analysis

Process piping and power piping are typically checked by pipe stress engineers to verify that the routing, nozzle loads, hangers, and supports are properly placed and selected such that allowable pipe stress is not exceeded under different situation such as sustain, operating, hydro test etc as per the ASME or any other legislative code and local government standards, Here it is necessary to check the occasional cases such as earthquake, high wind or special vibration, water hammer.[3] [4] This checking is usually done with the assistance of a (finite element) pipe stress analysis program such as Caesar II, ROHR2, CAEPIPE and AUTOPIPE.

Wooden piping history

Early wooden pipes were constructed out of logs that had a large hole bored lengthwise through the center. Later wooden pipes were constructed with staves and hoops similar to wooden barrel construction. Stave pipes have the advantage that they are easily transport as a compact pile of parts on a wagon and then assembled as a hollow structure at the job site. Wooden pipes were especially popular in mountain regions where transport of heavy iron or concrete pipes would have been difficult.

Wooden pipes were easier to maintain than metal, because the wood did not expand or contract as much as metal and so consequently expansion joints and bends were not required. The thickness of wood afforded some insulating properties to the pipes which helped prevent freezing as compared to metal pipes. Wood used for water pipes also does not rot very easily.

In the Western United States where redwood was used for pipe construction, it was found that redwood had "peculiar properties" that protected it from weathering, acids, insects, and fungus growths. Redwood pipes stayed smooth and clean indefinitely while iron pipe by comparison would rapidly begin to scale and corrode and could eventually plug itself up with the corrosion. [5]

See also

- Firestop
- Hydraulic machinery
- Hydrogen piping
- Hydrostatic test
- Pipe network analysis
- Piping and plumbing fittings
    - Coupling (piping)
    - Elbow (piping)
    - Nipple (plumbing)
    - Pipe cap
    - Street elbow
    - Union (plumbing)
    - Valve
    - → Victaulic
- Plastic Pressure Pipe Systems
- Riser clamp

- Thermal insulation
- Gasket

Further reading

- ASME B31.3 Process Piping Guide, Revision 1 [6] from Los Alamos National Laboratory Engineering Standards Manual OST220-03-01-ESM
- Seismic Design and Retrofit of Piping Systems, July 2002 [7] from American Lifelines Alliance website
- Engineering and Design, Liquid Process Piping [8] U.S. Army Corps of Engineers, EM 1110-l-4008, May 1999

External links

- Building services piping links [9] at the Open Directory Project

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Piston motion equations

The motion of a non-offset piston connected to a → crank through a connecting rod (as would be found in internal combustion engines), can be expressed through several mathematical equations. This article shows how these motion equations are derived, and shows an example graph.

Crankshaft geometry

Definitions

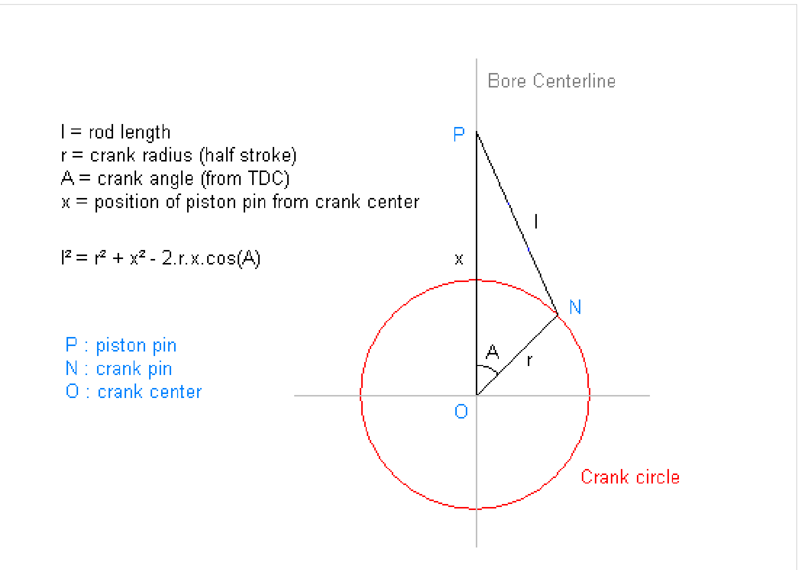


Diagram showing geometric layout of piston pin, crank pin and crank center

l = rod length (distance between → piston pin and crank pin)
r = → crank radius (distance between crank pin and crank center, i.e. half stroke)
A = crank angle (from cylinder bore centerline at TDC)
x = piston pin position (upward from crank center along cylinder bore centerline)
v = piston pin velocity (upward from crank center along cylinder bore centerline)
a = piston pin acceleration (upward from crank center along cylinder bore centerline)
ω = crank angular velocity in rad/s

Angular velocity

The crankshaft angular velocity is related to the engine revolutions per minute (RPM):

$$\omega = \frac{2\pi \cdot rpm}{60}$$

Triangle relation

As shown in the diagram, the crank pin, crank center and piston pin form triangle NOP.
By the cosine law it is seen that:

$$l^2 = r^2 + x^2 - 2 \cdot r \cdot x \cdot \cos A$$

Equations with respect to angular position (Angle Domain)

The equations that follow describe the → reciprocating motion of the piston with respect to crank angle.
Example graphs of these equations are shown below.

Position

Position with respect to crank angle (by rearranging the triangle relation):

$$l^2 - r^2 = x^2 - 2 \cdot r \cdot x \cdot \cos A$$
$$l^2 - r^2 = x^2 - 2 \cdot r \cdot x \cdot \cos A + r^2[(\cos^2 A + \sin^2 A) - 1]$$
$$l^2 - r^2 + r^2 - r^2 \sin^2 A = x^2 - 2 \cdot r \cdot x \cdot \cos A + r^2 \cos^2 A$$
$$l^2 - r^2 \sin^2 A = (x - r \cdot \cos A)^2$$
$$x - r \cdot \cos A = \sqrt{l^2 - r^2 \sin^2 A}$$
$$x = r \cos A + \sqrt{l^2 - r^2 \sin^2 A}$$

Velocity

Velocity with respect to crank angle (take first derivative, using the chain rule):

$$\begin{aligned} x' &= \frac{dx}{dA} \\ &= -r \sin A + \frac{(\frac{1}{2}).(-2).r^2 \sin A \cos A}{\sqrt{l^2 - r^2 \sin^2 A}} \\ &= -r \sin A - \frac{r^2 \sin A \cos A}{\sqrt{l^2 - r^2 \sin^2 A}} \end{aligned}$$

Acceleration

Acceleration with respect to crank angle (take second derivative, using the chain rule and the quotient rule):

$$\begin{aligned} x'' &= \frac{d^2x}{dA^2} \\ &= -r \cos A - \frac{r^2 \cos^2 A}{\sqrt{l^2 - r^2 \sin^2 A}} - \frac{-r^2 \sin^2 A}{\sqrt{l^2 - r^2 \sin^2 A}} - \frac{r^2 \sin A \cos A.(-\frac{1}{2})\cdot(-2).r^2 \sin A \cos A}{\left(\sqrt{l^2 - r^2 \sin^2 A}\right)^3} \\ &= -r \cos A - \frac{r^2(\cos^2 A - \sin^2 A)}{\sqrt{l^2 - r^2 \sin^2 A}} - \frac{r^4 \sin^2 A \cos^2 A}{\left(\sqrt{l^2 - r^2 \sin^2 A}\right)^3} \end{aligned}$$

Equations with respect to time (Time Domain)

Angular velocity derivatives

If angular velocity is constant, then

$$A = \omega t$$

and the following relations apply:

$$\frac{dA}{dt} = \omega$$
$$\frac{d^2A}{dt^2} = 0$$

Converting from Angle Domain to Time Domain

The equations that follow describe the → reciprocating motion of the piston with respect to time.

If time domain is required instead of angle domain, first replace A with ωt in the equations, and then scale for angular velocity as follows:

Position

Position wrt time is simply:

$$x$$

Velocity

Velocity wrt time (using the chain rule):

$$\begin{aligned} v &= \frac{dx}{dt} \\ &= \frac{dx}{dA} \cdot \frac{dA}{dt} \\ &= \frac{dx}{dA} \cdot \ \omega \\ &= x' \cdot \omega \end{aligned}$$

Acceleration

Acceleration wrt time (using the chain rule and product rule, and the angular velocity derivatives):

$$\begin{aligned} a &= \frac{d^2x}{dt^2} \\ &= \frac{d}{dt}\frac{dx}{dt} \\ &= \frac{d}{dt}\left(\frac{dx}{dA} \cdot \frac{dA}{dt}\right) \\ &= \frac{d}{dt}\left(\frac{dx}{dA}\right) \cdot \frac{dA}{dt} + \frac{dx}{dA} \cdot \frac{d}{dt}\left(\frac{dA}{dt}\right) \\ &= \frac{d}{dA}\left(\frac{dx}{dA}\right) \cdot \left(\frac{dA}{dt}\right)^2 + \frac{dx}{dA} \cdot \frac{d^2A}{dt^2} \\ &= \frac{d^2x}{dA^2} \cdot \left(\frac{dA}{dt}\right)^2 + \frac{dx}{dA} \cdot \frac{d^2A}{dt^2} \\ &= \frac{d^2x}{dA^2} \cdot \omega^2 \\ &= x'' \cdot \omega^2 \end{aligned}$$

Scaling for angular velocity

You can see that x is unscaled, x' is scaled by ω, and x" is scaled by ω^2.
To convert x' from velocity vs angle [inch/rad] to velocity vs time [inch/s] multiply x' by ω [rad/s].
To convert x" from acceleration vs angle [inch/rad²] to acceleration vs time [inch/s²] multiply x" by ω^2 [rad²/s²].
Note that dimensional analysis shows that the units are consistent.

Velocity maxima/minima

Acceleration zero crossings

The velocity maxima and minima do *not* occur at crank angles *(A)* of plus or minus 90°.
The velocity maxima and minima occur at crank angles that depend on rod length *(l)* and half stroke *(r)*,
and correspond to the crank angles where the acceleration is zero (crossing the horizontal axis).

Crank-Rod angle not right angled

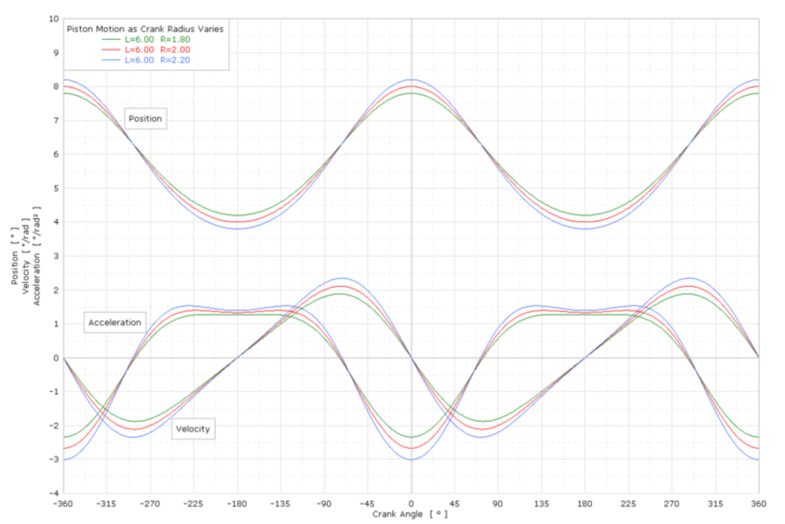
The velocity maxima and minima **do not necessarily occur** when the crank makes a right angle with the rod.
Counter-examples exist to **disprove** the *notion* that velocity maxima/minima occur when crank-rod angle is right angled.

Example

For rod length 6" and crank radius 2", numerically solving the acceleration zero-crossings finds the velocity maxima/minima to be at crank angles of ±73.17615°.
Then, using the triangle sine law, it is found that the crank-rod angle is 88.21738° and the rod-vertical angle is 18.60647°.
Clearly, in this example, the angle between the crank and the rod is not a right angle.
(Sanity check, summing the angles of the triangle 88.21738° + 18.60647° + 73.17615° gives 180.00000°)
A single counter-example is sufficient to **disprove** the statement **"velocity maxima/minima occur when crank makes a right angle with rod"**.

Example graph of piston motion

The graph shows x, x', x" wrt to crank angle for various half strokes, where L = rod length *(l)* and R = half stroke *(r)*:



The vertical axis units are inches for position, [inches/rad] for velocity, [inches/rad²] for acceleration.
The horizontal axis units are crank angle degrees.

See also

- Internal combustion engine
- Reciprocating engine
- Stroke
- Piston
- Connecting rod
- Crankshaft
- Scotch yoke

Power engineering

A steam turbine used to provide electric power.

Power engineering, also called **power systems engineering**, is a subfield of engineering that deals with the generation, transmission and distribution of electric power as well as the electrical devices connected to such systems including generators, motors and transformers. Although much of the field is concerned with the problems of three-phase AC power - the standard for large-scale power transmission and distribution across the modern world - a significant fraction of the field is concerned with the conversion between AC and DC power as well as the development of specialised power systems such as those used in aircraft or for electric railway networks.

History


A sketch of the Pearl Street Station

Electricity became a subject of scientific interest in the late 17th century with the work of William Gilbert.[1] Over the next two centuries a number of important discoveries were made including the incandescent lightbulb and the voltaic pile.[2] [3] Probably the greatest discovery with respect to power engineering came from Michael Faraday who in 1831 discovered that a change in magnetic flux induces an electromotive force in a loop of wire—a principle known as electromagnetic induction that helps explain why generators and transformers work.[4]

In 1881 two electricians built the world's first power station at Godalming in England. The station employed two waterwheels to produce an alternating current that was used to supply seven Siemans arc lamps at 250 volts and thirty-four incandescent lamps at 40 volts.[5] However supply was intermittent and in 1882 Thomas Edison and his company, The Edison Electric Light Company, developed the first steam-powered electric power

station on Pearl Street in New York City. The Pearl Street Station consisted of several generators and initially powered around 3,000 lamps for 59 customers.[6] [7] The power station used direct current and operated at a single voltage. Since the direct current power could not be easily transformed to the higher voltages necessary to minimise power loss during transmission, the possible distance between the generators and load was limited to around half-a-mile (800 m).[8]

That same year in London Lucien Gaulard and John Dixon Gibbs demonstrated the first transformer suitable for use in a real power system. The practical value of Gaulard and Gibbs' transformer was demonstrated in 1884 at Turin where the transformer was used to light up forty kilometres (25 miles) of railway from a single alternating current generator.[9] Despite the success of the system, the pair made some fundamental mistakes. Perhaps the most serious was connecting the primaries of the transformers in series so that switching one lamp on or off would affect other lamps further down the line. Following the demonstration George Westinghouse, an American entrepreneur, imported a number of the transformers along with a Siemens generator and set his engineers to experimenting with them in the hopes of improving them for use in a commercial power system.

One of Westinghouse's engineers, William Stanley, recognised the problem with connecting transformers in series as opposed to parallel and also realised that making the iron core of a transformer a fully-enclosed loop would improve the voltage regulation of the secondary winding. Using this knowledge he built a much improved alternating current power system at Great Barrington, Massachusetts in 1886.[10] Then in 1887 and 1888 another engineer called Nikola Tesla filed a range of patents related to power systems including one for a two-phase induction motor. Although Tesla cannot necessarily be attributed with building the first induction motor, his design, unlike others, was practical for industrial use.[11]

By 1890 the power industry had flourished and power companies had built literally thousands of power systems (both direct and alternating current) in the United States and Europe - these networks were effectively dedicated to providing electric lighting. During this time a fierce rivalry known as the "War of Currents" emerged between Edison, Westinghouse and Tesla over which form of transmission (direct or alternating current) was superior. In 1891, Westinghouse installed the first major power system that was designed to drive an electric motor and not just provide electric lighting. The installation powered a 100 horsepower (75 kW) synchronous motor at Telluride, Colorado with the motor being started by a Tesla induction motor.[12] On the other side of the Atlantic, Oskar von Miller built a 20 kV 176 km three-phase transmission line from Lauffen am Neckar to Frankfurt am Main for the Electrical Engineering Exhibition in Frankfurt.[13] In 1895, after a protracted decision-making process, the Adams No. 1 generating station at Niagara Falls began transmitting three-phase alternating current power to Buffalo at 11 kV. Following completion of the Niagara Falls project, new power systems increasingly chose alternating current as opposed to direct current for electrical transmission.[14]

Although the 1880s and 1890s were seminal decades in the field, developments in power engineering continued throughout the 20th and 21st century. In 1936 the first commercial HVDC (high voltage direct current) line using Mercury arc valves was built between Schenectady and Mechanicville, New York. HVDC had previously been achieved by installing direct current generators in series (a system known as the Thury system) although this suffered from serious reliability issues.[15] In 1957 Siemens demonstrated the first solid-state rectifier (solid-state rectifiers are now the standard for HVDC systems)

however it was not until the early 1970s that this technology was used in commercial power systems.[16] In 1959 Westinghouse demonstrated the first circuit breaker that used SF_6 as the interrupting medium.[17] SF_6 is a far superior dielectric to air and, in recent times, its use has been extended to produce far more compact switching equipment (known as switchgear) and transformers.[18] [19] Many important developments also came from extending innovations in the information technology and telecommunications field to the power engineering field. For example, the development of computers meant load flow studies could be run more efficiently allowing for much better planning of power systems. Advances in information technology and telecommunication also allowed for much better remote control of the power system's switchgear and generators.

Basics of electric power


An external AC to DC power adapter used for household appliances

Electric power is the mathematical product of two quantities: current and voltage. These two quantities can vary with respect to time (AC power) or can be kept at constant levels (DC power).

Most refridgerators, air conditioners, pumps and industrial machinary use AC power where as most computers and digital equipment use DC power (the digital devices you plug into the mains typically have an internal or external power adapter to convert from AC to DC power). AC power has the advantage of being easy to transform between voltages and is able to be generated and utilised by brushless machinary. DC power remains the only practical choice in digital systems and can be more economical to transmit over long distances at very high voltages (see HVDC).[20] [21]

The ability to easily transform the voltage of AC power is important for two reasons: Firstly, power can be transmitted over long distances with less loss at higher voltages. So in power networks where generation is distant from the load, it is desirable to step-up the voltage of power at the generation point and then step-down the voltage near the load. Secondly, it is often more economical to install turbines that produce higher voltages than would be used by most appliances, so the ability to easily transform voltages means this mismatch between voltages can be easily managed.[20]

Solid state devices, which are products of the semiconductor revolution, make it possible to transform DC power to different voltages, build brushless DC machines and convert between AC and DC power. Nevertheless devices utilising solid state technology are often more expensive than their traditional counterparts, so AC power remains in widespread use.[22]

Power


Transmission lines transmit power across the grid.

Power Engineering deals with the generation, transmission and distribution of electricity as well as the design of a range of related devices. These include transformers, electric generators, electric motors and power electronics.

In many regions of the world, governments maintain an electrical network that connects a variety electric generators together with users of their power. This network is called a power grid. Users purchase electricity from the grid avoiding the costly exercise of having to generate their own. Power engineers may work on the design and maintenance of the power grid as well as the power systems that connect to it. Such systems are called on-grid power systems and may supply the grid with additional power, draw power from the grid or do both.

Power engineers may also work on systems that do not connect to the grid. These systems are called off-grid power systems and may be used in preference to on-grid systems for a variety of reasons. For example, in remote locations it may be cheaper for a mine to generate its own power rather than pay for connection to the grid and in most mobile applications connection to the grid is simply not practical.

Today, most grids adopt three-phase electric power with alternating current. This choice can be partly attributed to the ease with which this type of power can be generated, transformed and used. Often (especially in the USA), the power is split before it reaches residential customers whose low-power appliances rely upon single-phase electric power. However, many larger industries and organizations still prefer to receive the three-phase power directly because it can be used to drive highly efficient electric motors such as three-phase induction motors.

Transformers play an important role in power transmission because they allow power to be converted to and from higher voltages. This is important because higher voltages suffer less power loss during transmission. This is because higher voltages allow for lower current to deliver the same amount of power, as power is the product of the two. Thus, as the voltage steps up, the current steps down. It is the current flowing through the components that result in both the losses and the subsequent heating. These losses, appearing in the form of heat, are equal to the current squared times the electrical resistance through which the current flows, so as the voltage goes up the losses are dramatically reduced.

For these reasons, electrical substations exist throughout power grids to convert power to higher voltages before transmission and to lower voltages suitable for appliances after transmission.

Components

Power engineering is a network of interconnected components which convert different forms of energy to electrical energy. Modern power engineering consists of three main subsystems: the generation subsystem, the transmission subsystem, and the distribution subsystem. In the generation subsystem, the power plant produces the electricity. The transmission subsystem transmits the electricity to the load centers. The distribution subsystem continues to transmit the power to the customers.

Generation

Generation of electrical power is a process whereby energy is transformed into an electrical form. There are several different transformation processes, among which are chemical, photo-voltaic, and electromechanical. Electromechanical energy conversion is used in converting energy from coal, petroleum, natural gas, uranium, water flow, and wind into electrical energy. Of these, all except the wind energy conversion process take advantage of the synchronous AC generator coupled to a steam, gas or hydro turbine such that the turbine converts steam, gas, or water flow into rotational energy, and the synchronous generator then converts the rotational energy of the turbine into electrical energy. It is the turbine-generator conversion process that is by far most economical and consequently most common in the industry today.

The AC synchronous machine is the most common technology for generating electrical energy. It is called synchronous because the composite magnetic field produced by the three stator windings rotate at the same speed as the magnetic field produced by the field winding on the rotor. A simplified circuit model is used to analyze steady-state operating conditions for a synchronous machine. The phasor diagram is an effective tool for visualizing the relationships between internal voltage, armature current, and terminal voltage. The excitation control system is used on synchronous machines to regulate terminal voltage, and the turbine-governor system is used to regulate the speed of the machine.

The operating costs of generating electrical energy is determined by the fuel cost and the efficiency of the power station. The efficiency depends on generation level and can be obtained from the heat rate curve. We may also obtain the incremental cost curve from the heat rate curve. Economic dispatch is the process of allocating the required load demand between the available generation units such that the cost of operation is minimized.

Transmission

The electricity is transported to load locations from a power station to a transmission subsystem. Therefore we may think of the transmission system as providing the medium of transportation for electric energy. The transmission system may be subdivided into the bulk transmission system and the sub-transmission system. The functions of the bulk transmission are to interconnect generators, to interconnect various areas of the network, and to transfer electrical energy from the generators to the major load centers. This portion of the system is called "bulk" because it delivers energy only to so-called bulk loads such as the distribution system of a town, city, or large industrial plant. The function of the sub-transmission system is to interconnect the bulk power system with the distribution system.

Transmission circuits may be built either underground or overhead. Underground cables are used predominantly in urban areas where acquisition of overhead rights of way are costly or not possible. They are also used for transmission under rivers, lakes and bays. Overhead transmission is used otherwise because, for a given voltage level, overhead conductors are much less expensive than underground cables.

The transmission system is a highly integrated system. It is referred to the substation equipment and transmission lines. The substation equipment contain the transformers, relays, and circuit breakers. Transformers are important static devices which transfer electrical energy from one circuit with another in the transmission subsystem. Transformers are used to step up the voltage on the transmission line to reduce the power loss which is dissipated on the way.[23] A relay is functionally a level-detector; they perform a switching action when the input voltage (or current) meets or exceeds a specific and adjustable value. A circuit breaker is an automatically-operated electrical switch designed to protect an electrical circuit from damage caused by overload or short circuit. A change in the status of any one component can significantly affect the operation of the entire system. There are three possible causes for power flow limitations to a transmission line. These causes are thermal overload, voltage instability, and rotor angle instability. Thermal overload is caused by excessive current flow in a circuit causing overheating. Voltage instabiliy is said to occur when the power required to maintain voltages at or above acceptable levels exceeds the available power. Rotor angle instability is a dynamic problem that may occur following faults, such as short circuit, in the transmission system. It may also occur tens of seconds after a fault due to poorly damped or undamped oscillatory response of the rotor motion.

Distribution

The distribution system transports the power from the transmission system to the customer. The distribution systems are typically radial because networked systems are more expensive. The equipment associated with the distribution system includes the substation transformers connected to the transmission systems, the distribution lines from the transformers to the customers and the protection and control equipment between the transformer and the customer. The protection equipment includes lightning protectors, circuit breakers, disconnectors and fuses. The control equipment includes voltage regulators, capacitors, relays and demand side management equipment.

See also

- Electric power transmission
- Energy economics
- Fault tolerance
- Power distribution
- Power electronics
- Power generation
- Power system protection
- Stationary engineer

External links

- IEEE Power Engineering Society [24]
- Jadavpur University, Department of Power Engineering [25]
- Power Engineering International Magazine Articles [26]
- Power Engineering Magazine Articles [27]
- American Society of Power Engineers, Inc. [28]
- National Institute for the Uniform Licensing of Power Engineer Inc. [29]

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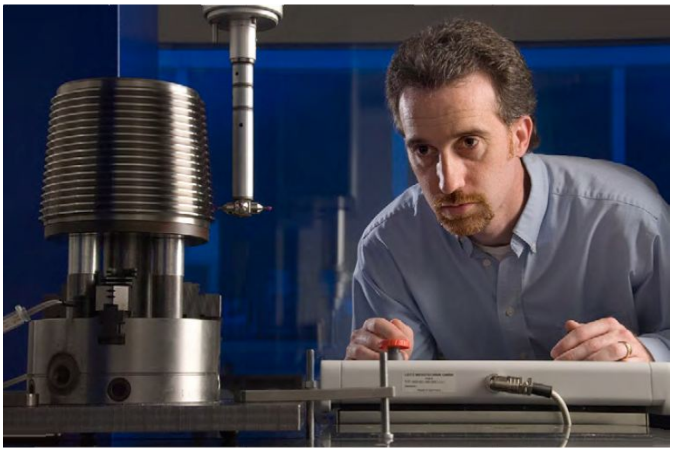
Precision engineering

Precision engineering is a subdiscipline of → mechanical engineering, electrical engineering, and optical engineering concerned with designing machines, fixtures, and other structures that have exceptionally high tolerances, are repeatable, and are stable over time. These approaches have applications in machine tools, MEMS, NEMS, optomechanical design, and many other fields.


NIST Precision engineering research. Measurement of API Rotary Master Gauge on CMM.[1]

Overview

A fundamental principle in precision engineering is that of determinism. System behavior is fully predictable even to nanometer-scale motions.

"The basic idea is that machine tools obey cause and effect relationships that are within our ability to understand and control and that there is nothing random or probabilistic about their behavior. Everything happens for a reason and the list of reasons is small enough to manage." - Jim Bryan

"By this we mean that machine tool errors obey cause-and-effect relationships, and do not vary randomly for no reason. Further, the causes are not esoteric and uncontrollable, but can be explained in terms of familiar engineering principles." - Bob Donaldson

Technical Societies

- → American Society for Precision Engineering
- euspen - European Society for Precision Engineering and Nanotechnology [2]

See also

- Abbe error
- Accuracy and precision
- Flexure bearing
- Kinematic coupling
- Measurement uncertainty
- → Kinematic determinacy

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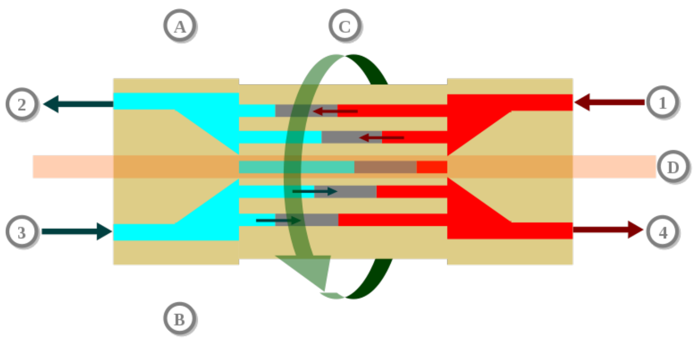
External links

- *Precision Engineering*, the Journal of the International Societies for Precision Engineering and Nanotechnology (http://www.elsevier.com/wps/find/journaldescription.cws_home/525017/description#description)

Pressure exchanger

A → pressure exchanger transfers pressure energy from a high pressure fluid stream to a low pressure fluid stream. Many industrial processes operate at elevated pressures and have high pressure waste streams. One way of providing a high pressure fluid to such a process is to transfer the waste pressure to a low pressure stream using a pressure exchanger.



Schematics of a rotary pressure exchanger. *A*: High pressure side, *B*: Low pressure side, *C*: Rotor rotation, *D*: Sealed area, *1*:High pressure reject water inflow, *2*:Pressurized sea water, *3*: Low pressure sea water inflow, *4*: Low pressure reject water drain, : Reject water / concetrate, : Piston / barrier, : Sea water

One particularly efficient type of pressure exchanger is a rotary pressure exchanger. This device uses a cylindrical rotor with longitudinal ducts parallel to its rotational axis. The rotor spins inside a sleeve between two end covers. Pressure energy is transferred directly from the high pressure stream to the low pressure stream in the ducts of the rotor. Some fluid that remains in the ducts serves as a barrier that inhibits mixing between the streams. This rotational action is similar to that of an old fashioned machine gun firing high pressure bullets and it is continuously refilled with new fluid cartridges. The ducts of the rotor charge and discharge as the pressure transfer process repeats itself.

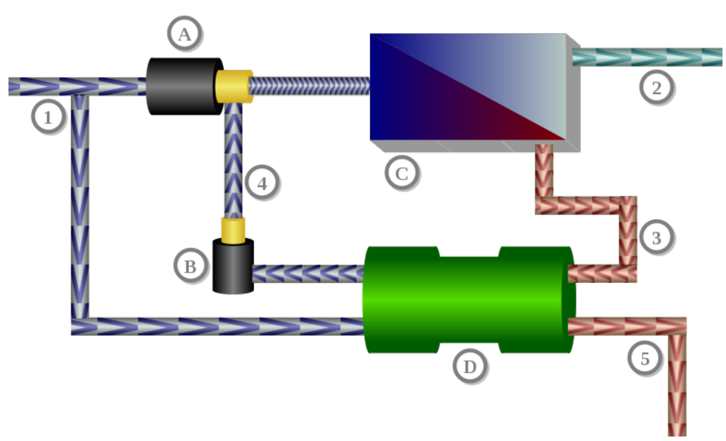
The performance of a pressure exchanger is measured by the efficiency of the energy transfer process and by the degree of mixing between the streams. The energy of the streams is the product of their flow rates and pressures. Efficiency is a function of the pressure differentials and the volumetric losses (leakage) through the device computed with the following equation:

$$\eta = \frac{\sum \text{energy out}}{\sum \text{energy in}} = \frac{(Q_G - L)\times(P_G - HDP) + (Q_B + L)\times(P_B - LDP)}{Q_G \times P_G + Q_B \times P_B} \qquad (1)$$

where Q is flow, P is pressure, L is leakage flow, HDP is high pressure differential, LDP is low pressure differential, the subscript B refers to the low pressure feed to the device and the subscript G refers to the high pressure feed to the device. Mixing is a function of the concentrations of the species in the inlet streams and the ratio of flow rates to the device. Equation 2 is an expression for volumetric mixing that was derived by mass balance.
Where C is the concentration of a dissolved species and the subscript D refers to the high-pressure outlet of the device. Reverse Osmosis with Pressure Exchangers One application in which pressure exchangers are widely used is reverse osmosis (RO). In an RO system, pressure exchangers are used as energy recovery devices (ERDs). As illustrated in Figure 3, high pressure membrane concentrate from the membranes is directed to the ERD. Pressure transfers from the high pressure concentrate stream [G] to a low pressure feedwater stream [B]. Pressurized feedwater flows from the ERD [D], driven by a circulation pump. This stream merges with the output of a high pressure pump [C] to form the membrane feed stream [E]. The concentrate leaves the ERD at low pressure [H], expelled by the incoming feedwater flow [B]. Figure 3 – Schematic Diagram of an RO Process with Pressure Exchanger Energy Recovery Devices

Pressure exchangers save energy in these systems by reducing the load on the high pressure pump. In a seawater RO system operating at a 40% membrane water recovery rate, the ERD supplies 60% of the membrane feed flow. Energy is consumed by the circulation pump, however, because this pump merely circulates and does not pressurize water, its energy consumption is almost negligible: less than 3% of the energy consumed by the high pressure pump. Therefore, nearly 60% of the membrane feed flow is pressurized with almost no energy input.

Energy Recovery and Pressure Exchange Systems



Schematics of a reverse osmosis system (desalination) using a pressure exchanger. *1*:Sea water inflow, *2*: Fresh water flow (40%), *3*:Concentrate Flow (60%), *4*:Sea water flow (60%), *5*: Concentrate (drain), *A*: High pressure pump flow (40%), *B*: Circulation pump, *C*:Osmosis unit with membrane, *D*: Pressure exchanger

Seawater desalination plants have produced potable water for many years. However, until recently desalination had been used only in extreme circumstances because of the very high-energy consumption of the process.

Early designs for desalination plants made use of various evaporation technologies. The most advanced though is the seawater evaporation desalters which made use of multiple stages have an energy consumption of over 9 kWh per cubic meter of potable water produced. For this

reason large seawater desalters were initially constructed in locations with very low energy costs, such as the Middle East or next to process plants with available waste heat.

In the 1970s the seawater reverse osmosis (SWRO) process was developed which made potable water from seawater by forcing it under high pressure through a tight membrane thus filtering out salts and impurities. These salts and impurities are discharged from the SWRO device as a concentrated brine solution in a continuous stream, which contains a large amount of high-pressure energy. Most of this energy can be recovered with a suitable device. Many early SWRO plants built in the 1970s and early 1980s had an energy consumption of over 6.0 kWh per cubic meter of potable water produced, due to low membrane performance, pressure drop limitations and the absence of energy recovery devices.

An example where a pressure exchange engine finds application is in the production of potable water using the reverse osmosis membrane process. In this process, a feed saline solution is pumped into a membrane array at high pressure. The input saline solution is then divided by the membrane array into super saline solution (brine) at high pressure and potable water at low pressure. While the high pressure brine is no longer useful in this process as a fluid, the pressure energy that it contains has high value. A pressure exchange engine is employed to recover the pressure energy in the brine and transfer it to feed saline solution. After transfer of the pressure energy in the brine flow, the brine is expelled at low pressure to drain.

Nearly all reverse osmosis plants operated for the desalination of sea water in order to produce drinking water in industrial scale are equipped with an energy recovery system based on turbines. These are activated by the concentrate (brine) leaving the plant and transfer the energy contained in the high pressure of this concentrate usually mechanically to the high-pressure pump. In the pressure exchanger the energy contained in the brine is transferred hydraulically and with an efficiency of approximately 98% to the feed. This reduces the energy demand for the desalination process significantly and thus the operating costs. Therefrom results an economic energy recovery, amortization times for such systems varying between 2 and 4 years depending on the place of operation. Reduced energy and capital costs mean that for the first time ever it is possible to produce potable water from seawater at a cost below $1 per cubic meter in many locations worldwide. Although the cost may be a bit higher on islands with high power costs, the PE has the potential to rapidly expand the market for seawater desalination.

By means of the application of a pressure exchange system, which is already used in other domains, a considerably higher efficiency of energy recovery of reverse osmosis systems may be achieved than with the use of reverse running pumps or turbines. The pressure exchange system is suited, above all, for bigger plants i.e. approx. ≥ 2000 m3/d permeate production.

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Proactive maintenance

Proactive maintenance is a maintenance strategy for stabilizing the reliability of machines or equipment. Its central theme involves directing corrective actions aimed at failure root causes, not active failure symptoms, faults, or machine wear conditions.

A typical proactive maintenance regimen involves three steps:

- (1) setting a quantifiable target or standard relating to a root cause of concern (e.g., a target fluid cleanliness level for a lubricant),
- (2) implementing a maintenance program to control the root cause property to within the target level (e.g., routine exclusion or removal of contaminants),
- and (3) routine monitoring of the root cause property using a measurement technique (e.g., particle counting) to verify the current level is within the target.

Process integration

Process integration is a term in chemical engineering which has two possible meanings.

1. A holistic approach to process design which considers the interactions between different unit operations from the outset, rather than optimising them separately. This can also be called *integrated process design* or *process synthesis*. Smith (2005) describes the approach well. An important first step is often *product design* (Cussler and Moggridge 2003) which develops the specification for the product to fulfil its required purpose.

2. → *Pinch analysis*, a technique for designing a process to minimise energy consumption and maximise heat recovery, also known as *heat integration*, *energy integration* or *pinch technology*. The technique calculates thermodynamically attainable *energy targets* for a given process and identifies how to achieve them. A key insight is the pinch temperature, which is the most constrained point in the process. The most detailed explanation of the techniques is by Kemp (2006).

In the context of chemical engineering, Process Integration can be defined as a holistic approach to process design and optimization, which exploits the interactions between different units in order to employ resources effectively and minimize costs.

Note that Process Integration is not limited to the design of new plants, but it also covers retrofit design (e.g. new units to be installed in an old plant) and the operation of existing systems.

The main advantage of process integration is to consider a system as a whole (i.e. integrated or holistic approach) in order to improve their design and/or operation. In contrast, an analytical approach would attempt to improve or optimize process units separately without necessarily taking advantage of potential interactions among them.

For instance, by using process integration techniques it might be possible to identify that a process can use the heat rejected by another unit and reduce the overall energy consumption, even if the units are not running at optimum conditions on their own. Such an opportunity would be missed with an analytical approach, as it would seek to optimize each unit, and thereafter it wouldn't be possible to re-use the heat internally.

Typically, process integration techniques are employed at the beginning of a project (e.g. a new plant or the improvement of an existing one) to screen out promising options to optimize the design and/or operation of a process plant.

Also it is often employed, in conjunction with simulation and mathematical optimization tools to identify opportunities in order to better integrate a system (new or existing) and reduce capital and/or operating costs.

Most process integration techniques employ Pinch Analysis or Pinch Tools to evaluate several processes as a whole system. Therefore, strictly speaking, both concepts are not the same, even if in certain contexts they are used interchangeably.

OA

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Pulverizer

A **pulverizer** is a mechanical device for the grinding of many different types of materials. For example, they are used to pulverize coal for combustion in the steam-generating furnaces of fossil fuel power plants.

Types of pulverizers

Ball and tube mills

A ball mill is a pulverizer that consists of a horizontal rotating cylinder, up to three diameters in length, containing a charge of tumbling or cascading steel balls, pebbles, or rods.

A tube mill is a revolving cylinder of up to five diameters in length used for fine pulverization of ore, rock, and other such materials; the material, mixed with water, is fed into the chamber from one end, and passes out the other end as slime.

Ring and ball mill

This type of mill consists of two rings separated by a series of large balls. The lower ring rotates, while the upper ring presses down on the balls via a set of spring and adjuster assemblies. The material to be pulverized is introduced into the center or side of the pulverizer (depending on the design) and is ground as the lower ring rotates causing the balls to orbit between the upper and lower rings. The pulverized material is carried out of the mill by the flow of air moving through it. The size of the pulverized particles released from the grinding section of the mill is determined by a classifer separator.

MPS mill

Similar to the ring and ball mill, this mill uses large "tires" to crush the coal. These are usually found in utility plants.

Bowl mill

Similar to the MPS mill, it also uses tires to crush coal. There are two types, a deep bowl mill, and a shallow bowl mill.

Demolition pulverizer

An attachment fitted to an excavator. Commonly used in demolition work to break up large pieces of concrete.

See also

- Grinding mill
- Burr mill
- Cement mill
- Power station
- Fossil fuel power plant
- Thermal power plant

Range of motion

Range of motion or (**ROM**), is the distance (linear or angular) that a movable object may normally travel while properly attached to another object. It is also called **range of travel**, particularly when talking about mechanical devices and in → mechanical engineering fields. For example, a volume knob (a rotary fader) may have a 300° range of travel from the "off" or muted (fully attenuated) position at lower left, going clockwise to its maximum-loudness position at lower right.

As used in the biomedical and weightlifting communities, it is the measurement of the achievable distance between the flexed position and the extended position of a particular joint or muscle group. The act of attempting to increase this distance through therapeutic exercises (range-of-motion therapy—stretching from flexion to extension for physiological gain) is also sometimes called range of motion.

A person who uses a wheelchair may improve the range of motion in their spine, hips, knees and ankles by using a standing frame, if possible. It is necessary that the gain in joint range be accompanied by the gain in function of the muscles which control that particular range of motion.

Measuring range of motion

As measurement results will vary by the degree of resistance, two levels of range-of-motion results are recorded in most cases. Passive range of motion, where another person, such as a caregiver or therapist, moves the joint. Active (or manual) range of motion, where the individual moves the joint themselves. Free active movements - the only resistance is the weight of the limb or body and the force of gravity that it fights. Free active movements are generally performed to increase and retain strength and flexibility. Resisted active movements - for resistance, weights are added to the limb, a physician, therapist or another person applies pressure, or a stretch band is used. Resisted active movement exercises are used to increase strength and endurance.

A goniometer is used to measure ROM. The segments of a goniometer include the stationary arm, protractor, fulcrum and movement arm.

An inclinometer is used to measure ROM. It typically uses 2 sensors, one in a reference position, and another attached to the moving part being examined.

See also

- Joint locking (symptom)

Rayleigh-Ritz method

In applied mathematics and → mechanical engineering, the **Rayleigh-Ritz method** is a widely used, classical method for the calculation of the natural vibration frequency of a structure in the second or higher order. It is a direct variational method in which the minimum of a functional defined on a normed linear space is approximated by a linear combination of elements from that space. This method will yield solutions when an analytical form for the true solution may be intractable.

The method is also widely used in Quantum Chemistry.

Typically in → mechanical engineering it is used for finding the approximate real resonant frequencies of multi degree of freedom systems, such as spring mass systems or → flywheels on a shaft with varying cross section. It is an extension of Rayleigh's method. It can also be used for finding buckling loads for columns, as well as more esoteric uses.

The following discussion uses the simplest case, where the system has two lumped springs and two lumped masses, and only two mode shapes are assumed. Hence M=[m_1,m_2] and K=[k_1,k_2].

A mode shape is assumed for the system, with two terms, one of which is weighted by a factor B, eg Y= [1,1] +B*[1,-1]. Simple harmonic motion theory says that the velocity at the time when deflection is zero, is the angular frequency ω times the deflection (y) at time of maximum deflection. In this example the kinetic energy (KE) for each mass is $\frac{1}{2}\omega^2 Y_1^2 m_1$ etc, and the potential energy (PE) for each spring is $\frac{1}{2}k_1 Y_1^2$etc . For continuous systems the expressions are more complex.

We also know, since no damping is assumed, that KE when y=0 equals the PE when v=0 for the whole system. As there is no damping all locations reach v=0 simultaneously.

so, since KE=PE

$$\sum_{i=1}^{2}(\frac{1}{2}\omega^2 Y_i^2 M_i) = \sum_{i=1}^{2}(\frac{1}{2}K_i Y_i^2)$$

Note that the overall amplitude of the mode shape cancels out from each side, always. That is, the actual size of the assumed deflection does not matter, just the mode *shape*.

A bit of mathematical skullduggery then reveals a solution for ω, in terms of B. Then differentiate ω with respect to B, and find the minimum, i.e. when $d\omega/dB = 0$. This gives the value of B for which ω is lowest. This is an upper bound solution for ω if ω is hoped to be the predicted fundamental frequency of the system because the mode shape is *assumed*, but we have found the lowest value of that upper bound, given our assumptions, because B is used to find the optimal 'mix' of the two assumed mode shape functions.

There are many tricks with this method, the most important is to try and choose realistic assumed mode shapes. For example in the case of beam deflection problems it is wise to use a deformed shape that is compatible with links and that is analyticaly similar to the expected solution. A quartic may fit most of the easy problems of simply linked beams even

if the order of the deformed solution may be lower. The springs and masses do not have to be discrete, they can be continuous (or a mixture), and this method can be easily used in a spreadsheet to find the natural frequencies of quite complex distributed systems, if you can describe the distributed KE and PE terms easily, or else break the continuous elements up into discrete parts.

This method could be used iteratively, adding additional mode shapes to the previous best solution, or you can build up a long expression with many Bs and many mode shapes, and then differentiate them partially.

See also

- Ritz method

External links

- http://www.samparker.co.uk - Guide to Dunkerley and Rayleigh Method.
- http://www.math.nps.navy.mil/~bneta/4311.pdf - Course on Calculus of Variations, has a section on Rayleigh-Ritz method.

Reciprocating compressor

A **reciprocating compressor** or **piston compressor** is a positive-displacement compressor that uses pistons driven by a crankshaft to deliver gases at high pressure.[1] [2]


A motor-driven six-cylinder reciprocating compressor that can operate with two, four or six cylinders.

The intake gas enters the suction manifold, then flows into the compression cylinder where it gets compressed by a piston driven in a reciprocating motion via a crankshaft, and is then discharged. We can categorize reciprocating compressors into many types and for many applications. Primarily, it is used in a great many industries, including oil refineries, gas pipelines, chemical plants, natural gas processing plants and refrigeration plants. One specialty application is the blowing of plastic bottles made of Polyethylene Terephthalate (PET).

Portable compressors

Reciprocating compressors were formerly used for powering portable tools such as pneumatic drills. The unit was mounted on a trailer or a lorry and comprised a reciprocating compressor driven, through a centrifugal clutch, by a diesel engine. The engine's governor provided only two speeds:

- idling, when the clutch was disengaged
- maximum, when the clutch was engaged and the compressor was running

Modern versions use rotary compressors and have more sophisticated variable governors.

See also

- Centrifugal compressor
- Vapor-compression refrigeration
- Diving air compressor

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Calculation of required cylinder compression for a multistage reciprocating compressor (http:/ / www. vinamaso. net/ marine-engineering/ auxiliary-machinery/ calculation-of-required-cylinder-compression-for-a-multistage-reciprocating-compressor. html)

Reciprocating motion

Reciprocating motion , also called **Reciprocation**, is an up and down (or back-and-forth) motion which repeats over and over again. It is seen in a wide range of reciprocating engines and pumps.

A → crank can be used to turn circular motion into reciprocating motion or turn reciprocating motion into circular motion.

As an example, inside of an internal combustion engine an explosion within the cylinder pushes the piston down and the connecting rod pushes the crankshaft around, which in turn might drive the wheels of a car. The continuing rotation of the crankshaft drives the piston back up, ready for the next cycle. The piston is undergoing reciprocating motion but only circular motion is visible. The vibrations felt when the engine is running are a side effect of the reciprocating motion going on inside the cylinders.

In early steam engines, particularly horizontal stationary engines, and outside-cylindered steam locomotives, the reciprocating action is clearly visible as the mechanism is not usually enclosed.

See also

- Oscillation
- Rotary reciprocation
- Reciprocating saw
- Rotary reciprocating saw
- Agitation

Recuperator

A **recuperator** is a special purpose counter-flow heat exchanger used to recover waste heat from exhaust gases. In many types of processes, combustion is used to generate heat, and the recuperator serves to recuperate, or reclaim this heat, in order to reuse or recycle it. The term recuperator refers as well to liquid-liquid counterflow heat exchangers used for heat recovery in the chemical and refinery industries and in closed processes such as ammonia-water or LiBr-water absorption refrigeration cycles. Other forms of heat or enthalpy recovery include the regenerative heat exchanger (see blast furnace), the heat wheel (see rotating recuperator, below), and the enthalpy wheel (see energy recovery ventilation).

Recuperators are often used in association with the burner portion of a heat engine, to increase the overall efficiency. For example, in a gas turbine engine, air is compressed, mixed with fuel, which is then burned and used to drive a turbine. The recuperator transfers some of the waste heat in the exhaust to the compressed air, thus preheating it before entering the fuel burner stage. Since the gases have been pre-heated, less fuel is needed to heat the gases up to the turbine inlet temperature. By recovering some of the energy usually lost as waste heat, the recuperator can make a heat engine or gas turbine significantly more efficient.

Rotating recuperator

During the automotive industry's interest in gas turbines for vehicle propulsion (around 1965), Chrysler invented a unique recuperator[1] that consisted of a rotary drum constructed from corrugated metal (similar in appearance to corrugated cardboard). This drum was continuously rotated by reduction gears driven by the turbine. The hot exhaust gasses were directed through a portion of the device, which would then rotate to a section that conducted the induction air, where this intake air was heated. This recovery of the heat of combustion significantly increased the efficiency of the turbine engine. This engine proved impractical for an automotive application due to its poor low-rpm torque. Even such an efficient engine, if large enough to deliver the proper performance, would have a low average fuel economy. Such an engine may at some future time be attractive when combined with an electric motor in a hybrid vehicle owing to its robust longevity and an ability to burn a wide variety of liquid fuels.

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Reel

A **reel** is an object around which lengths of another material (usually long and flexible) are wound for storage. Generally a reel has a cylindrical core and walls on the sides to retain the material wound around the core. In some cases the core is hollow, although other items may be mounted on it, and grips may exist for mechanically turning the reel.


A 250V-16A electrical wire on a reel

The size of the core is dependent on several factors. A smaller core will obviously allow more material to be stored in a given space. However, there is a limit to how tightly the stored material can be wound without damaging it and this limits how small the core can be.

Other issues affecting the core size include:

- Mechanical strength of the core (especially with large reels)
- Acceptable turning speed (for a given rate of material moving on or off the reel a smaller core will mean that an almost empty reel has to turn faster)
- any functional requirements of the core e.g.
  - For a reel that must be mechanically turned the size of the grips that mount it on the mechanical turning device.
  - The size of the mountings needed to support the core during unwinding.
  - Anything mounted on the cores (e.g. the sockets on an extension reel)

With material such as photographic film that is flat and long but is relatively wide, the material generally is stored in successive single layers. In cases where the material is more uniform in cross-section (for example, a cable), the material may be safely wound around a reel that is wider than its width. In this case, several windings are needed to create a layer on the reel.

Uses

- A fishing reel is used on a fishing rod to wind the fishing line up.
- Kite lines frequently are operated from reels.
- Specialized reels for holding tow line for hang glider, glider, and sailplane launching
- Laying of communications table use giant reels
- Winches wind cables on reels
- Webbing barriers that allow mobile post positions collect tensionally excess webbing.
- Tow trucks hold steel cable on reels.
- Garden hoses reeled solve hose kink problems.
- Rope, wire and cable is often supplied on reels.
- Badge reels are used to hold badges, ski passes and the like.
- A cave diving reel is safety equipment used for running a guideline.[1]

An irrigation reel with travelling sprinkler

A badge reel

Motion picture terminology


35mm film reels and boxes

It is traditional to discuss the length of theatrical motion pictures in terms of "reels." The standard length of a 35 mm motion picture reel is 1000 feet (300 m). This length runs approximately 11 minutes at sound speed (24 frames per second) and slightly longer at silent movie speed (which may vary from approximately 16 to 18 frames per second). Most films have visible cues which mark the end of the reel. This allows projectionists running reel-to-reel to change-over to the next reel on the other projector.

A so-called "two-reeler" would have run about 20–24 minutes since the actual short film shipped to a movie theater for exhibition may have had slightly less (but rarely more) than 1000ft (about 305m) on it. Most projectionists today use the term "reel" when referring to a 2000-foot (610 m) "two-reeler," as modern films are rarely shipped by single 1000-foot (300 m) reels. A standard Hollywood movie averages about five 2000-foot (610 m) reels in length.

The "reel" was established as a standard measurement because of considerations in printing motion picture film at a film laboratory, for shipping (especially the film case sizes) and for the size of the physical film magazine attached to the motion picture projector. Had it not been standardized (at 1000 feet (300 m) of 35 mm film) there would have been many difficulties in the manufacture of the related equipment. A 16 mm "reel" is 400 feet (120 m). It runs, at sound speed, approximately the same amount of time (11–12 minutes) as a 1000-foot 35 mm reel.

A **split reel** is a motion picture film reel in two halves that, when assembled, hold a specific length of motion picture film that has been wound on a plastic core. Using a split reel allows film to be shipped or handled in a lighter and smaller form than film would on a "fixed" reel. In silent film terminology, two films on one reel.

Demo reels

A **demo reel**, or **show reel**, is the motion picture or video equivalent of an artist's portfolio. It is typically used as a tool to promote the artist's skill, talent, and experience in a selected field, such as acting, directing, cinematography, editing, special effects, animation, or video games and other graphics. The demo reel is frequently submitted with a résumé to a prospective employer. When a reel contains scenes from actual productions, a shot list or credit list may also be submitted to describe the artist's specific involvement in each portion of the reel. While the usage of video excerpts on such showreels can be regarded as a breach of copyright, it is generally accepted in the film industry to do so, as it is the only tool of an artist to actually self-promote her/his work.

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Relief valve

For similar articles see Relief valve (disambiguation)

The **relief valve** is a type of valve used to control or limit the pressure in a system or vessel which can build up by a process upset, instrument or equipment failure, or fire. The pressure is relieved by allowing the pressurised fluid to flow from an auxiliary passage out of the system. The relief valve is designed or set to open at a predetermined set pressure to protect pressure vessels and other equipment from being subjected to pressures that exceed their design limits. When the set pressure is exceeded, the relief valve becomes the "path of least resistance" as the valve is forced open and a portion of the fluid is diverted through the auxiliary route. The diverted fluid (liquid, gas or liquid-gas mixture) is usually routed through a → piping system known as a *flare header* or *relief header* to a central, elevated gas flare where it is usually burned and the resulting combustion gases are released to the atmosphere. As the fluid is diverted, the pressure inside the vessel will drop. Once it reaches the valve's reseating pressure, the valve will close. The *blowdown* is usually stated as a percentage of set pressure and refers to how much the pressure needs to drop before the valve reseats. The blowdown can vary from roughly 2-20%, and some valves have adjustable blowdowns.

In high-pressure gas systems, it is recommended that the outlet of the relief valve is in the open air. In systems where the outlet is connected to piping, the opening of a relief valve will give a pressure build up in the piping system downstream of the relief valve. This often means that the relief valve will not re-seat once the set pressure is reached. For these systems often so called "differential" relief valves are used. This means that the pressure is only working on an area, that is much smaller than the openings area of the valve. If the valve is opened the pressure has to decrease enormously before the valve closes and also the outlet pressure of the valve can easily keep the valve open. Another consideration is that if other relief valves are connected to the outlet pipe system, they may open as the pressure in exhaust pipe system increases. This may cause undesired operation. [1]

In some cases, a so-called *bypass valve* acts as a relief valve by being used to return all or part of the fluid discharged by a pump or gas compressor back to either a storage reservoir or the inlet of the pump or gas compressor. This is done to protect the pump or gas compressor and any associated equipment from excessive pressure. The bypass valve and bypass path can be internal (an integral part of the pump or compressor) or external (installed as a component in the fluid path). Many fire engines have such relief valves to

prevent the overpressurization of fire hoses.

In other cases, equipment must be protected against being subjected to an internal vacuum (i.e., low pressure) that is lower than the equipment can withstand. In such cases, *vacuum relief valves* are used to open at a predetermined low pressure limit and to admit air or an inert gas into the equipment so as control the amount of vacuum.

Technical Terms

In the petroleum refining, petrochemical and chemical manufacturing, natural gas processing and power generation industries, the term **relief valve** is associated with the terms **pressure relief valve (PRV)**, **pressure safety valve (PSV)** and **safety valve**.

It should be noted that in practice people often do not stick to the technical distinctions between the most common abbreviations: SRV, PRV, SV and RV - they just use the term they are comfortable with.

Pressure Relief Valve (PRV) or Pressure Safety Valve (PSV): the most generic terms. Most PRV are spring operated. At lower pressures some use a diaphragm in place of a spring. The oldest PRV designs use a weight to seal the valve.

Set Pressure: When increasing system pressure reaches this value the PRV opens. Accuracy of set pressure often follows guidelines set by the → ASME.

Relief valve (RV): A valve used on a liquid service, which opens proportionally as the increasing pressure overcomes the spring pressure.

Safety valve (SV): Used in gas service. Most SV are full lift or snap acting, they pop open all the way.

Safety relief valve (SRV): A PRV that can be used for gas or liquid service. But set pressure will usually only be accurate for one type of fluid at a time (the type it was set with).

Pilot-operated relief valve (POSRV, PORV, POPRV): device that relieves by remote command from a pilot valve that is connected to the upstream system pressure. Low pressure safety valve (LPSV): automatic system that relieves by static pressure on a gas. The pressure is small and near the atmospheric pressure.

Vacuum pressure safety valve (VPSV): automatic system that relieves by static pressure on a gas. The pressure is small, negative and near the atmospheric pressure.

Low and vacuum pressure safety valve (LVPSV): automatic system that relieves by static pressure on a gas. The pressure is small, negative or positive and near the atmospheric pressure.

Snap Acting: The opposite of modulating, refers to a valve that "pops" open, it goes into full lift in milliseconds. Usually accomplished with a skirt on the disc so that the fluid passing the seat suddenly affects a larger area and creates more lifting force.

Modulating: Opens in proportion to the overpressure.

Pressure relief valve is very much important in order to cotrol the transient effect-Kiran

Legal and code requirements in industry

In most countries, industries are legally required to protect pressure vessels and other equipment by using relief valves. Also in most countries, equipment design codes such as those provided by the → ASME, API and other organizations like ISO (ISO 4126) must be complied with and those codes include design standards for relief valves.[2] [3]

The main standards, laws or directives are:

- ASME (→ American Society of Mechanical Engineers) Boiler & Pressure Vessel Code, Section VIII Division 1 and Section I
- API (American Petroleum Institute) Recommended Practice 520/521, API Standard 2000 et API Standard 526
- ISO 4126 (International Organisation for Standardisation)
- EN 764-7 (European Standard based on pressure Equipment Directive 97/23/EC)
- AD Merckblatt (German)
- PED 97/23/EC [4] (Pressure Equipment Directive - European Union)

Pressure relief valves in oil hydraulics

Whereas pressure relief valves in gas pressure systems are always used to protect the system, in oil hydraulic systems a pressure relief valve can act as part of the control system. The easiest use of the relief valve is as a sort of check valve, a seat with a ball and an adjustable spring. More sophisticated relief valves are pilot operated, so that the pressure can be set at zero (by-pass) and sometimes at 2 or 3 other pressures. In these cases, the highest pressure acts as the maximum working pressure and the others as a set pressure during a certain operation of the installation.

See also

- Safety valve
- Blowoff valve
- Rupture disc
- Pilot-operated relief valve

External links

- Continental Disc Corporation [5]
- Groth Corporation [6]
- Eversteel [7]

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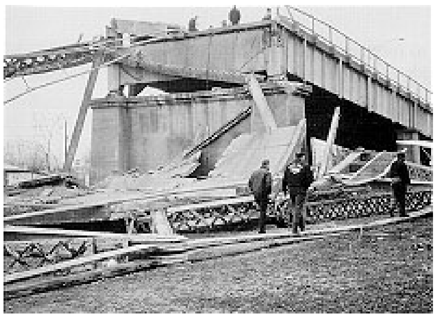
[1] Beychok, Milton R. (2005). *Fundamentals Of Stack Gas Dispersion* (4th Edition ed.). author-published. ISBN 0-9644588-0-2. See Chapter 11, *Flare Stack Plume Rise*.
[2] List of countries accepting the ASME Boiler & Pressure Vessel Code (http://www.onetb.com/asme_code_countries.htm)
[3] API 5210-1, Sizing and Selection of Pressure-Relieving Devices (http://www.techstreet.com/cgi-bin/detail?product_id=235758)
[4] http://ec.europa.eu/enterprise/pressure_equipment/ped/index_en.html
[5] http://www.contdisc.com
[6] http://www.grothcorp.com
[7] http://www.breather-valves.com

Residual stress

Residual stresses are stresses that remain after the original cause of the stresses (external forces, heat gradient) has been removed. They remain along a cross section of the component, even without the external cause. Residual stresses occur for a variety of reasons, including inelastic deformations and heat treatment. Heat from welding may cause localized expansion, which is taken up during welding by either the molten metal or the placement of parts being welded. When the finished weldment cools, some areas cool and contract more than others, leaving residual stresses.

Premature failure

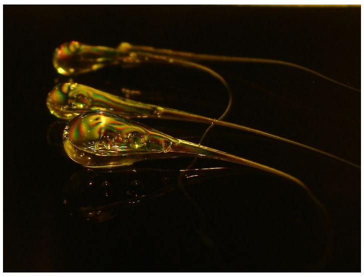

The collapsed Silver Bridge, as seen from the Ohio side

Castings may also have large residual stresses due to uneven cooling. Residual stress is often a cause of premature failure of critical components, and was one factor in the collapse of the suspension bridge at Silver Bridge in West Virginia, United States in December 1967. The eyebar links were castings which showed high levels of residual stress, which in one eyebar, encouraged crack growth. When the crack reached a critical size, it grew catastrophically, and from that moment, the whole structure started to fail in a chain reaction. Because the structure failed in less than a minute, 46 drivers and passengers in cars on the bridge at the time were killed as the suspended roadway fell into the river below.

Controlled residual stress

While uncontrolled residual stresses are undesirable, some designs rely on them. For example, toughened glass and pre-stressed concrete depend on residual stress to prevent brittle failure. A demonstration of the effect is shown by Prince Rupert's Drop, where a molten glass globule is quenched to produce a toughened outer layer.

→ Bolted joints use residual stress to avoid subjecting bolts to fatigue. A gradient in martensite formation leaves residual stress in some swords with particularly hard edges (notably the katana), which can prevent the opening of edge cracks.



Prince Rupert's Drops

In certain types of gun barrels made with two tubes forced together, the inner tube is compressed while the outer tube stretches, preventing cracks from opening in the rifling when the gun is fired. Parts are often heated or dropped into liquid nitrogen to aid assembly.

Press fits

Press fits are the most common intentional use of residual stress. Automotive wheel studs, for example are pressed into holes on the wheel hub. The holes are smaller than the studs, requiring force to drive the studs into place. The residual stresses fasten the parts together. Nails are another example where the stress created by penetration of wood then helps to keep the nail in place.

See also

- Shot peening
- Autofrettage
- Tempered glass
- Prince Rupert's Drop
- Prestressed concrete
- Low Plasticity Burnishing

References

- Cary, Howard B. and Scott C. Helzer (2005). Modern Welding Technology. Upper Saddle River, New Jersey: Pearson Education. ISBN 0-13-113029-3.

External links

- Residual stresses at The Welding Institute [1]

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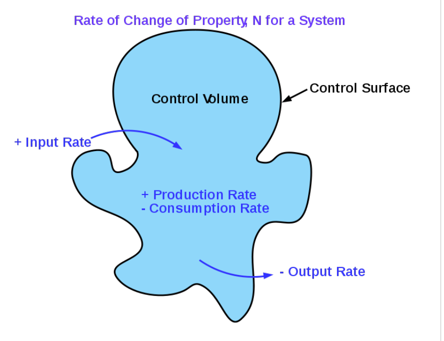
[1] http://www.twi.co.uk/j32k/protected/band_3/ksrhl001.html

Reynolds transport theorem



Reynolds Transport Theorem

Reynolds transport theorem (also known as the Leibniz-Reynolds transport theorem), or in short **Reynolds theorem**, is a three-dimensional generalization of the Leibniz integral rule. This theorem is used to compute derivatives of integrated quantities.

Reynolds transport theorem can be simply stated as - What was already there plus what goes in minus what comes out is equal to what is there. Reynolds theorem is used in formulating the basic conservation laws of continuum mechanics, particularly fluid dynamics and large-deformation solid mechanics. These conservation laws (law of conservation of mass, law of conservation of linear momentum, and law of conservation of energy) are adopted from classical mechanics and thermodynamics where the system approach is normally followed. In fluid mechanics, it is often more convenient to work with control volumes as it is difficult to identify and follow a system of fluid particles. Thus, there is a need to relate the system equations and corresponding control volume equations. The link between the two is given by the Reynolds transport theorem. The theorem is named after Osborne Reynolds (1842–1912).

Imagine a system and a coinciding control volume with a control surface. Reynolds transport theorem states that the rate of change of an extensive property *N*, for the system is equal to the time rate of change of *N* within the control volume and the net rate of flux of the property *N* through the control surface. For an example, the law of conservation of mass states that rate of change of the property, mass, is equal to the sum of the rate of accumulation of mass within a control volume and the net rate of flow of mass across the control surface.

The differential forms of these equations with additional assumption of Newton's viscosity law are commonly known as the Navier-Stokes equations.

General form

The Reynolds transport theorem refers to any extensive property, *N*, of the fluid in a particular control volume. It is expressed in terms of a substantive derivative on the left-hand side.

$$\frac{DN_{sys}}{Dt} = \int_{c.v.} \frac{\partial}{\partial t}(\rho\eta)dV + \int_{c.s.} \rho\eta\vec{v}_b \cdot \hat{n}dA + \int_{c.s.} \rho\eta\vec{v}_r \cdot \hat{n}dA,$$

where η is the intensive property related to extensive property *N*, (*N* per unit mass), *t* is time, *c.v.* refers to the control volume, *c.s.* refers to the control surface, ρ is the fluid density, *V* is the volume, v_b is the velocity of the boundary of the control volume (the control surface), v_r is the velocity of the fluid with respect to the control surface, *n* is the outward pointing normal vector on the control surface, and *A* is the area.

Mass formulation

Also called the continuity equation, the control volume form of the conservation of mass is found by substituting mass in for *N*. This means that η is equal to 1.

$$0 = \int_{c.v.} \frac{\partial \rho}{\partial t} dV + \int_{c.s.} \rho \vec{v}_b \cdot \hat{n}\ dA + \int_{c.s.} \rho \vec{v}_r \cdot \hat{n}\ dA$$

All variables are defined as in the general formulation. *M* is equal to the mass of the control volume. Applying the Conservation of mass principle, the left hand side reduces to 0 since mass of a system cannot change in time. In a steady flow system, the first term on the right hand side of the equation will be equal to 0, i.e. the mass of the control volume does not change, implying that the mass flow rate into the control volume is equal to the mass flow rate out of the control volume.

Momentum formulation

The momentum equation is found by substituting momentum in for *N*. From this, η is found to be velocity. From Newton's second law, we have the time rate of change of momentum (now the left hand side of the equation) is equal to the net force. Thus,

$$\sum \vec{F} = \int_{c.v.} \frac{\partial}{\partial t}(\rho \vec{v}) dV + \int_{c.s.} \rho \vec{v}(\vec{v}_b \cdot \hat{n}) dA + \int_{c.s.} \rho \vec{v}(\vec{v}_r \cdot \hat{n}) dA,$$

where *F* is force, v is the velocity of fluid in a coordinate system attached to the control surface, and all other variables are defined as in the general formulation. Note that the integral form of the momentum equation is a vector equation.

Energy formulation

The energy equation is found by substituting energy in for *N*. From this, η is found to be energy per unit mass.

$$\dot{Q} - \sum \dot{W} = \int_{c.v.} \frac{\partial}{\partial t} \left[\rho \left(\frac{v^2}{2} + gz + \tilde{u} \right) \right] dV + \int_{c.s.} \left[\frac{v^2}{2} + gz + \tilde{u} + \frac{p}{\rho} \right] \rho \vec{v}_b \cdot \hat{n} dA + \int_{c.s.} \left[\frac{v^2}{2} + gz + \tilde{u} + \frac{p}{\rho} \right] \rho \vec{v}$$

where *Q* is the heat transfer into the control volume, *W* is the work done by the system, *g* is the acceleration due to gravity, *z* is the vertical distance from an arbitrary datum, $\tilde{u}$ is the specific internal energy of the fluid, *p* is the pressure and all other variables are defined as in the general formulation.

Note that these equations make no consideration for chemical reactions or potential energy associated with electromagnetic fields.

Formulation used in solid mechanics

Suppose $\Omega(t)$ is a region in Euclidean space with boundary $\partial\Omega(t)$, and let $\mathbf{n}(\mathbf{x},t)$ be the outward unit normal to the boundary at time t. Let $\mathbf{x}(t)$ be the positions of points in the region, $\mathbf{v}(\mathbf{x},t)$ the velocity field in the region, and let $\mathbf{f}(\mathbf{x},t)$ be a vector field in the region (it may also be a scalar field). Reynolds transport theorem states that[1]

$$\frac{d}{dt}\left(\int_{\Omega(t)} \mathbf{f}\ \text{dV}\right) = \int_{\Omega(t)} \frac{\partial \mathbf{f}}{\partial t}\ \text{dV} + \int_{\partial\Omega(t)} (\mathbf{v}\cdot\mathbf{n})\mathbf{f}\ \text{dA}\ .$$

Proof Let Ω_0 be reference configuration of the region $\Omega(t)$. Let the motion and the deformation gradient be given by

$$\mathbf{x} = \boldsymbol{\varphi}(\mathbf{X}, t) \; ; \qquad \implies \qquad \boldsymbol{F}(\mathbf{X}, t) = \boldsymbol{\nabla}_\circ \boldsymbol{\varphi} \; .$$

Let $J(\mathbf{X}, t) = \det[\boldsymbol{F}(\mathbf{X}, t)]$. Then, integrals in the current and the reference configurations are related by

$$\int_{\Omega(t)} \mathbf{f}(\mathbf{x}, t)\ \mathrm{dV} = \int_{\Omega_0} \mathbf{f}[\boldsymbol{\varphi}(\mathbf{X}, t), t]\ J(\mathbf{X}, t)\ \mathrm{dV}_0 = \int_{\Omega_0} \hat{\mathbf{f}}(\mathbf{X}, t)\ J(\mathbf{X}, t)\ \mathrm{dV}_0 \; .$$

The time derivative of an integral over a volume is defined as

$$\frac{d}{dt}\left(\int_{\Omega(t)} \mathbf{f}(\mathbf{x}, t)\ \mathrm{dV}\right) = \lim_{\Delta t \to 0} \frac{1}{\Delta t}\left(\int_{\Omega(t+\Delta t)} \mathbf{f}(\mathbf{x}, t+\Delta t)\ \mathrm{dV} - \int_{\Omega(t)} \mathbf{f}(\mathbf{x}, t)\ \mathrm{dV}\right) \; .$$

Converting into integrals over the reference configuration, we get

$$\frac{d}{dt}\left(\int_{\Omega(t)} \mathbf{f}(\mathbf{x}, t)\ \mathrm{dV}\right) = \lim_{\Delta t \to 0} \frac{1}{\Delta t}\left(\int_{\Omega_0} \hat{\mathbf{f}}(\mathbf{X}, t+\Delta t)\ J(\mathbf{X}, t+\Delta t)\ \mathrm{dV}_0 - \int_{\Omega_0} \hat{\mathbf{f}}(\mathbf{X}, t)\ J(\mathbf{X}, t)\ \mathrm{dV}_0\right)$$

Since $\Omega_0$is independent of time, we have

$$\begin{aligned}\frac{d}{dt}\left(\int_{\Omega(t)} \mathbf{f}(\mathbf{x}, t)\ \mathrm{dV}\right) &= \int_{\Omega_0}\left[\lim_{\Delta t \to 0} \frac{\hat{\mathbf{f}}(\mathbf{X}, t+\Delta t)\ J(\mathbf{X}, t+\Delta t) - \hat{\mathbf{f}}(\mathbf{X}, t)\ J(\mathbf{X}, t)}{\Delta t}\right]\ \mathrm{dV}_0 \\ &= \int_{\Omega_0} \frac{\partial}{\partial t}[\hat{\mathbf{f}}(\mathbf{X}, t)\ J(\mathbf{X}, t)]\ \mathrm{dV}_0 \\ &= \int_{\Omega_0}\left(\frac{\partial}{\partial t}[\hat{\mathbf{f}}(\mathbf{X}, t)]\ J(\mathbf{X}, t) + \hat{\mathbf{f}}(\mathbf{X}, t)\ \frac{\partial}{\partial t}[J(\mathbf{X}, t)]\right)\ \mathrm{dV}_0\end{aligned}$$

Now, the time derivative of $\det \boldsymbol{F}$is given by [2]

$$\frac{\partial J(\mathbf{X}, t)}{\partial t} = \frac{\partial}{\partial t}(\det \boldsymbol{F}) = (\det \boldsymbol{F})(\boldsymbol{\nabla}\cdot\mathbf{v}) = J(\mathbf{X}, t)\ \boldsymbol{\nabla}\cdot\mathbf{v}(\boldsymbol{\varphi}(\mathbf{X}, t), t) = J(\mathbf{X}, t)\ \boldsymbol{\nabla}\cdot\mathbf{v}(\mathbf{x}, t) \, .$$

Therefore,

$$\begin{aligned}\frac{d}{dt}\left(\int_{\Omega(t)} \mathbf{f}(\mathbf{x}, t)\ \mathrm{dV}\right) &= \int_{\Omega_0}\left(\frac{\partial}{\partial t}[\hat{\mathbf{f}}(\mathbf{X}, t)]\ J(\mathbf{X}, t) + \hat{\mathbf{f}}(\mathbf{X}, t)\ J(\mathbf{X}, t)\ \boldsymbol{\nabla}\cdot\mathbf{v}(\mathbf{x}, t)\right)\ \mathrm{dV}_0 \\ &= \int_{\Omega_0}\left(\frac{\partial}{\partial t}[\hat{\mathbf{f}}(\mathbf{X}, t)] + \hat{\mathbf{f}}(\mathbf{X}, t)\ \boldsymbol{\nabla}\cdot\mathbf{v}(\mathbf{x}, t)\right)\ J(\mathbf{X}, t)\ \mathrm{dV}_0 \\ &= \int_{\Omega(t)}\left(\dot{\mathbf{f}}(\mathbf{x}, t) + \mathbf{f}(\mathbf{x}, t)\ \boldsymbol{\nabla}\cdot\mathbf{v}(\mathbf{x}, t)\right)\ \mathrm{dV}\end{aligned}$$

where $\dot{\mathbf{f}}$is the material time derivative of $\mathbf{f}$. Now, the material derivative is given by

$$\dot{\mathbf{f}}(\mathbf{x}, t) = \frac{\partial \mathbf{f}(\mathbf{x}, t)}{\partial t} + [\boldsymbol{\nabla}\mathbf{f}(\mathbf{x}, t)]\cdot\mathbf{v}(\mathbf{x}, t) \; .$$

Therefore,

$$\frac{d}{dt}\left(\int_{\Omega(t)} \mathbf{f}(\mathbf{x}, t)\ \mathrm{dV}\right) = \int_{\Omega(t)}\left(\frac{\partial \mathbf{f}(\mathbf{x}, t)}{\partial t} + [\boldsymbol{\nabla}\mathbf{f}(\mathbf{x}, t)]\cdot\mathbf{v}(\mathbf{x}, t) + \mathbf{f}(\mathbf{x}, t)\ \boldsymbol{\nabla}\cdot\mathbf{v}(\mathbf{x}, t)\right)\ \mathrm{dV}$$

or,

$$\frac{d}{dt}\left(\int_{\Omega(t)} \mathbf{f}\ \mathrm{dV}\right) = \int_{\Omega(t)}\left(\frac{\partial \mathbf{f}}{\partial t} + \boldsymbol{\nabla}\mathbf{f}\cdot\mathbf{v} + \mathbf{f}\ \boldsymbol{\nabla}\cdot\mathbf{v}\right)\ \mathrm{dV} \; .$$

Using the identity

$$\boldsymbol{\nabla}\cdot(\mathbf{v}\otimes\mathbf{w}) = \mathbf{v}(\boldsymbol{\nabla}\cdot\mathbf{w}) + \boldsymbol{\nabla}\mathbf{v}\cdot\mathbf{w}$$

we then have

$$\frac{d}{dt}\left(\int_{\Omega(t)} \mathbf{f}\ \mathrm{dV}\right) = \int_{\Omega(t)} \left(\frac{\partial \mathbf{f}}{\partial t} + \boldsymbol{\nabla}\cdot(\mathbf{f}\otimes\mathbf{v})\right)\ \mathrm{dV}\ .$$

Using the divergence theorem and the identity $(\mathbf{a}\otimes\mathbf{b})\cdot\mathbf{n} = (\mathbf{b}\cdot\mathbf{n})\mathbf{a}$ we have

$$\frac{d}{dt}\left(\int_{\Omega(t)} \mathbf{f}\ \mathrm{dV}\right) = \int_{\Omega(t)} \frac{\partial \mathbf{f}}{\partial t}\ \mathrm{dV} + \int_{\partial\Omega(t)} (\mathbf{f}\otimes\mathbf{v})\cdot\mathbf{n}\ \mathrm{dV} = \int_{\Omega(t)} \frac{\partial \mathbf{f}}{\partial t}\ \mathrm{dV} + \int_{\partial\Omega(t)} (\mathbf{v}\cdot\mathbf{n})\mathbf{f}\ \mathrm{dV} \qquad \square$$

See also

- Differentiation under the integral sign
- Leibniz integral rule
- Navier-Stokes equations
- Reynolds number

References

- M.C. Potter, J.F. Foss, *Fluid Mechanics*, Great Lakes Press, 1982

External links

- Osborne Reynolds, Collected Papers on Mechanical and Physical Subjects, in three volumes, published circa 1903, now fully and freely available in digital format:
  Volume 1 [3]
  Volume 2 [4]
  Volume 3 [5]
- http://www.catea.org/grade/mecheng/mod6/mod6.html#slide1

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[2] Gurtinm M. E., 1981, *An Introduction to Continuum Mechanics*. Academic Press, New York, p. 77.

[3] http://www.archive.org/details/papersonmechanic01reynrich

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[5] http://www.archive.org/details/papersonmechanic03reynrich

Rotary feeder

Rotary feeders (also known as rotary airlocks or rotary valves) are commonly used in industrial and agricultural applications as a component in a bulk or specialty material handling system. Rotary feeders are primarily used for discharge of bulk solid material from hoppers/bins, receivers, and cyclones into a pressure or vacuum-driven pneumatic conveying system. Components of a rotary feeder include a rotor shaft, housing, head plates, and packing seals and bearings. Rotors have large vanes cast or welded on and are typically driven by small internal combustion engines or electric motors.

Rotary airlock feeders have wide application in industry wherever dry free-flowing powders, granules, crystals, or pellets are used. Typical materials include: cement, ore, sugar, minerals, grains, plastics, dust, fly ash, flour, gypsum, lime, coffee, cereals, pharmaceuticals, etc...

Industries requiring this type are cement, asphalt, chemical, mining, plastics, food, etc...

Rotary feeders are ideal for pollution control applications in wood, grain, food, textile, paper, tobacco, rubber, and paint industries, the Standard Series works beneath dust collectors and cyclone separators even with high temperatures and different pressure differentials.

Rotary valves are available with square or round inlet and outlet flanges. Housing can be fabricated out of sheet material or cast. Common materials are cast iron, carbon steel, 304 SS, 316 SS, and other materials. Rotary airlock feeders are often available in standard and heavy duty models, the difference being the head plate and bearing configuration. Heavy duty models use an outboard bearing in which the bearings are moved out away from the head plate. Housing inlet and discharge configurations are termed drop-thru or side entry. Different wear protections are available such as hard chrome or ceramic plating on the inner housing surfaces. Grease and air purge fittings are often provided to prevent contaminants from entering the packing seals.

Used as:

- **Rotary airlock**

The basic use of the rotary airlock feeder is as an airlock transition point, sealing pressurized systems against loss of air or gas while maintaining a flow of material between components with different pressure and suitable for air lock applications ranging from gravity discharge of filters, rotary valves, cyclone dust collectors, and rotary airlock storage devices to precision feeders for dilute phase and continuous dense phase pneumatic convey systems.

- **Rotary valve**

Rotary airlock feeders/ rotary airlock valves are used in pneumatic conveying systems, dust control equipment, and as volumetric feed-controls.

- **Volumetric feeder**

Rotary airlock valves are also widely used as volumetric feeders for metering materials at precise flow rates from bins, hoppers, or silos onto conveying or processing systems.

Rotary airlock feeders

Drop thru rotary airlock feeders are designed for rugged applications that require an outboard bearing style unit where contamination and /or an abrasive product cannot be handled with an inboard bearing style. The outboard bearing feeders is engineered for use in high pressure pneumatic conveying systems, with high temperatures where more of an effective seal is required due to high or excessive wear that is experienced with a simple dust collector.

Blow-thru rotary airlock feeder

The blow-thru rotary airlock feeder is ideal for pneumatic conveying applications in food, grain, chemical, milling, baking, plastics and pharmaceutical industries. The blow-thru airlocks feature a low profile with large capacity. High pressure differentials integral mounting feet, and retrofit competitive units. The blow-thru valves are available with 10-vane open-end rotor; outboard bearings and replaceable shaft seals.

Easy clean rotary feeder

The easy-clean series rotary feeders can be fast and simply disassembled, thoroughly quick cleaned, sanitized and inspected or maintenance in a minimum amount of time without the use of tools or removal from service, thereby reducing downtime and increasing system production. Reassembly without tools is accomplished in minutes. Internal clearances are automatically re-established every time.

The Clean-in-place rotary feeder is a special purpose valve designed for where cross-contamination is a major concern and lengthy shut-downs for clean-out are cost-prohibitive, suited for Dairy, Pharmaceutical industries, Food, Baking, Chemical, Plastics, Paint, and Powder Coating plants.

It is ideal for batch mixing systems such as those handling different colored resins which demand regular cleaning between cycles.

Filter valve

The filter valve is a low-cost solution designed for light duty dust collector applications.

Knife rotary feeder

This type of feeder is used for discharge of secondary fuel as for example: plastics or wood. The knife is cutting the oversize material and is preventing the rotor from blockage.

External links

- The Powder and Bulk Channel - Solutions for the Powder and Bulk Industry [1]

References

[1] http://www.powderbulkchannel.com

Rotary screw compressor

A rotary screw compressor is a type of gas compressor which uses a rotary type positive displacement mechanism. The mechanism for gas compression utilises either a single screw element or two counter rotating intermeshed helical screw elements housed within a specially shaped chamber. As the mechanism rotates, the meshing and rotation of the two helical rotors produces a series of volume-reducing cavities. Gas is drawn in through an inlet port in the casing, captured in a cavity, compressed as the cavity reduces in volume, and then discharged through another port in the casing. [1][1]

The effectiveness of this mechanism is dependent on close fitting clearances between the helical rotors and the chamber for sealing of the compression cavities.

Rotary screw compressors are used in a diverse range of applications. Typically, they are used to supply compressed air for general industrial applications. Trailer mounted diesel powered units are often seen at construction sites, and are used to power air operated construction machinery.

Size

Rotary screw compressors tend to be compact and smooth running with limited vibration and thus do not require spring suspension. Many rotary screw compressors are, however, mounted using elastomer vibration isolating mounts to absorb high-frequency vibrations, especially in rotary screw compressors that operate at high rotational speeds.

Oil-flooded screw compressors

In an oil-flooded rotary screw compressor, oil is injected into the compression cavities to aid sealing and provide cooling sink for the gas charge. The oil is separated from the discharge stream, then cooled, filtered and recycled. The oil captures non-polar particulates from the incoming air, effectively reduing the particle loading of compressed air particulate filtration. It is usual for some entrained compressor oil to carry over into the compressed gas stream downstream of the compressor. In some applications, this is rectified by coalescer/filter vessels.[2] In other applications, this is rectified by the use of receiver tanks that reduce the local velocity of compressed air, allowing oil to condense and drop out of the air stream to be removed from the compressed air system via condensate management equipment.

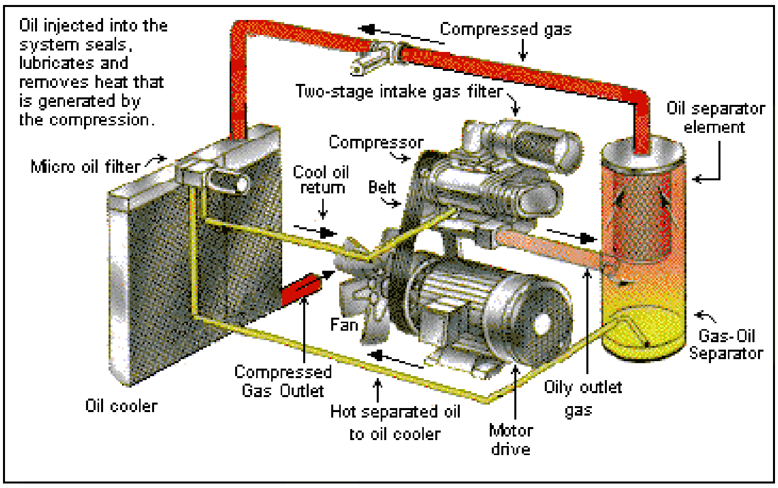


Diagram of a rotary screw compressor

Standard oil-flooded compressors are capable of achieving output pressures over 200 psig, and output volumes of over 1500 cubic feet per minute (measured at 60 °C and atmospheric

pressure).

Oil-free screw compressors

In an oil-free compressor, the air is compressed entirely through the action of the screws, without the assistance of an oil seal. They usually have lower maximum discharge pressure capability as a result. However, multi-stage oil-free compressors, where the air is compressed by several sets of screws, can achieve pressures of over 150 psig, and output volume of over 2000 cubic feet per minute (measured at 60 °C and atmospheric pressure).

Oil-free compressors are used in applications where entrained oil carry-over is not acceptable, such as medicial research and semiconductor manufacturing. However, this does not preclude the need for filtration as hydrocarbons and other contaminants ingested from the ambient air must also be removed prior to the point-of-use. Subsequently, air treatment comparable to an Oil-flooded screw compressor is frequently still required to ensure a given quality of compressed air.

Control Schemes

Among rotary screw compressors, there are multiple control schemes, each with differing advantages and disadvantages.

Start/Stop

In a start/stop control scheme, relays actuate to apply and remove power to the compressor airend according to compressed air needs.

Load/Unload

In a load/unload control scheme, the compressor airend remains continuously powered. However, when the demand for compressed air is satisfied, instead of disconnecting power to the compressor airend, the inlet valve is closed, *unloading* the compressor. This reduces the number of start/stop cycles for electric motors over a start/stop control scheme in electrically-driven compressors, improving equipment service life with a minimal change in operating cost. This scheme is utilised by nearly all industrial air compressor manufacturers, including Atlas Copco, Ingersoll Rand, Kaeser Kompressoren, and Sullair. When a load/unload control scheme is combined with a timer to stop the compressor after a predetermined period of continuously unloaded operation, it is known as a dual-control scheme.

Modulation

Instead of starting and stopping the compressor or actuating the inlet valve between two distinct positions, a modulation control scheme proportionally adjusts the inlet valve open and closed, altering the compressor discharge according to demand. While this yield a consistent discharge pressure over a wide range of demand, power consumption is significantly higher than with a load/unload scheme, resulting in approximately 70% of full-load power consumption when the compressor is at a zero-load condition. This control scheme was popularized in industrial air compressor applications by Gardner Denver.

Variable Displacement

Utilized by compressor companies Gardner Denver, Sullair, and Ingersoll Rand, variable displacement alters the percentage of the screw compressor rotors working to compress air by allowing air flow to bypass portions of the screws. While this has slightly reduced power consumption when compared to a modulation control scheme, it yields significantly higher power consumption than a load/unload control scheme in a precisely calibrated compressor system.

Variable Speed

While the variable speed air compressor can offer the lowest operating energy cost without any appreciable reduction in service life over a properly-maintained load/unload compressor, the variable speed drive typically adds significant cost to the design of such a compressor, potentially negating its economic benefits for applications where there is limited variation in demand. A comprehensive air audit can provide the information necessary to determine if a variable speed rotary screw compressor offers improved economy over a load/unload rotary screw compressor.

See also

- Gas compressor
- Variable speed air compressor
- Vapor-compression refrigeration

References

[1] Screw Compressor (http://www.blackmer.com/tech-screw.jsp) Describes how screw compressors work and include photographs.
[2] Technical Centre (http://www.domnickhunter.com/technicalcentre/3.3.3) Discusses oil-flooded screw compressors including a complete system flow diagram

"Rotary Screw Compressor." (http:/ / www. werther. com/ category/ Rotary-Screw-Compressors/ Categories. html?search=1& catid=3) "Compressed Air Solution"]

Rotor

Rotor may refer to:

- A rotating part of a mechanical device, for example in an electric motor, generator, alternator or pump.

In **engineering**:

- Rotor (electric), the non-stationary part of an alternator or electric motor, operating with a stationary element called the stator.
- Helicopter rotor, the rotary wing(s) of a rotorcraft such as a helicopter
- ROTOR, a former radar project in the UK following the Second World War
- Rotor (turbine), the rotor of a turbine powered by fluid pressure
- Rotor (crank), a variable-angle bicycle crank
- Rotor (brake), the disc of a disc brake, in U.S. terminology
- Rotor (brake mechanism), a device that allows the handlebars and fork to revolve indefinitely without tangling the rear brake cable
- Rotor (distributor), a component of the ignition system of an internal combustion engine
- Rotor (engine), the rotary piston in a rotary combustion engine
- Rotor (antenna), an electric motor that rotates an antenna to the direction of transmission or reception

In **computing**:

- Rotor machine, the rotating wheels used in certain cipher machines, such as the German Enigma machine
- Rotor (software project), the former code name for Microsoft's shared source implementation of its Common Language Infrastructure

In **medicine**:

- Rotor syndrome, a rare liver disorder

In **music**:

- Rotor (band), a German progressive stoner rock band
- Rotor (label), a Swedish record label publishing, among other things, music for silent films

In **biology** and **chemistry**:

- The rotating part of a centrifuge, which also holds the samples

In **other fields**:

- SC Rotor Volgograd, a Russian football club
- Rotor (Sonic the Hedgehog), a fictional character from the Sonic the Hedgehog universe
- Rotor (ride), the trade name for an amusement ride
- Rotor (meteorology), a turbulent horizontal vortex that forms in the trough of lee waves
- Rotor (mathematics), an n-blade object in geometric algebra, which rotates another n-blade object about a fixed or translated point
- Curl (mathematics), known as rotor in some countries, a vector operator that shows a vector field's rate of rotation
- Rotor, a space colony in Isaac Asimov's book *Nemesis*
- R.O.T.O.R., a 1989 science fiction/action movie
- Vibrator (sex toy), a Japanese usage of similar sounds in English. Also spelt as rotar.

Rotordynamics

Rotordynamics is a specialized branch of applied mechanics concerned with the behavior and diagnosis of rotating structures. It is commonly used to analyze the behavior of structures ranging from jet engines and steam turbines to auto engines and computer disk storage. At its most basic level rotordynamics is concerned with one or more mechanical structures (rotors) supported by bearings and influenced by internal phenomena that rotate around a single axis. The supporting structure is called a stator. As the speed of rotation increases the amplitude of vibration often passes through a maximum that is called a → critical speed. This amplitude is commonly excited by unbalance of the rotating structure; everyday examples include engine balance and tire balance. If the amplitude of vibration at these critical speeds is excessive catastrophic failure[1] occurs. In addition to this, turbomachinery often develop instabilities which are related to the internal makeup of turbomachinery, and which must be corrected. This is the chief concern of engineers who design large rotors.

Basic principles

The equation of motion, in generalized matrix form, for an axially symmetric rotor rotating at a constant spin speed Ω is

$$M\ddot{q}(t) + (C + G)\dot{q}(t) + (K + N)q(t) \quad = \quad f(t)$$

where:

M is the symmetric mass matrix

C is the symmetric damping matrix

G is the skew-symmetric gyroscopic matrix

K is the symmetric bearing or seal stiffness matrix

N is the gyroscopic matrix of deflection for inclusion of e.g. centrifugal elements.

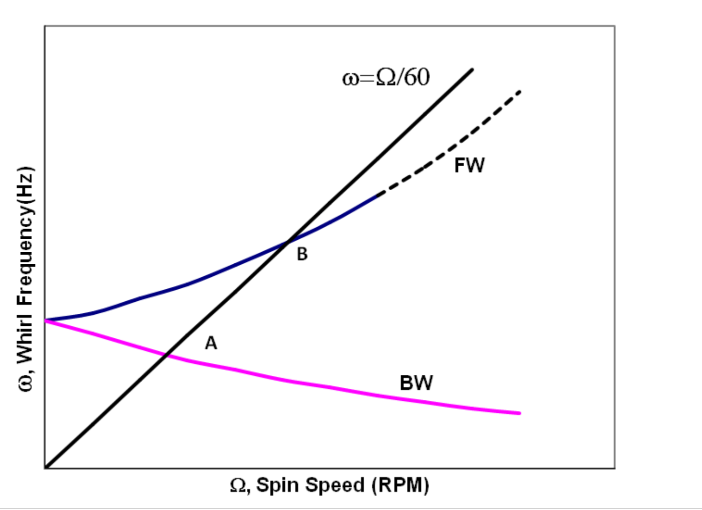
in which *q* is the generalized coordinates of the rotor in inertial coordinates and *f* is a forcing function.

The gyroscopic matrix *G* is proportional to spin speed Ω. The general solution to the above equation involves complex eigenvectors which are spin speed dependent. Engineering specialists in this field rely on the → Campbell Diagram to explore these solutions.

An interesting feature of the rotordynamic system of equations are the off-diagonal terms of stiffness, damping, and mass. These terms are called cross-coupled stiffness, cross-coupled damping, and cross-coupled mass. When there is a positive cross-coupled stiffness, a deflection will cause a reaction force opposite the direction of deflection to react the load, and also a reaction force in the direction of positive whirl. If this force is large enough compared with the available direct damping and stiffness, the rotor will be unstable. When a rotor is unstable it will typically require immediate shutdown of the machine to avoid catastrophic failure.

Campbell diagram

The → Campbell diagram of a simple rotor system is shown on the right. The red and blue curves show the backward whirl (BW) and forward whirl (FW) modes, which diverge as the spin speed increases. When the BW frequency or the FW frequency equal the spin speed Ω, indicated by the intersections A and B with the synchronous spin speed line, the response of the rotor may show a peak. This is called a → critical speed.



→ Campbell Diagram for a Simple Rotor

Jeffcott rotor

The Jeffcott rotor (also known as the DeLaval rotor in Europe) is a simplified lumped parameter model used to solve these equations. The Jeffcott rotor is a mathematical idealization that may not reflect actual rotor mechanics.

History

The history of rotordynamics is replete with the interplay of theory and practice. W. J. M. Rankine first performed an analysis of a spinning shaft in 1869, but his model was not adequate and he predicted that supercritical speeds could not be attained. In 1895 Dunkerley published an experimental paper describing supercritical speeds. Carl Gustaf De Laval, a Swedish engineer, ran a steam turbine to supercritical speeds in 1889, and Kerr published a paper showing experimental evidence of a second critical speed in 1916.

Henry Jeffcott was commissioned by the Royal Society of London to resolve the conflict between theory and practice. He published a paper now considered classic in the *Philosophical Magazine* in 1919 in which he confirmed the existence of stable supercritical speeds. August Föppl published much the same conclusions in 1895, but history largely ignored his work.

Between the work of Jeffcott and the start of World War II there was much work in the area of instabilities and modeling techniques culminating in the work of Prohl and Myklestad which led to the Transfer Matrix Method (TMM) for analyzing rotors. The most prevalent method used today for rotordynamics analysis is the Finite Element Method.

Modern computer models have been commented on in a quote attributed to Dara Childs, "the quality of predictions from a computer code has more to do with the soundness of the basic model and the physical insight of the analyst. ... Superior algorithms or computer codes will not cure bad models or a lack of engineering judgment."

Prof. F. Nelson has written extensively on the history of rotordynamics and most of this section is based on his work.

Software

There are many software packages that are capable of solving the rotordynamic system of equations. Rotordynamic specific codes are more versatile for design purposes. These codes make it easy to add bearing coefficients, side loads, and many other items only a rotordynamicist would need. The non-rotordynamic specific codes are full featured FEA solvers, and have many years of development in their solving techniques. The non-rotordynamic specific codes can also be used to calibrate a code designed for rotordynamics.

Rotordynamic specific codes:

- MADYN 2000 (DELTA JS Inc. [2]) - Commercial combined finite element (3D Timoshenko beam) lateral, torsional, axial and coupled solver for multiple rotors and gears, various bearings (fluid film, spring damper, magnetic)
- Dyrobes (Eigen Technologies, Inc. [3]) - Commercial 1-D beam element solver
- XLRotor (Rotating Machinery Analysis, Inc. [4]) - Commercial 1-D beam element solver
- iSTRDYN (DynaTech Software LLC [5]) - Commercial 2-D Axis-symmetric finite element solver
- ARMD (Rotor Bearing Technology & Software, Inc. [6]) - Commercial 1-D beam element solver
- XLTRC2 (Texas A&M [7]) - Academic 1-D beam element solver
- ComboRotor (University of Virginia [8]) - Combined finite element lateral, torsional, axial solver for multiple rotors evaluating critical speeds, stability and unbalance response extensively verified by industrial use
- Dynamics R4 (Alfa-Tranzit Co. Ltd [9]) - Commercial software developed for design and analysis of spatial systems
- MESWIR (Institute of Fluid-Flow Machinery, Polish Academy of Sciences [10]) - Academic computer code package for analysis of rotor and bearings whitin the linear and non-linear range.

Non-rotordynamic specific codes:

- Ansys - Version 11 workbench and classic is capable of solving the rotordynamic equations (3-D/2-D and beam element)
- Nastran - Finite element based (3-D/2-D and beam element)

See also

- Axle
- Balancing machine
- Bearing (mechanical)
- Bently Nevada
- Driveshaft
- Magnetic bearing
- Turbine

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[3] http://www.dyrobes.com
[4] http://www.xlrotor.com
[5] http://www.istrdyn.com
[6] http://www.rbts.com
[7] http://turbolab.tamu.edu
[8] http://www.virginia.edu/romac/
[9] http://www.alfatran.com
[10] http://www.imp.gda.pl/index_a.html

Rubber bushing

A **rubber bushing** is a device, primarily used in suspension systems, which separates the faces of two metal objects whilst still allowing a set degree of movement. This movement allows the suspension parts to move freely for example when traveling over a large bump but minimizes transmission of noise and small vibrations through to the chassis of the vehicle. A rubber bushing may also be described as a *flexible mounting* or *anti-vibration mounting*.

Uses

Uses for the rubber bushing include anti-roll bar links and mountings, shock absorber mountings and front wishbone assemblies to name only a few.

Advantages

Advantages of using a rubber bushing over a solid bearing system are that less noise and vibration are transmitted through rubber. Rubber also requires little or no lubrication.

Disadvantages

Disadvantages of rubber bushings are that they can deteriorate quickly in the presence of mineral oil and that extreme heat and cold can also lead to failure. The flexibility of rubber also introduces an element of play in the suspension system. This may result in camber, caster or toe changes in the wheels of the vehicle during high load conditions (cornering and braking), adversely affecting the vehicle's handling. For this reason a popular aftermarket performance upgrade is the replacement of rubber suspension bushes with bushes made of more rigid materials, such as polyurethane.

Trademarks

Trademarks for particular types of rubber bushing include *Isolastic*, *Metalastic* and *Metalastik*.

See also

- → Vibration isolation

SAWE

The **Society of Allied Weight Engineers (SAWE)** is a professional society of engineers that pertains to the specific field of Mass Properties. The society was founded originally as the 'Society of Aeronautics Weight Engineers' in 1939 but was later renamed to the Society of Allied Weight Engineers, Inc. on January 1, 1973 due to a diverse membership including those outside the field of aeroautics.

Purpose

- Providing a means for those interested in mass properties engineering to work together to further their professional goals.
- Promoting recognition of mass properties engineering as a specialized discipline in the entire spectrum of professional engineering.
- Serving as a medium for the exchange of current mass properties related techniques and state of the art improvements in the profession.
- Promoting the design and manufacture of optimum weight equipment, development of new materials, and improvements in the state of the art.
- Encouraging members to promote continuous improvement in the interrelations between mass properties engineers for mutual benefit.
- Publicly recognizing any person or organization that significantly enhances the professionalism of the Society or develops new technology that improves the state of the art of mass properties engineering efficiencies.
- Promoting the inclusion of mass properties engineering in the curriculum of study in institutions of higher learning.
- Providing training for those working in the field of Mass Properties.

Membership

Membership to the society is open to all those involved in the field of Mass Properties. This includes those who actively practice Mass Properties and those whose line of work contributes to the advancement of Mass Properties.

Ranks of Membership

- Honorary Fellows
- Fellows
- Members
- Academic Members
- Student Members
- Retired Members
- Lifetime Members
- Company Members

Benefits of Membership

- Three issues of the Weight Engineering Journal
- Four issues of the SAWE Newsletter
- The Annual Membership Roster
- The Technical Paper Index (issued every three years)
- The Conference Announcement
- The opportunity to take specialized training classes
- A 15% discount on technical papers purchased
- Free handbook updates and revisions.

Conference

A yearly conference is sponsored by SAWE and hosted by one of the local chapters. The 2006 SAWE Conference was held in Valencia, California and the 2007 was held in Madrid, Spain. They 2008 International Conference will be held in Seattle, Washington, just in time for the delivery of the first Boeing 787.

External links

- SAWE.org [1]
- [2] - For 2008 Conference information

References

[1] http://www.sawe.org
[2] http://seattle.sawe.org

Sacrificial part

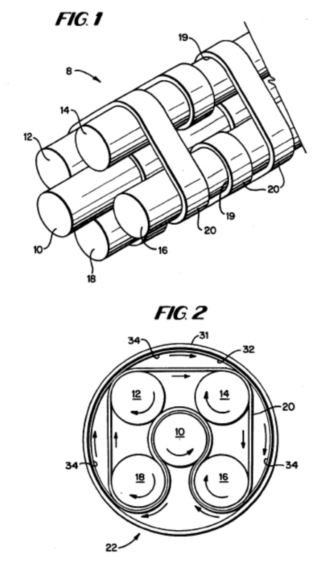
A **sacrificial part** is a part of a machine or product that is intentionally engineered to fail under excess mechanical stress, electrical stress, or other unexpected and dangerous situations. The sacrificial part is engineered to fail first, and thus protect other parts of the system.

Examples of sacrificial part include:

- Electrical fuses
- Over-pressure burst disks
- → Mechanical shear pins

Scrollerwheel

A **scrollerwheel** is a mechanical device composed of a number of rollers (four or more) and connective bands under tension, which wrap around and weave between the rollers forming a self-supporting cluster possessing a central roller. The cluster of rollers is bound by the connective bands in such a way that the static friction between the rollers and bands prevent the rollers from slipping as they roll and orbit the central roller.[1] Scrollerwheels are related in operational principle to rolamite linear bearings (developed at Sandia National Labs in the late 1960s), and like them, they display only rolling friction, and not the kinetic friction inherent in most mechanical bearings.



Structure of a scrollerwheel

The rollers can have a cross section in a variety of shapes other than circular, such as: ovoids (which with a single ovoid roller as the central roller, or one of the outer rollers, results in a → cammed motion), various varieties of superellipses and Reuleaux triangles.

Advantages

Unlike conventional rolling-element bearings, they do not require lubrication. Consequentially, they can be employed in environments hostile to lubricated bearings: underwater, in a vacuum (where grease will boil) and at elevated temperatures.

They can be constructed from a wide variety of materials.

Disadvantages

Scrollerwheels cannot have an aspect ratio (diameter compared to thickness) as high as conventional mechanical bearings.

See also

- Rolamite

External links

- U.S. Patent #5,462,363 [2]
- Video of a scrollerwheel [3]
- ScrollerWheel Details [4]

References

[1] Canadians Reinvent the Wheel (http://www.businessweek.com/archives/1995/b343792.arc.htm)*Business Week* August 14, 1995

[2] http://patft.uspto.gov/netacgi/nph-Parser?Sect1=PTO1&Sect2=HITOFF&d=PALL&p=1&u=%2Fnetahtml%2FPTO%2Fsrchnum.htm&r=1&f=G&l=50&s1=5,462,363.PN.&OS=PN/5,462,363&RS=PN/5,462,363

[3] http://www.youtube.com/watch?v=y-BK_iEJ7Go

[4] http://erikbrinkman.com/Scroller/Home.html

Self-exciting oscillation

Self-exciting oscillation is a phenomenon in many fields, including engineering, economics and biology.

Mathematical basis

Self-exciting oscillations are a logical consequence of systems which are described by a closed loop of time-lagged differential equations, i.e. where a change in variable N is driven by a change in variable N+1 but only after a time delay, a change in variable N+1 is driven by a change in variable N+2 but only after a time delay, ... a change in variable N is driven by a change in variable N+x but only after a time delay.

Examples in Engineering

Railway and automotive wheels

Hunting in railway wheels and shimmy in automotive tires can cause an uncomfortable wobbling effect, which in extreme cases can derail trains and cause cars to lose grip.

For a mathematical analysis of the phenomenon in the context of railway vehicle dynamics, see Hunting oscillation.

Central heating thermostats

Early central heating thermostats were guilty of hunting because they responded too quickly. The problem was overcome by hysteresis, i.e., making them switch state only when the temperature varied from the target by a specified minimum amount.

Automatic transmissions

Hunting occurred in early automatic transmission designs when the vehicle was traveling at a speed which was between the ideal speeds of 2 gears. In these situations the transmission system would switch almost continuously between the 2 gears, which was both annoying and hard on the transmission. Such behavior is now inhibited by introducing hysteresis into the system.

Steering of vehicles when course corrections are delayed

There are many examples of hunting caused by delayed course corrections, ranging from light aircraft in a strong wind to erratic steering of road vehicles by a driver who is inexperienced or drunk.

Examples in other fields

Boom-bust cycles in economics

No doubt in practice these are partly due to herd psychology, but closed loops of time-lagged differential equations are a sufficient explanation. In economics the time delay is caused by the need for individuals and organizations to gather information and make decisions. The classic example is the stock market: prices start rising, after a while investors notice this and increase their buying, this forces prices up, etc. - until something (e.g. a scandal or an economic crisis) stops prices from rising, after a while investors decide to sell, etc.

Population cycles in biology

For example a reduction in population of a herbivore species because of e.g. illness, this makes the populations of predators of that species decline, the reduced level of predation allows the herbivore population to increase, this allows the predator population to increase, etc. Closed loops of time-lagged differential equations are a sufficient explanation for such cycles - in this case the delays are caused mainly by the breeding cycles of the species involved.

SEIG (Self Excited Induction Generator)

If an asynchronous motor is connected to a capacitor and the shaft turns with above critical speed, an electric hunting occurs which appears as line voltage on the terminals and provides useful function. See Exciter [1], an open source generator that is built on this principle.

References

[1] http://ronja.twibright.com/exciter/

Shear pin

A **shear pin** is the mechanical → sacrificial part, analogue of an electric fuse. Installed in a drive train, it is designed to break in the case of a mechanical overload, preventing other, more-expensive parts of the drive train from being damaged.

A shear pin may be plain metal rod inserted through a hub and axle; the diameter of the rod is carefully chosen to allow the shearing action when the desired breakaway force or shock is reached. A cotter pin may also be used as a low-tech shear pin.

A common use of shear pins is in the drive train of a snow blower's auger or the propellers attached to marine engines.

External links

- company specializing in shear pins [1]

References

[1] http://www.powertrainsavers.com/

Shear strength

Shear strength in engineering is a term used to describe the strength of a material or component against the type of yield or structural failure where the material or component fails in shear.

In structural and → mechanical engineering the shear strength of a component is important for designing the dimensions and materials to be used for the manufacture/construction of the component (e.g. beams, plates, or bolts) In a reinforced concrete beam, the main purpose of stirrups is to increase the shear strength.

For shear stress τ applies

$$\tau = \frac{\sigma_1 - \sigma_2}{2},$$

where

σ_1 is major principal stress

σ_2 is minor principal stress

In general: ductile materials fail in shear (ex. aluminum), whereas brittle materials (ex. cast iron) fail in tension. See tensile strength.

To calculate: Given failing force and area, example-bolt shear strength:

$$\tau = \frac{F}{A} = \frac{F}{\pi r_{bolt}^2} = \frac{4F}{\pi d_{bolt}^2}$$

As a very rough guide[1] :

Material	Ultimate Strength Relationship	Yield Strength Relationship
Steels	USS = approx. 0.75*UTS	SYS = approx. 0.58*TYS
Ductile Iron	USS = approx. 0.9*UTS	SYS = approx. 0.75*TYS
Malleable Iron	USS = approx. 1.0*UTS	

Wrought Iron	USS = approx. 0.83*UTS	
Cast Iron	USS = approx. 1.3*UTS	
Aluminiums	USS = approx. 0.65*UTS	SYS = approx. 0.55*TYS

USS: Ultimate Shear Strength, UTS: Ultimate Tensile Strength, SYS: Shear Yield Stress, TYS: Tensile Yield Stress

See also

- Shear modulus
- Shear stress
- Shear strain
- Shear strength (soil)
- Strength of materials
- Tensile strength

References

[1] http://www.roymech.co.uk/Useful_Tables/Matter/shear_tensile.htm

Sieving coefficient

In → mass transfer, the **sieving coefficient** is a measure of equilibration between of the concentrations of two mass transfer streams. It is defined as the mean pre- and post-contact concentration of the mass receiving stream divided by the pre- and post-contact concentration of the mass donating stream.

$$S = \frac{C_r}{C_d}$$

where

- S is the sieving coefficient
- C_r is the mean concentration mass receiving stream
- C_d is the mean concentration mass donating stream

A sieving coefficient of unity implies that the concentrations of the receiving and donating stream equilibrate, i.e. the out-flow concentrations (post-mass transfer) of the mass donating and receiving stream are equal to one another. Systems with sieving coefficient that are greater than one require an external energy source, as they would otherwise violate the laws of thermodynamics.

Sieving coefficients less than one represent a mass transfer process where the concentrations have not equilibrated.

Contact time between mass streams in important in consider in mass transfer and affects the sieving coefficient.

In kidney

In renal physiology, the sieving coefficient can be expressed as: sieving coefficient = clearance / ultrafiltration rate[1]

See also

- Heat exchanger
- Condenser pinch point
- Sieve

References

[1] Sieving coefficient in drug clearance (http://www.aic.cuhk.edu.hk/web8/Renal replacement therapy - CVVH.htm) - cuhk.edu.hk

Sight glass

A **sight glass** or **water gauge** is a transparent tube through which the operator of a tank or boiler can observe the level of liquid contained within.

Water gauge on a steam locomotive. Here the water is at the “top nut”, the maximum working level. Note the patterned backplate to help reading and toughened glass shroud.

Liquid in tanks

Simple sight glasses may be just a plastic or glass tube connected to the bottom of the tank at one end and the top of the tank at the other. The level of liquid in the sight glass will be the same as the level of liquid in the tank. Today, however, sophisticated float switches have replaced sight glasses in many such applications.

Steam boilers

If the liquid is hazardous or under pressure, more sophisticated arrangements must be made. In the case of a boiler, the pressure of the water below and the steam above is equal, so any change in the water level will be seen in the gauge. The transparent tube (the “glass” itself) may be mostly enclosed within a metal or toughened glass shroud to prevent it from being damaged through scratching or impact and offering protection to the operators in the case of breakage. This usually has a patterned backplate to make the magnifying effect of the water in the tube more obvious and so allow for easier reading. In some locomotives

where the boiler operated at very high pressures, the tube itself would be made of metal-reinforced toughened glass.[1] It is important to keep the water at the specified level, otherwise the top of the firebox will be exposed, creating an overheat hazard and causing damage and possibly catastrophic failure.

To check that the device is offering a correct reading and the connecting pipes to the boiler are not blocked by scale, the water level needs to be “bobbed” by quickly opening the taps in turn and allowing a brief spurt of water through the drain cock.[2]

Failure

The gauge glass on a boiler needs to be inspected periodically and replaced if it is seen to have worn thin in the vicinity of the gland nuts, but a failure in service can still occur. Drivers are expected to carry two or three glass tubes, pre-cut to the required length, together with hemp or rubber seals, to replace the tubes on the road.[1] Familiarity with this disquieting occurrence was considered so important that a glass would often be smashed deliberately while a trainee driver was on the footplate, to give them practice in fitting a new tube.[3] Although automatic ball valves are fitted in the mounts to limit the release of steam and scalding water, these can fail through accumulation of limescale. It was standard procedure to hold the coal scoop in front of the face while the other hand, holding the cap for protection, reached to turn off the valves at both ends of the glass.

Repair of a broken glass

The following is the generally accepted procedure of safely fitting a new tubular glass on a steam boiler in industrial applications. Leather work gloves and a full face shield should be worn while working with the glass; this to prevent burns, cuts, and protect the operator's eyesight.

1. Shut both the valves and open the glass drain cock
2. Loosen and remove both gland nuts
3. Remove any broken glass or other debris from glass valve body
4. Place gland nuts and new seals on the precut glass
5. Install glass in upper valve first and loosely tighten the nut. Pull glass down to bottom so that the gap in upper and lower valve body is even (this allows for expansion of the glass)
6. Hand tighten both nuts, and then using a wrench, give each nut an additional quarter turn.
7. Crack open steam side valve and allow the steam to lightly blow through to warm the glass. This prevents the glass from being subject to sudden thermal shock. (Should the glass be subject to thermal shock the effects may not be noticed immediately. However, the glass may then be much more brittle and even a slight bump might shatter it.)
8. Close drain valve and crack open valve on water side of glass
9. Observe gland for leakage and tighten as required
10. Open both valves fully.

History

The first locomotive to be fitted with the device was built in 1829 by John Rastrick at his Stourbridge works.[4]

See also

- Fuel gauge
- Fusible plug

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Simple machine

A **simple machine** is a mechanical device that changes the direction or magnitude of a force.[2] In general, they can be defined as the simplest mechanisms that use → mechanical advantage (also called leverage) to multiply force.[3] A simple machine uses a single applied force to do work against a single load force. Ignoring friction losses, the work done on the load is equal to the work done by the applied force. They can be used to increase the amount of the output force, at the cost of a proportional decrease in the distance moved by the load. The ratio of the output to the input force is called the mechanical advantage.

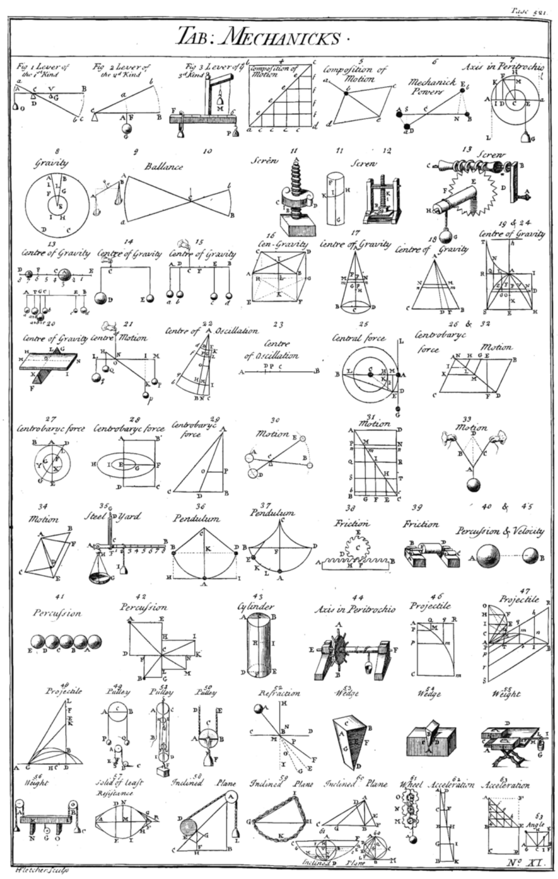

Table of simple mechanisms, from Chambers' Cyclopedia, 1728.[1] Simple machines provide a "vocabulary" for understanding more complex machines.

Usually the term refers to the six classical simple machines which were defined by Renaissance scientists:[4]

- → Lever
- Wheel and axle
- Pulley
- Inclined plane
- Wedge
- Screw

They are the elementary "building blocks" of which all complicated machines are composed.[3] [5] For example, wheels, levers, and pulleys are all used in the mechanism of a bicycle.

Simple machines fall into two classes; those dependent on the vector resolution of forces (inclined plane, wedge, screw) and those in which there is an equilibrium of torques (lever, pulley, wheel).

History

The idea of a "simple machine" originated with the Greek philosopher Archimedes around the 3rd century BC, who studied the "Archimedean" simple machines: lever, pulley, and screw. He discovered the principle of → mechanical advantage in the lever.[6] His understanding was limited to the static balance of forces and did not include the trade-off between force and distance moved. Heron of Alexandria (ca. 10–75 AD) in his work *Mechanics* lists five mechanisms with which a load can be set in motion: The winch, lever, pulley, wedge, and screw.[7] During the Renaissance the classic five simple machines (excluding the wedge) began to be studied as a group. The complete dynamic theory of simple machines was worked out by Italian scientist Galileo Galilei in 1600 in *Le Meccaniche* ("On Mechanics"). He was the first to understand that simple machines do not create energy, only transform it.[8]

Alternate definitions

Any list of simple machines is somewhat arbitrary; the central idea is that every mechanism that manipulates force should be able to be understood as a combination of devices on the list. Some variations that have been proposed to the classical list of six simple machines:

- Some say there are only five simple machines, arguing that the wedge is a moving inclined plane.
- Others further simplify the list to four saying that the screw is a helical inclined plane.[9] This position is less accepted because a screw simultaneously converts a rotational force (torque) to a linear force.
- Some go even further to insist that only two simple machines exist, as a pulley and wheel and axle can be viewed as unique forms of levers, leaving only the lever and the inclined plane.[10] [11] [12] [13]
- The most extreme view is that only one simple machine exists, the inclined plane, in the theory that any object (ie. Spoon) is an Inclined Plane, but used in the right circumstances, acts as a Lever.
- Hydraulic systems can also provide amplification of force, so some say they should be added to the list.[14] [15] [12]

Frictionless analysis

Although each machine works differently, the way they function is similar mathematically. In each machine, a force F_{in} is applied to the device at one point, and it does work moving a load, F_{out} at another point. Although some machines only change the direction of the force, such as a stationary pulley, most machines multiply (or divide) the magnitude of the force by a factor, the → mechanical advantage, that can be calculated from the machine's geometry. For example, the mechanical advantage of a → lever is equal to the ratio of its

lever arms.

Simple machines do not contain a source of energy, so they cannot do more work than they receive from the input force. When friction and elasticity are ignored, the work output (that is done on the load) is equal to the work input (from the applied force). The work is defined as the force multiplied by the distance it moves. So the applied force, times the distance the input point moves, D_{in}, must be equal to the load force, times the distance the load moves, D_{out} [13] :

$$F_{in}D_{in} = F_{out}D_{out}.$$

So the ratio of output to input force, the → mechanical advantage, is the inverse ratio of distances moved:

$$\text{Mechanical Advantage} \equiv \frac{F_{out}}{F_{in}} = \frac{D_{in}}{D_{out}}.$$

In the screw, which uses rotational motion, the input force should be replaced by the torque, and the distance by the angle the shaft is turned.

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Slip joint

A **slip joint** is a mechanical construction allowing extension and compression in a linear structure.

General forms

Slip joints can be designed to allow continuous relative motion of two components or it can allow an adjustment from one temporarily fixed position to another. Examples of the latter are tripods, hiking poles, or similar telescoping device. The position is fixed using a clamping mechanism based on a → cam, a set screw or similar locking mechanism. Slip joints can also be non-telescoping, such as the joints on some older wooden surveyor's levelling rods. These use a joint that keeps the sections offset from each other but able to be slid together for transport.

Examples of continuous slip joints are given below.

Special purpose slip joints

Civil Engineering

Slip joints in large structures are used to allow independent motion of large components while enabling them to be joined in some way. For example, if two tall buildings are to be joined with a pedestrian skyway at some high level, there are two options in structural engineering. If the buildings are identical in mass and elasticity they will tend to respond similarly to ground motion induced by earthquakes. In this case it may be appropriate to construct a rigid connection between the buildings, although this may require additional supporting members within the structures. On the other hand, a lower cost connection may be made by using a lightweight structure that is not coupled rigidly but instead which is allowed to slide or "float" relative to one or both structures. This is especially suitable where the two structures may respond differently to ground motion. The structure will not be completely free to move but rather may use elastic materials to locate it near the center of its range of motion and viscous shock absorbers to absorb energy and to restrict the speed of relative motion. When a sliding connection is used it is extremely important that there be sufficient range of motion without failure to accommodate the maximum credible relative motion of the structures. Additional "fail safe" flexible connections may be added to ensure that the structure does not fall, although it may be damaged to a point of being unservicable or unrepairable

Slip joints are common under conditions where temperature changes can cause expansion and contraction that may overstress a structure. These are generally referred to as *expansion joints.* Bridges and overpasses frequently have sliding joints that allow a deck to move relative to piers or abutments. The joints can be constructed with elastomeric pads that permit motion or can use rollers on flat surfaces to allow the ends to move smoothly. The exact details are limited by the imagination of the designer.

Mechanical Engineering

Slip joints are sometimes found in tubular structures such as piping, but are generally avoided for this application due to requirements for sealing against leakage, instead using either a large loop that is allowed to flex or a semi-rigid bellows. Pipe supports often are slip joints to allow for the thermal expansion or contraction or the pipe relative to the support.

See also

- Slip critical joint

South Pointing Chariot

South Pointing Chariot	
Traditional Chinese	指南車
Simplified Chinese	指南车
Transliterations	
Mandarin	
- Hanyu Pinyin	zhi3 nan2 che1
Cantonese	
- Jyutping	zi2 naam4 ce1

The **South Pointing Chariot** is widely regarded as one of the most complex geared mechanisms of the ancient Chinese civilization, and was continually used throughout the medieval period as well. It was supposedly invented sometime around 2600 BC in China by the Yellow Emperor Huang Di, yet the first valid historical version was created by Ma Jun (c. 200-265 AD) of Cao Wei during the Three Kingdoms. The chariot is a two-wheeled vehicle upon which is a pointing figure connected to the wheels by means of differential gearing. Through careful selection of wheel size, track and gear ratios, the figure atop the chariot will always point in the same direction, hence acting as a non-magnetic compass vehicle. Throughout history, many Chinese historical texts have mentioned the South Pointing Chariot, while some described in full detail the inner components and workings of the device.

Reconstruction of a South Pointing Chariot, 2005

Model in the Science Museum in London

Legend and history

Legend

Legend has it that Huang Di, credited as being the founder of the Chinese nation, lived in a magnificent palace in the Kunlun Mountains.

There was also at this time another tribal leader, Chi You, who was skilled at making weapons and waging war. He attacked the tribe of Yan Di, driving them into the lands of Huang Di. Huang Di was angered by this and went to war with Yan Di, initially suffering several defeats. At some stage in the fighting, Chi You conjured up a thick fog to confound Huang Di's men. However, the South Pointing Chariot was used to find their way and they were ultimately victorious.

History

Despite legend, it was recorded in the *Sanguo Zhi* (Records of the Three Kingdoms) that the 3rd century mechanical engineer Ma Jun from the Kingdom of Wei was the inventor of the South Pointing Chariot (also called the south-pointing carriage). After being mocked by Permanent Counsellor Caotang Long and the Cavalry General Qin Lang that he could not reproduce what they deemed a non-historical and nonsensical pursuit, Ma Jun retorted "Empty arguments with words cannot (in any way) compare with a test which will show practical results". After inventing the device and proving those who were doubtful wrong, he was praised by many, including his contemporary Fu Xuan, a noted poet of his age.

After Ma Jun, the South Pointing Chariot was re-invented by Zu Chongzhi (429-500 AD), after the details of its instructions had been lost temporarily in China. During the Tang Dynasty (618-907 AD) and Song Dynasty (960-1279 AD) the South Pointing Chariot was combined with another mechanical wheeled vehicle, the distance-measuring odometer.

Some early historical records states that the south pointing chariot was invented around the first millennium B.C.E., but such evidence is obscure.

Historical texts for the South Pointing Chariot

Earliest sources

The South Pointing Chariot, a differential mechanical-geared wheeled vehicle used to discern the southern cardinal direction (without magnetics), was given a brief description by Ma's contemporary Fu Xuan.[1] The contemporary 3rd century source of the *Weilüe*, written by Yuan Huan also described the South Pointing Chariot of Ma Jun.[2] The Jin Dynasty (265-420 AD) era text of the *Shu Zheng Ji* (Records of Military Expeditions), written by Guo Yuansheng, recorded that South Pointing Chariots were often stored in the northern gatehouse of the Government Workshops (Shang Fang) of the capital city.[2] However, the later written *Song Shu* (*Book of Song*) (6th century AD) recorded the South Pointing Chariot's design and use in further detail, as well as created background legend of the device's (supposed) use long before Ma's time, in the Western Zhou Dynasty (1050 BC-771 BC). The book also provided description of the South Pointing Chariot's re-invention and use in times after Ma Jun and the Three Kingdoms. The 6th century text reads as follows (in Needham's translation, the South Pointing Chariot is referred to as the south-pointing carriage):

> “The south-pointing carriage was first constructed by the Duke of Zhou (beginning of the -1st millennium BC) as a means of conducting homewards certain envoys who had arrived from a great distance beyond the frontiers. The country to be traversed was a boundless plain, in which people lost their bearings as to east and west, so (the Duke) caused this vehicle to be made in order that the ambassadors should be able to distinguish north and south. The *Gui Gu Zi* book says that the people of the State of Zheng, when collecting jade, always carried with them a 'south-pointer', and by means of this were never in doubt (as to their position). During the Qin and Former Han dynasties, however, nothing more was heard of the vehicle. In the Later Han period, Zhang Heng re-invented it, but owing to the confusion and turmoil at the close of the dynasty it was not preserved.[3] ”

> In the State of Wei, (in the San Guo period) Gaotong Long and Qin Lang were both famous scholars; they disputed about the south-pointing carriage before the court, saying that there was no such thing, and that the story was nonsense. But during the Qing-long reign period (233-237 AD) the emperor Ming Di commissioned the scholar Ma Jun to construct one, and he duly succeeded. This again was lost during the troubles attending the establishment of the Jin Dynasty.[4]

> Later on, Shi Hu (emperor of the Jie Later Zhao Dynasty) had one made by Xie Fei, and again Linghu Sheng made one for Yao Xing (emperor of the Later Qin dynasty). The latter was obtained by emperor An Di of the Jin in the 13th year of the Yi-xi reign-period (417 AD), and it finally came into the hands of emperor Wu Di of the Liu Song Dynasty when he took over the administration of Chang'an. Its appearance and construction was like that of a drum-carriage (odometer). A wooden figure of a man was placed at the top, with its arm raised and pointing to the south, (and the mechanism was arranged in such a way that) although the carriage turned round and round, the pointer-arm still indicated the south. In State processions, the south-pointing carriage led the way, accompanied by the imperial guard.[5]

> These vehicles, constructed as they had been by barbarian (Qiang) workmen, did not function particularly well. Though called south-pointing carriages, they very often did not point true, and had to negotiate curves step by step, with the help of someone inside to adjust the machinery. The ingenious man from Fanyang, Zi Zu Chongzhi frequently said, therefore, that a new (and properly automatic) south-pointing carriage ought to be constructed. So towards the close of the Sheng-Ming reign period (477-479 AD) the emperor Shun Di, during the premiership of the Prince of Qi, commissioned (Zi Zu Chongzhi) to make one, and when it was completed it was tested by Wang Seng-qian, military governor of Tanyang, and Liu Hsiu, president of the Board of Censors. The workmanship was excellent, and although the carriage was twisted and turned in a hundred directions, the hand never failed to point to the south. Under the Jin, moreover, there had also been a south pointing ship.[5]

The last sentence of the passage is of great interest for navigation at sea, since the magnetic compass used for seafaring navigation was not used until the time of Shen Kuo (1031-1095). Although the *Song Shu* text describes earlier precedents of the South Pointing Chariot before the time of Ma Jun, this is not entirely credible, as there are no pre-Han or Han Dynasty era texts that describe the device.[6] In fact, the first known source to describe stories of its legendary use during the Zhou period was the *Gu Jin Zhu* book of Cui Bao (c. 300 AD), written soon after the Three Kingdoms era.[2] Cui Bao also wrote that the intricate details of construction for the device were once written in the *Shang Fang Gu Shi* (Traditions of the Imperial Workshops), but the book was lost by his time.[2]

Japan

The invention of the South Pointing Chariot also made its way to Japan by the 7th century. The *Nihon Shoki* (The Chronicles of Japan) of 720 AD described the earlier Chinese Buddhist monks Zhi Yu and Zhi You constructing several South Pointing Chariots for Emperor Tenji of Japan in 658 AD.[7] This was followed up by several more chariot devices built in 666 AD as well.[7]

South Pointing Chariot in the *Song Shi*

The South Pointing Chariot was also combined with the earlier Han Dynasty era invention of the odometer (also Greco-Roman), a mechanical device used to measure distance traveled, and found in all modern automobiles. It was mentioned in the Song Dynasty (960-1279 AD) historical text of the *Song Shi* (compiled in 1345) that between the engineers Yan Su (in 1027 AD) and Wu Deren (in 1107 AD) both created South Pointing Chariots, which it details as follows:[8]

> In the 5th year of the Tian-Sheng reign period of the emperor Renzong (1027 AD), Yan Su, a Divisional Director in the Ministry of Works, made a south-pointing carriage. He memorialised the throne, saying, [after the usual historical introduction]: 'Throughout the Five Dynasties and until the reigning dynasty there has been, so far as I know, no one who has been able to construct such a vehicle. But now I have invented a design myself and have succeeded in completing it'.[8]

> 'The method involves using a carriage with a single pole (for two horses). Above the outside framework of the body of the carriage let there be a cover in two stories. Set a wooden image of a *xian* (immortal) at the top, stretching out its arm to indicate the south. Use 9 wheels, great and small, with a total of 120 teeth, i.e. 2 foot-wheels (i.e. road-wheels, on which the carriage runs) 6 ft. high and 18 ft. in circumference, attached to the foot wheels, 2 vertical subordinate wheels, 2.4 ft. in diameter and 7.2 ft. in circumference, each with 24 teeth, the teeth being at intervals of 3 inches apart.[8]

> '...Then below the crossbar at the end of the pole, two small vertical wheels 3 inches in diameter and pierced by an iron axle, to the left 1 small horizontal wheel, 1.2 feet in diameter, with 12 teeth, to the right 1 small horizontal wheel, 1.2 ft. in diameter, with 12 teeth, in the middle 1 large horizontal wheel, of diameter 4.8 ft. and circumference 14.4 ft., with 48 teeth, the teeth at intervals of 3 inches apart; in the middle a vertical shaft piercing the center (of the large horizontal wheel) 8 ft. high and 3 inches in diameter; at the top carrying the wooden figure of the *xian*'.[8]

> 'When the carriage moves (southward) let the wooden figure point south. When it runs (and goes) eastwards, the (back end of the) pole is pushed to the right; the subordinate wheel attached to the right road-wheel will turn forward 12 teeth, drawing with it the right small horizontal wheel one revolution (and so) pushing the central large horizontal wheel to revolve a quarter turn to the left. When it has turned around 12 teeth, the carriage moves eastwards, and the wooden figure stands crosswise and points south. If (instead) it turns (and goes) westwards, the (back end of the) pole is pushed to the left; the subordinate wheel attached to the left road-wheel will turn forward with the road-wheel 12 teeth, drawing with it the left small horizontal wheel one revolution, and pushing the central large horizontal wheel to revolve a quarter turn to the right. When it has turned round 12 teeth, the carriage moves due west, but still the wooden figure stands crosswise and points south. If one wishes to travel northwards, the turning round, whether by east or west, is done in the same way'.[9]

After this initial description of Yan Su's device, the text continues to describe the work of Wu Deren, who crafted a wheeled device that would combine the odometer and South Pointing Chariot:

> It was ordered that the method should be handed down to the (appropriate) officials so that the machine might be made. In the first year of the Da-Guan reign period (1107 AD), the Chamberlain Wu Deren presented specifications of the south-pointing carriage and the carriage with the li-recording drum (odometer). The two vehicles were made, and were first used that year at the great ceremony of the ancestral sacrifice.[10]

> The body of the south-pointing carriage was 11.15 ft. (long), 9.5 ft. wide, and 10.9 ft. deep. The carriage wheels were 5.7 ft. in diameter, the carriage pole 10.5 ft. long, and the carriage body in two stories, upper and lower. In the middle was placed a partition. Above there stood a figure of a *xian* holding a rod, on the left and right were tortoises and cranes, one each on either side, and four figures of boys each holding a tassel. In the upper story there were at the four corners trip-mechanisms, and also 13 horizontal wheels, each 1.85 ft. in diameter, 5.55 ft. in circumference, with 32 teeth at intervals of 1.8 inches apart. A central shaft, mounted on the partition, pierced downwards.[10]

> In the lower story were 13 wheels. In the middle was the largest horizontal wheel, 3.8 ft. in diameter, 11.4 ft. in circumference, and having 100 teeth at intervals of 2.1 inches apart. (On vertical axles) reaching to the top (of the compartment) left and right, were two small horizontal wheels which could rise and fall, having an iron weight (attached to) each. Each of these was 1.1 ft. in diameter and 3.3 ft. in circumference, with 17 teeth, at intervals of 1.9 inches apart. Again, to left and right, were attached wheels, one on each side, in diameter 1.55 ft., in circumference 4.65 ft., and having 24 teeth, at intervals of 2.1 inches.[10]

> Left and right, too, were double gear-wheels (lit. tier-wheels), a pair on either side. Each of the lower component gears was 2.1 ft. in diameter and 6.3 ft. in circumference, with 32 teeth, at intervals of 2.1 inches apart. Each of the upper component gears was 1.2 ft. in diameter and 3.6 ft. in circumference, with 32 teeth, at intervals of 1.1 inches apart. On each of the road-wheels of the carriage, left and right, was a vertical wheel 2.2 ft. in diameter, 6.6 ft. in circumference, with 32 teeth at intervals of 2.25 inches apart. Both to left and right at the back end of the pole there were small wheels without teeth (pulleys), from which hung bamboo cords, and both were tied above the left and right (ends of the) axle (of the carriage) respectively.[10]

> If the carriage turns to the right, it causes the small pulley to the left of the back end of the pole to let down the left-hand (small horizontal) wheel. If it turns to the left, it causes the small pulley to the right of the back end of the pole to let down the right (small horizontal) wheel. However, the carriage moves the xian and the boys stand crosswise and point south. The carriage is harnessed with two red horses, bearing frontlets of bronze.[10]

After the work of these various engineers, to put the device of the South Pointing Chariot into global perspective, the first true differential gear used in the Western world was by Joseph Williamson in 1720.[11] Joseph Williamson used a differential for correcting the equation of time for a clock that displayed both mean and solar time.[11] Even then, the differential was not fully appreciated in Europe until James White emphasized its importance and provided details for it in his *Century of Inventions* (1822).[11]

How it works

The South Pointing Chariot is a mechanical compass that transports a direction, given by the pointer, along the path it travels. The differential in the gear system integrates the difference in wheel rotation between the two wheels and thus detects the rotation of the base of the chariot. The mechanism compensates this rotation by rotating the pointer in the opposite direction.

Mathematically the device approximates parallel transport along the path it travels. In the Euclidean plane, the device performs parallel transport. On a curved surface it only approximates parallel transport. In the limit where the distance between the wheels tends to zero, the approximation becomes exact.

The chariot can be used to detect straight lines or geodesics. A path on a surface the chariot travels along is a geodesic if and only if the pointer does not rotate with respect to the base of the chariot.

Timeline

The South Pointing Chariot has been invented and reinvented at many times throughout Chinese history. Below is a partial timeline of the major events;

Year	Event
2634 BC	According to Legend, the Yellow Emperor designs the South Pointing Chariot. It is built for him by the craftsman Fang Bo.
1115 BC	During the reign of the Duke of Chou, the duke gives five such devices (called Zhinan) to ambassadors of Yueshang to get them back home.
150 .. 100 BC	Estimated construction of the Antikythera mechanism in ancient Greece.
120 .. 139 AD	Zhang Heng might have reinvented the vehicle.
233 .. 237	Ma Jun constructs a working vehicle for Emperor Ming of Wei.
300	Cui Bao reports that the construction is described in a book (not preserved) named Shang Fang Ku Shih.
334 .. 349	Xie Fei makes one for emperor Shih Hu.
394 .. 416	Linghu Sheng makes one for Emperor Xiaowu of Jin China.
417	Linghu Sheng's vehicle is captured by Emperor An of Jin. It is reported that, at this time, there is no machinery, but only a man inside who turns the figure.
423 .. 452	Guo Shanming fails to make one for Emperor Taiwu of Northern Wei.
423 .. 452	Ma Yue succeeds, but he is killed by Guo Shanming.
478	Zu Chongzhi makes a new improved (bronze gears) vehicle for Emperor Shun of Liu Song.
658	Buddhist monk Chiyu constructs vehicle for Japanese Emperor Tenji
666	Monk Chiyu constructs another vehicle for Japanese Emperor Tenji.
806 .. 821	Jin Gongli presents a south-pointing carriage to Emperor Xianzong of Tang.
1027	Engineer Yan Su (member of the "Board of Works") describes his construction (5 cogged, 4 non-cogged gear wheels, 18 soldier-drivers).
1088	Su Song constructs a water wheel clock, using an escapement.
1107	Chamberlain Wu Deren presents a specification (24 cogged, 4 non-cogged gear wheels), which is successfully built twice.
1341	Chu Tê-Jun describes a jade figure as part of a miniature south-pointing carriage.
1720	Joseph Williamson uses a differential gear in a clock.
1834	Julius Klaproth writes to Alexander von Humboldt, noting the south-pointing chariot chih-nan-ch´ê, but assumes that a magnetic compass is hidden in the little doll.
1879	James Starley first uses a differential gear in a vehicle.
1909	Professor Giles points out that the directional property of the south pointing chariot was effected by a mechanical system, and not by magnetism.
1909	Professor Bertram Hopkinson (Cambridge) remarks that some mechanism would have been required to ensure that the gears connected to the chariot wheels at right and left were engaged or disengaged when the chariot turned right or left. After some years of study, he declares that Yen Su's specification is insufficient to build a working model.

1910	The first mechanical navigation aide, "Jones Live Map", is invented. Like in the south-pointing chariot, the movement of the road wheels is geared down, but this time to show the relative position of the vehicle on a map.
1924	Rev. A. C. Moule (Cambridge) proposes a realization of Wu Tê-Jen's specification, where the chariot is allowed to drive only in straight lines. For each turn it is stopped, a gear connected and the turn done on the spot, the pointer now being corrected automatically.
1924	K. T. Dykes is the first to propose a differential gearing, arguing that the clutch mechanism proposed by Moule is "slow and complicated to drive".
1932	Dr. J.B.Kramer discovers references to the mechanical nature of the south-pointing chariot and declares that the Chinese therefore did not invent the magnetic compass.
1932	George Lanchester (chief engineer at Lanchester Motor Company) proposes that the ancient machines (Ma Jun notably) embodied some kind of differential gear. He builds a working model to prove his concept.
1937	Wang Zhenduo proposes a realization of Yan Su's specification and builds a working model from it.
1948	Bao Sihe proposes another reconstruction.
1955	F.W. Cousins introduces the Lanchester reconstruction to a broader public, namely the Meccano fans.
1956	J. Coales points out that by hanging a carrot from the emperor's hand, the south-pointing chariot would become self-steering!
1977	Professor André Wegener Sleeswyk publishes a scientific essay on the historic chariots. He proves their feasibility exactly to the words in the ancient texts.
1978	Dr. Alan Partridge starts a contest in Meccano Magazine for the design with the fewest gears. It is shown subsequently that no gears are necessary at all!
1979	Dr. Noel C. Ta'Bois (LDS RCS Eng) publishes a concise treatise on the theoretical aspects. Working specimens are shown, which do not adhere to the "width equals wheel diameter" rule.
1979	Lu Zhiming produces three reconstructions based on differential gears.
1980	Mr. Don Frantz from New York re-discovers the south pointing chariot, builds models along the Lanchester path and manages to place them in the Museum of the Province of Xian.
1982	Yan Zhiren builds another model, stressing that only differential gears provide the accuracy reported by the old writings.
1991	Mr. M. Santander from Spain proposes to use the chariot to teach students the basic concepts of parallel transport and curvature. *En passant* a mathematical model is given for Mr. Nuttall's design.

Where they can be seen

While none of the historic South Pointing Chariots remain, full sized replicas can be found.

The History Museum in Beijing, China holds a replica based on the mechanism of Yen Su (1027). The National Palace Museum in Taipei, Taiwan holds a replica based on the Lanchester mechanism of 1932.

See also

- List of Chinese inventions
- History of science and technology in China
- Technology of the Song Dynasty

- → Mechanical engineering
- Compass

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External links

- South Pointing Things [13] - Useful site with lot of info, images and plans [14] for building chariots

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[7] Needham, Volume 4, Part 2, 289.
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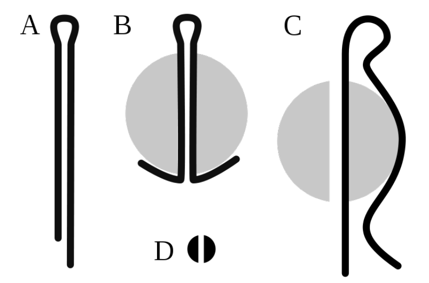
[9] Needham, Volume 4, Part 2, 291-292.
[10] Needham, Volume 4, Part 2, 292.
[11] Needham, Volume 4, Part 2, 298.
[12] http://scitation.aip.org/getpdf/servlet/GetPDFServlet?filetype=pdf&id=AJPIAS000060000009000782000001&idtype=cvips&ident=freesearch&prog=search
[13] http://www.odts.de/southptr/
[14] http://www.odts.de/southptr/reposito.htm

Split pin

A **split pin**, also known in U.S. usage as a **cotter pin** or **cotter key**,[1] is a metal fastener with two tines that are bent during installation, similar to a staple or rivet. Typically made of thick wire with a half-circular cross section, split pins come in multiple sizes and types.



Split pins: A: New B: Installed C: Spring type D: Cross-section of traditional design

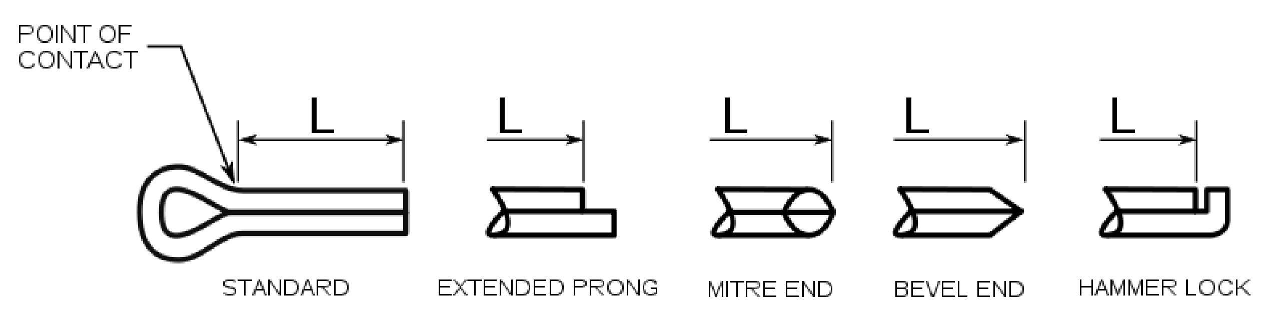
The British definition of "**cotter pin**" is equivalent to U.S. term "cotter", which can be a cause for confusion when companies of both countries work together. There are signs that manufacturers and stockists are increasingly listing both names together to avoid confusion; this led to the term **split cotter** sometimes being used for a split pin.

Construction

A new split pin (see figure A) has its flat inner surfaces touching for most of its length so that it appears to be a split cylinder (figure D). Once inserted, the two ends of the pin are bent apart, locking it in place (figure B). When they are removed they are supposed to be discarded and replaced, because of fatigue from bending.[2]

Split pins are typically made of soft metal, making them easy to install and remove, but also making it inadvisable to use them to resist strong shear forces. Common materials include mild steel, brass, bronze, stainless steel, and aluminium.[3]

Types



As shown above, there are different types of ends available on split pins. The most common is the extended prong with a square cut, but extended prongs are available with all of the other types of ends. The extended prong type is popular because it makes it easier to separate the tines. To ease insertion into a hole the longer tine may be slightly curved to overlap the tip of the shorter tine or it is beveled. The length, L, of the split pin is defined as the distance from the end of the shortest tine to the point of the eyelet that contacts the the hole.[3]

Hammer lock split pins are properly installed by striking the bent tine end with a hammer to secure the pin. This type of pin is used when the spread tines of another type of split pin can pose problems.[4]

- Standard
- Humped
- Clinch

Sizes

The diameter of split pins are standardized. American split pins start at $^1/_{32}$ in and end at $^3/_4$ in.[4]

American split pin sizes

Nominal diameter [in]	Hole size [in]	For bolt size [in]
$^1/_{32}$	$^3/_{64}$	
$^3/_{64}$	$^1/_{16}$	
$^1/_{16}$	$^5/_{64}$	$^1/_4$
$^5/_{64}$	$^3/_{32}$	$^5/_{16}$
$^3/_{32}$	$^7/_{64}$	$^3/_8$
$^7/_{64}$	$^1/_8$	
$^1/_8$	$^9/_{64}$	$^1/_2$
$^9/_{64}$	$^5/_{32}$	$^5/_8$
$^5/_{32}$	$^{11}/_{64}$	$^3/_4$
$^3/_{16}$	$^{13}/_{64}$	1, 1.125
$^7/_{32}$	$^{15}/_{64}$	1.25, 1.375
$^1/_4$	$^{17}/_{64}$	1.5
$^5/_{16}$	$^5/_{16}$	1.75
$^3/_8$	$^3/_8$	
$^7/_{16}$	$^7/_{16}$	
$^1/_2$	$^1/_2$	
$^5/_8$	$^5/_8$	
$^3/_4$	$^3/_4$	

Metric split pin sizes

Nominal diameter [mm]	Hole size [mm]	For bolt size [mm]
1.5	1.9	6
2	2.4	8
2.5	2.8	10
3	3.4	12, 14
4	4.5	20

5	5.6	24, 28
6	6.3	30, 36, 42
8	8.5	48

Applications

Split pins are frequently used to secure other fasteners, e.g. clevis pins, as well as being used in combination with hardboard discs as a traditional joining technique for teddy bears.[5]

Split pins may be used in some applications as low-tech → shear pins. A common application of this is when used to secure a castellated nut. One problem with this type of use is that the castles on the nut must line up with the hole in the mating part so that the split pin can be installed. When the nut is torqued properly, but the holes still do not line up it is preferable to over-tighten the nut than under-tighten it.[6]


A car hub showing a castellated nut cover and split pin (near center).

See also

- Circlips, which have replaced split pins in some applications.
- R-clip, sometimes used where easier removal and re-use are desirable.
- Linchpin, sometimes used where easier removal and re-use are desirable.

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Standard conditions for temperature and pressure

In physical sciences, **standard conditions for temperature and pressure** (informally abbreviated as **STP**) are standard sets of conditions for experimental measurements, to allow comparisons to be made between different sets of data. The most used standards are those of the International Union of Pure and Applied Chemistry (IUPAC) and the National Institute of Standards and Technology (NIST) but are far from being universally accepted standards. Other organizations have established a variety of alternative definitions for their standard reference conditions. The current version of IUPAC's standard is a temperature of 0 °C (273.15 K, 32 °F) and an absolute pressure of 100 kPa (14.504 psi, 0.986 atm)[1] , while NIST's version is a temperature of 20 °C (293.15 K, 68 °F) and an absolute pressure of 101.325 kPa (14.696 psi, 1 atm).

In industry and commerce, standard conditions for temperature and pressure are often necessary to define the standard reference conditions to express the volumes of gases and liquids and related quantities such as the rate of volumetric flow (the volumes of gases and liquids vary significantly with temperature and pressure). However many technical publications (books, journals, advertisements for equipment and machinery) simply state "standard conditions" without specifying them, often leading to confusion and errors.

Definitions

Past use

In the last five to six decades, professionals and scientists using the metric system of units defined the standard reference conditions of temperature and pressure for expressing gas volumes as being 0 °C (273.15 K; 32.00 °F) and 101.325 kPa (1 → atm or 760 Torr). During those same years, the most commonly used standard reference conditions for people using the imperial or U.S. customary systems was 60 °F (15.56 °C; 288.71 K) and 14.696 psi (1 atm) because it was almost universally used by the oil and gas industries worldwide. However, the above two definitions are no longer the most commonly used in either system of units.

Current use

Many different definitions of standard references conditions are currently being used by organizations all over the world. The table below lists a few of them, but there are more. Some of these organizations used other standards in the past, such as IUPAC which currently defines standard reference conditions as being 0 °C and 100 kPa (1 bar) of pressure rather since 1982, in contrast to their old standard of 0 °C and 101.325 kPa (1 atm).[2] Another example is from the oil industry. While a standard of 60 °F and 14.696 psi was used in the past, the current usage (particularly in North America) is predominantly of 60 °F and 14.73 psi.

Natural gas companies in Europe and South America have adopted 15 °C (59 °F) and 101.325 kPa (14.696 psi) as their standard gas volume reference conditions.[3] [4] [5] Also, the International Organization for Standardization (ISO), the United States Environmental Protection Agency (EPA) and National Institute of Standards and Technology (NIST) each have more than one definition of standard reference conditions in their various standards and regulations.

The *SATP* used for presenting chemical thermodynamic properties (such as those published by the National Bureau of Standards) is standardized at 100 kPa (1 bar) but the temperature may vary and usually needs to be specified separately if complete information is desired (see standard state). Some standards are specified at certain humidity level.

Table 1: Standard reference conditions in current use

Temperature	**Absolute pressure**	**Relative humidity**	**Publishing or establishing entity**
°C	**kPa**	**% RH**	
0	100.000		IUPAC (present definition)[1]
0	101.325		IUPAC (former definition)[1] , NIST[6] , ISO 10780[7]
15	101.325	0[8] [9]	ICAO's ISA,[8] ISO 13443,[9] EEA,[10] EGIA[11]
20	101.325		EPA,[12] NIST[13]
25	101.325		EPA[14]
25	100.000		SATP[15]
20	100.000	0	CAGI[16]
15	100.000		SPE[17]
20	101.3	50	ISO 5011[18]
°F	**psi**	**% RH**	
60	14.696		SPE,[17] U.S. OSHA,[19] SCAQMD[20]
60	14.73		EGIA,[11] OPEC,[21] U.S. EIA[22]
59	14.503	78	U.S. Army Standard Metro[23] [24]
59	14.696	60	ISO 2314, ISO 3977-2[25]
°F	**in Hg**	**% RH**	
70	29.92	0	AMCA,[26] [27] air density = 0.075 lbm/ft³. This AMCA standard applies only to air.

Notes:

- EGIA: Electricity and Gas Inspection Act (of Canada)
- SATP: Standard Ambient Pressure and Temperature

International Standard Atmosphere

In aeronautics and fluid dynamics the term "International Standard Atmosphere" is often used to denote the variation of the principal thermodynamic variables (pressure, temperature, density, etc.) of the atmosphere *with altitude* at mid latitudes.

Standard laboratory conditions

Due to the fact that many definitions of standard temperature and pressure differ in temperature significantly from standard laboratory temperatures (e.g., 0 °C vs. ~25 °C), reference is often made to "standard laboratory conditions" (a term deliberately chosen to be different from the term "standard conditions for temperature and pressure", despite its semantic near identity when interpreted literally). However, what is a "standard" laboratory temperature and pressure is inevitably culture-bound, given that different parts of the world differ in climate, altitude and the degree of use of heat/cooling in the workplace. The concept of "standard laboratory conditions" taught as part of the New South Wales high school chemistry syllabus is 25 °C at 100 kPa.[28]

Molar volume of a gas

It is equally as important to indicate the applicable reference conditions of temperature and pressure when stating the molar volume of a gas[29] as it is when expressing a gas volume or volumetric flow rate. Stating the molar volume of a gas without indicating the reference conditions of temperature and pressure has no meaning and it can cause confusion.

The molar gas volumes can be calculated with an accuracy that is usually sufficient by using the universal gas law for ideal gases. The usual expression is:

$$PV = nRT$$

...which can be rearranged thus:

$$\frac{V}{n} = \frac{RT}{P}$$

where (in SI metric units):

P	= the absolute pressure of the gas, in Pa
n	= amount of substance, in mol
V	= the volume of the gas, in m^3
T	= the absolute temperature of the gas, in K
R	= the universal gas law constant of 8.3145 m^3·Pa/(mol·K)

or where (in customary USA units):

P	= the absolute pressure of the gas, in psi
n	= number of moles, in lbmol
V	= the volume of the gas, in ft^3/lbmol
T	= the absolute temperature of the gas absolute, in °R
R	= the universal gas law constant of 10.7316 ft^3·psi/(lbmol·°R)

The molar volume of any ideal gas may be calculated at various standard reference conditions as shown below:

- **V/n** = 8.3145 × 273.15 / 101.325 = 22.414 m^3/kmol at 0 °C and 101.325 kPa
- **V/n** = 8.3145 × 273.15 / 100.000 = 22.711 m^3/kmol at 0 °C and 100 kPa
- **V/n** = 8.3145 × 298.15 / 101.325 = 24.466 m^3/kmol at 25 °C and 101.325 kPa
- **V/n** = 8.3145 × 298.15 / 100.000 = 24.790 m^3/kmol at 25 °C and 100 kPa
- **V/n** = 10.7316 × 519.67 / 14.696 = 379.48 ft^3/lbmol at 60 °F and 14.696 psi
- **V/n** = 10.7316 × 519.67 / 14.730 = 378.61 ft^3/lbmol at 60 °F and 14.73 psi

The technical literature can be confusing because many authors fail to explain whether they are using the universal gas law constant $\boldsymbol{R}$, which applies to any ideal gas, or whether they are using the gas law constant $\boldsymbol{R_s}$, which only applies to a specific individual gas. The relationship between the two constants is $\boldsymbol{R_s} = \boldsymbol{R} / \boldsymbol{M}$, where $\boldsymbol{M}$ is the molecular weight of the gas.

The US Standard Atmosphere uses 8.31432 m^3·Pa/(mol·K) as the value of R for all calculations. (See Gas constant)

See also

- Atmospheric models
- ISO 1 – standard reference temperature for geometric product specifications
- Standard Dry Air
- Standard state

External links

- "Standard conditions for gases" [30] from the IUPAC *Gold Book*.
- "Standard pressure" [31] from the IUPAC *Gold Book*.
- "STP" [32] from the IUPAC *Gold Book*.
- "Standard state" [33] from the IUPAC *Gold Book*.

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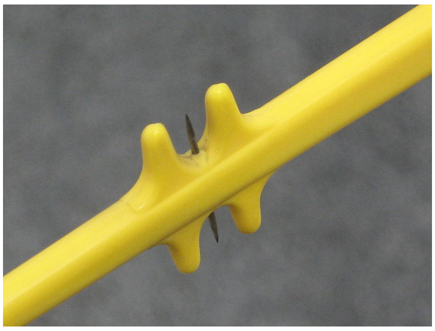
[30] http://www.iupac.org/goldbook/S05910.pdf
[31] http://www.iupac.org/goldbook/S05921.pdf
[32] http://www.iupac.org/goldbook/S06036.pdf
[33] http://www.iupac.org/goldbook/S05925.pdf

Static discharger



A portion of a static discharger on an aircraft. Note the two sharp 3/8" metal micropoints and the protective yellow plastic.

Static dischargers are commonly known as static wicks or static discharge wicks. They are used on aircraft to allow the continuous satisfactory operation of onboard navigation and radio communication systems. During adverse charging conditions (air friction), they limit the potential static buildup on the aircraft and control interference generated by static charge. Static dischargers are not lightning arrestors and do not reduce or increase the likelihood of an aircraft being struck by lightning. Static dischargers are subject to damage or significant changes in electrical resistance as a result of lightning strike to the aircraft, and should be inspected after a lightning strike to ensure proper static discharge operation. Static dischargers are fabricated with a wick of wire or a conductive element on one end, which provides a continuous low resistance discharge path between the aircraft and the air. They are attached on some aircraft to the trailing edges of (electrically grounded*) ailerons, elevators, rudder, wing, horizontal and vertical stabilizer tips. On smaller aircraft static dischargers are typically constructed out of glass-reinforced resin surrounding a woven metal conductor. These are fragile and easily damaged by inattentive operators.

See also

- Precipitation (meteorology)
- Electrostatic discharge
- Triboelectric effect
- Ground loop (electricity)

The wing of a landing BMI Airbus A319-100. Click on the picture to see static dischargers lining the trailing edge of the aileron (immediately inboard of the red winglet) and on the winglet itself.

Statical determinacy

Statical determinacy is a term used in structural mechanics to describe a structure where force and moment equilibrium conditions alone can be utilized to calculate internal member actions.

Descriptively, a statically determinate structure can be defined as a structure where, if it is possible to find internal actions in equilibrium with external loads, those internal actions are unique. The structure has no possible states of self-stress, i.e. internal forces in equilibrium with zero external loads are not possible.

Mathematically, this requires a stiffness matrix to have full rank.

A statically indeterminate structure can only be analytically analyzed by including further information like material properties and deflections. Numerically, this can be achieved by using methods like matrix structural analyses and finite element analyses.

See also

- → Kinematic determinacy

Steam rupture

A **steam rupture** occurs within a pressurized system of super critical water when the pressure exceeds the design plus safety margin specification. A steam rupture can occur in any elevated temperature pressurized system, including, but not limited to: Automobile cooling systems, stationary power plants, mobile power plants, steam driven tools (such as some trip hammers), and even the delivery systems for application processes such as cleaning and fabric fullering.

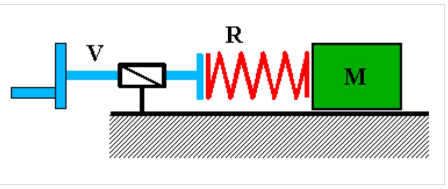
Stick-slip phenomenon

Stick-slip (or "slip-stick") refers to the phenomenon of a spontaneous jerking motion that can occur while two objects are sliding over each other.

Cause

Stick-slip is caused by the surfaces alternating between sticking to each other and sliding over each other, with a corresponding change in the force of friction. Typically, the static friction coefficient between two surfaces is larger than the kinetic friction coefficient. If an applied force is large enough to overcome the static friction, then the reduction of the friction to the kinetic friction can cause a sudden jump in the velocity of the movement.

The attached picture shows symbolically an example of stick-slip.



V is a drive system, R is the elasticity in the system, and M is the load that is lying on the floor and is being pushed horizontally. When the drive system is started, the Spring R is loaded and its pushing force against load M increases until the static friction coefficient between load M and the floor is not able to hold the load anymore. The load starts sliding and the friction coefficient decreases from its static value to its dynamic value. At this moment in fact the spring can give more power and accelerates M. During M’s movement, the force of the spring decreases, until it is insufficient to overcome the dynamic friction. At this point, the M stops. The drive system however continues, and the spring is loaded again etc.

Examples

Examples of stick-slip can be heard from hydraulic cylinders, honing machines etc. Special dopes can be added to the hydraulic fluid or the cooling fluid to overcome or minimize the stick-slip effect. Stick-slip is also experienced in lathes, mill centres, and other machinery where something slides on a slideway. Slideway oil typically lists "prevention of stick-slip" as one of their features. Other examples of the stick-slip phenomenon include the music that comes from a violin, the noise of car brakes and tires, and the noise of a stopping train. Another example of the stick-slip phenomenon occurs when you play musical notes with a glass harp by rubbing a wet finger along the rim of a crystal wine glass. One animal that produces sound using stick-slip friction is the spiny lobster which rubs its antennae over smooth surfaces on its head. [1]

Stick-slip can also be observed on the atomic scale using a friction force microscope[2] . In such case, the phenomenon can be interpreted using the Tomlinson model.
See also: Simulation [3] of stick-slip behaviour in a friction force microscope (movie)

The behaviour of seismically-active faults is also explained using a stick-slip model, with earthquakes being generated during the periods of rapid slip.

One can move objects by stick-slip affect. Take a piece of paper (A4, for example), put the paper on a solid surface (table, for example) and place a heavy object on it (a coffee mug, for example). Put a mark on the paper to determine the initial position of the object. Now slowly move the paper to one side (left, for example) and suddenly slide it to the other side. If you do it couple of times properly than you can observe that the object will be on the left side of the initial position.

References

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[2] *Atomic-scale friction of a tungsten tip on a graphite surface* C.M. Mate, G.M. McClelland, R. Erlandsson, and S. Chiang Phys. Rev. Lett. **59**, 1942 (1987)
[3] http://www.youtube.com/watch?v=idlHxu7TTWU

Strain hardening exponent

The **strain hardening exponent** (also called **strain hardening index**), noted as *n*, is a materials constant which is used in calculations for stress-strain behaviour in work hardening.

In the formula $\sigma = K \varepsilon^{n}$, σ represents the applied stress on the material, ε is the strain and K is the strength coefficient. The value of the strain hardening exponent lies between 0 and 1. A value of 0 means that a material is a perfectly plastic solid, while a value of 1 represents a 100% elastic solid. Most metals have an n value between 0.10 and 0.50.

External links

- More complete picture about the strain hardening exponent in the stress-strain curve on *www.key-to-steel.com* [1]

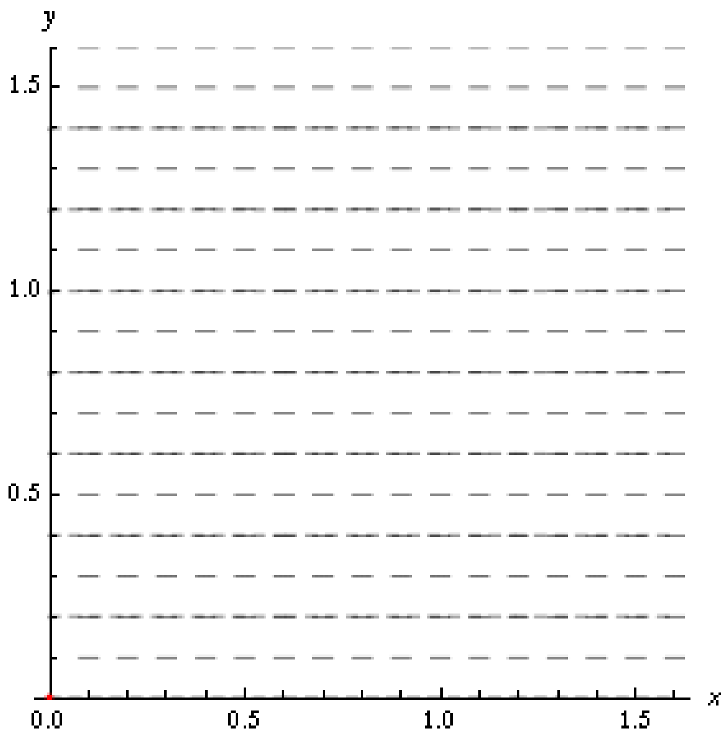
References

[1] http://steel.keytometals.com/Articles/Art42.htm

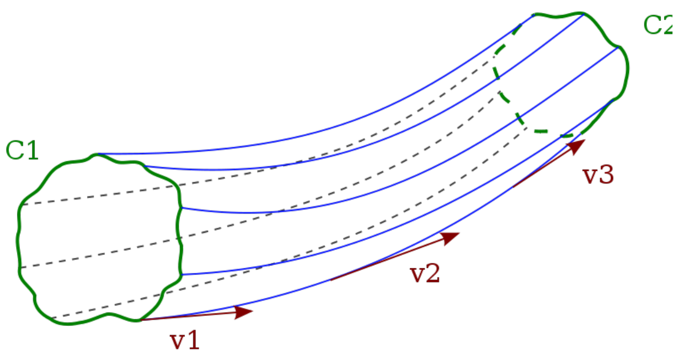
Streamlines, streaklines, and pathlines

Fluid flow is characterized by a velocity vector field in three-dimensional space, within the framework of continuum mechanics. **Streamlines, streaklines and pathlines** are field lines resulting from this vector field description of the flow. They differ only when the flow changes with time: that is, when the flow is not steady.

- **Streamlines** are a family of curves that are instantaneously tangent to the velocity vector of the flow. These show the direction a fluid element will travel in at any point in time.
- **Streaklines** are the locus of points of all the fluid particles that have passed continuously through a particular spatial point in the past. Dye steadily injected into the fluid at a fixed point extends along a streakline. These can be thought of as a "recording" of the path a fluid element in the flow takes over a certain period. The direction the path takes will be determined by the streamlines of the fluid at each moment in time.
- **Pathlines** are the trajectories that individual fluid particles follow.
- **Timelines** are the lines formed by a set of fluid particles that were marked at a previous instant in time, creating a line or a curve that is displaced in time as the particles move.



The red particle moves in a flowing fluid; its *pathline* is traced in red; the tip of the trail of blue ink released from the origin follows the particle, but unlike the static pathline (which records the earlier motion of the dot), previously released ink moves up with the flow. (This is a *streakline*.) The dashed lines represent contours of the velocity field (*streamlines*), showing the motion of the whole field at the same time. (*See high resolution version*.)



Solid blue lines and broken grey lines represent the streamlines. The red arrows show the direction and magnitude of the flow velocity. These arrows are tangential to the streamline. The group of streamlines enclose the green curves ($C_1$and C_2) to form a streamtube.

By definition, different streamlines at the same instant in a flow do not intersect, because a fluid particle cannot have two different velocities at the same point. Similarly, streaklines cannot intersect themselves or other streaklines, because two particles cannot be present at the same location at the same instant of time. However, pathlines are allowed to intersect themselves or other pathlines (except the starting and end points of the different pathlines, which need to be distinct).

In simple terms, streamlines and timelines provide a snapshot of some flowfield characteristics, whereas streaklines and pathlines depend on the full time-history of the flow. However, often sequences of timelines (and streaklines) at different instants—being presented either in a single image or with a video stream—may be used to provide insight in the flow and its history.

A region bounded by streamlines is called a **streamtube**. In a steady flow—because the streamlines are tangent to the flow velocity—fluid that is inside a stream tube must remain forever within that same stream tube. A scalar function whose contour lines define the streamlines is known as the **stream function**.

Dye line may refer either to a streakline: dye released gradually from a fixed location during time; or it may refer to a timeline: a line of dye applied instantaneously at a certain moment in time, and observed at a later instant.

Mathematical description

Streamlines

Streamlines are defined as[1]

$$\frac{d\vec{x}_S}{ds} \times \vec{u}(\vec{x}_S) = 0,$$

with "×" denoting the vector cross product and $\vec{x}_S(s)$ is the parametric representation of *just one* streamline at one moment in time.

If the components of the velocity are written $\vec{u} = (u, v, w),$ and those of the streamline as $\vec{x}_S = (x_S, y_S, z_S),$ we deduce:[1]

$$\frac{dx_S}{u} = \frac{dy_S}{v} = \frac{dz_S}{w},$$

which shows that the curves are parallel to the velocity vector. Here s is a variable which parametrizes the curve $s \mapsto \vec{x}_S(s).$ Streamlines are calculated instantaneously, meaning that at one instance of time they are calculated throughout the fluid from the instantaneous flow velocity field.

Pathlines

Pathlines are defined by

$$\begin{cases} \frac{d\vec{x}_P}{dt} = \vec{u}_P(\vec{x}_P, t) \\ \vec{x}_P(t_0) = \vec{x}_{P0} \end{cases}$$

The suffix P indicates that we are following the motion of a fluid particle. Note that at point $\vec{x}_P$ the curve is parallel to the flow velocity vector $\vec{u}$, where the velocity vector is evaluated at the position of the particle $\vec{x}_P$ at that time t.

Streaklines

Streaklines can be expressed as,

$$\begin{cases} \frac{d\vec{x}_P}{dt} = \vec{u}_P(\vec{x}_P, t) \\ \vec{x}_P(t = \tau_P) = \vec{x}_{P0} \end{cases}$$

where, $\vec{u}_P$ is the velocity of a particle P at location $\vec{x}_P$ and time t. The parameter τ_P, parametrizes the streakline $\vec{x}_P(t, \tau_P)$ and $0 \leq \tau_P \leq t_0$, where t_0 is a time of interest.

Steady flows

In steady flow (when the velocity vector-field does not change with time), the streamlines, pathlines, and streaklines coincide. This is because when a particle on a streamline reaches a point, a_0, further on that streamline the equations governing the flow will send it in a certain direction $\vec{x}$. As the equations that govern the flow remain the same when another particle reaches a_0 it will also go in the direction $\vec{x}$. If the flow is not steady then when the next particle reaches position a_0 the flow would have changed and the particle will go in a different direction.

This is useful, because it is usually very difficult to look at streamlines in an experiment. However, if the flow is steady, one can use streaklines to describe the streamline pattern.

Frame dependence

Streamlines are frame-dependent. That is, the streamlines observed in one inertial reference frame are different from those observed in another inertial reference frame. For instance, the streamlines in the air around an aircraft wing are defined differently for the passengers in the aircraft than for an observer on the ground. When possible, fluid dynamicists try to find a reference frame in which the flow is steady, so that they can use experimental methods of creating streaklines to identify the streamlines. In the aircraft example, the observer on the ground will observe unsteady flow, and the observers in the aircraft will observe steady flow, with constant streamlines.

Applications

Knowledge of the streamlines can be useful in fluid dynamics. For example, Bernoulli's principle, which describes the relationship between pressure and velocity in an inviscid fluid, is derived for locations along a streamline.

The curvature of a streamline is related to the pressure gradient acting perpendicular to the streamline. The radius of curvature of the streamline is in the direction of decreasing radial pressure. The magnitude of the radial pressure gradient can be calculated directly from the density of the fluid, the curvature of the streamline and the local velocity.

Engineers often use dyes in water or smoke in air in order to see streaklines, from which pathlines can be calculated. Streaklines are identical to streamlines for steady flow. Further, dye can be used to create timelines.[2] The patterns guide their design modifications, aiming to reduce the drag. This task is known as *streamlining*, and the resulting design is referred to as being *streamlined*. Streamlined objects and organisms, like steam locomotives, streamliners, cars and dolphins are often aesthetically pleasing to the eye. The Streamline Moderne style, an 1930s and 1940s offshoot of Art Deco, brought flowing lines to architecture and design of the era. The canonical example of a streamlined shape is a chicken egg with the blunt end facing forwards. This shows clearly that the curvature of the front surface can be much steeper than the back of the object. Most drag is caused by eddies in the fluid behind the moving object, and the objective should be to allow the fluid to slow down after passing around the object, and regain pressure, without forming eddies.

The same terms have since become common vernacular to describe any process that smooths an operation. For instance, it is common to hear references to streamlining a business practice, or operation.

See also

- Stream function
- Flow visualization
- Drag coefficient
- Equipotential surface

Notes and references

References

- Faber, T.E. (1995). *Fluid Dynamics for Physicists*. Cambridge University Press. ISBN 0-521-42969-2.

External links

- Streamline illustration [3]
- Flow Description at University of Sydney [4]
- Flow Visualization at the College of Engineering at Purdue University [5]
- Streamlines [6]
- Tutorial - Illustration of Streamlines, Streaklines and Pathlines of a Velocity Field(with applet) [7]

References

[1] Granger, R.A. (1995), *Fluid Mechanics*, ISBN 0486683567, pp. 422–425.
[2] " Flow visualisation (http://modular.mit.edu:8080/ramgen/ifluids/Flow_Visualization.rm)" (realmedia). National Committee for Fluid Mechanics Films (NCFMF). . Retrieved 2009-04-20.
[3] http://www.centennialofflight.gov/essay/Dictionary/streamlining/DI44.htm
[4] http://www.ae.su.oz.au/aero/fprops/cvanalysis/node8.html
[5] https://widget.ecn.purdue.edu/~meapplet/java/flowvis/Index.html
[6] https://visualization.hpc.mil/wiki/index.php/Streamlines
[7] http://web.mit.edu/fluids-modules/www/potential_flows/LecturesHTML/lec02/tutorial/tutorial-spsl.html

Structural load

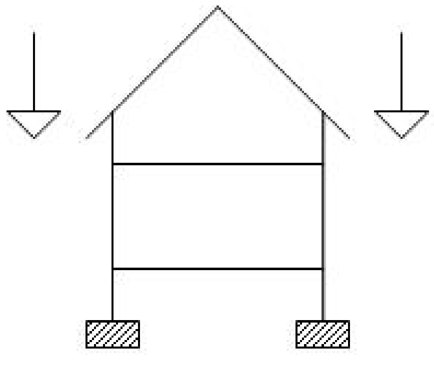
Structural loads are forces applied to a component of a structure or to the structure as a unit.[1]

In structural design, assumed loads are specified in national and local design codes for types of structures, geographic locations, and usage. In addition to the load magnitude, its frequency of occurrence, distribution, and nature (static or dynamic) are important factors in design. Loads cause stresses, deformations and displacements in structures. Assessment of their effects is carried out by the methods of structural analysis. Excess load or overloading may cause structural failure, and hence such possibility should be either considered in the design or strictly controlled.

In the Eurocodes, the term **actions** has a similar meaning to loads, but encompasses applied deformations as well as forces.

The following lists the common loading types primarily for civil infrastructure and land machinery. Structures for aerospace (e.g. aircraft, satellites, rockets, space stations, etc...) and marine environments (e.g. boats, submarines, etc.) have their own particular design loads and consideratio includes dead loads but also includes forces set up by irreversible changes in a structure's constraints - for example, loads due to settlement, the secondary effects of prestress or due to shrinkage and creep in concrete.

Dead load

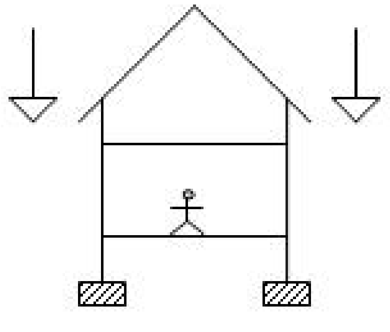


Dead load

The dead load is the weight of the structure acting with gravity on the foundations below. Snow load is the weight of the dead load and the imposed load but also the weight of the snow on top which could cause damage to the roof.

Live loads

Live loads, or imposed loads, are temporary, of short duration, or moving. Examples include snow, wind, earthquake, traffic, movements, water pressures in tanks, and occupancy loads. For certain specialized structures, vibro-acoustic loads may be considered.

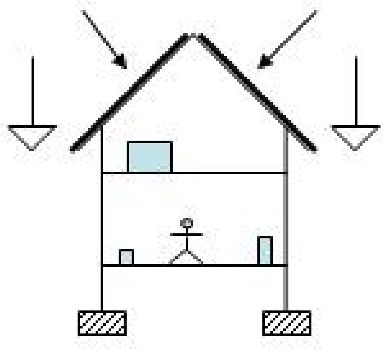


Imposed load

Environmental loads

- Temperature changes leading to thermal expansion cause thermal loads
- loads caused by humidity or moisture induced expansion
- Ice movements
- Water waves
- Shrinkage

Static loads



Live snow load

These are loads that build up gradually over time, or with negligible dynamic effects. Since structural analysis for static loads is much simpler than for dynamic loads, design codes usually specify statically-equivalent loads for dynamic loads caused by wind, traffic or earthquake.

Dynamic loads

These are loads that display significant dynamic effects. Examples include impact loads, waves, wind gusts and strong earthquakes. Because of the complexity of analysis, dynamic loads are normally treated using statically equivalent loads for routine design of common structures. dynamic loads are also caused by aforce other than gravity

Load combination

A load combination results when more than one load type acts on the structure. Design codes usually specify a variety of load combinations together with weighting factors for each load type in order to ensure the safety of the structure under different probable loading scenarios.

References

[1] Chen, Wai-Fah; Lui, E. M. (2005). *Handbook of Structural Engineering*. CRC Press. ISBN 0849315697.

Surface integrity

Surface integrity the nature of the surface condition of a workpiece after manufacturing processes. It can also be defined as the "unimpaired or enhanced surface condition of a component or specimen which influences its performance". The term was coined by Michael Field[1] and John F. Kahles[2] in 1964.[3]

The surface integrity of a workpiece or item changes the material's properties. The consequences of changes to surface integrity are a → mechanical engineering design problem, but the preservation of those properties are a manufacturing consideration.[4]

Surface integrity can have a great impact on a parts function; for example, Inconel 718 can have a fatigue limit has high as 540 MPa (78000 psi) after a gentle grinding or as low as 150 MPa (22000 psi) after electrical discharge machining (EDM).[5]

Definition

There are two aspects to surface integrity: *topography characteristics* and *surface layer characteristics*. The topography is made up of surface roughness, waviness, errors of form, and flaws. The surface layer characteristics that can change through processing are: plastic deformation, → residual stresses, cracks, hardness, overaging, phase changes, recrystallization, intergranular attack, and hydrogen embrittlement. When a traditional manufacturing process is used, such as machining, the surface layer sustains local plastic deformation.[3] [4]

The processes that affect surface integrity can be conveniently broken up into three classes: *traditional processes*, *non-traditional processes*, and *finishing treatments*. Traditional processes are defined as processes where the tool contacts the workpiece surface; for example: grinding, turning, and machining. These processes will only damage the surface integrity if the improper parameters are used, such as dull tools, too high feed speeds, improper coolant or lubrication, or incorrect grinding wheel hardness. Nontraditional processes are defined as processes where the tool does not contact the workpiece; examples of this type of process include EDM, electrochemical machining, and chemical milling. These processes will always change the surface integrity no matter how well controlled; for instance, they can leave a stress-free surface, a remelted surface, or excessive surface roughness. Finishing treatments are defined as processes that negate surface finishes imparted by traditional and non-traditional processes or improve the surface integrity. For example, residual stress can be removed via peening or roller burnishing or the recast layer left by EDMing can be removed via chemical milling.[6]

Finishing treatments can affect the workpiece surface in a wide variety of manners. Some clean and/or remove defects, such as scratches, pores, burrs, flash, or blemishes. Other processes improve or modify the surface appearance by improving smoothness, texture, or color. They can also improve corrosion resistance, wear resistance, and/or reduce friction. Coatings are another type of finishing treatment that may be used to plate an expensive or scarce material onto a less expensive base material.[6]

Variables

Manufacturing processes have five main variables: the workpiece, the tool, the machine tool, the environment, and process variables. All of these variables can affect the surface integrity of the workpiece by producing:[3]

- High temperatures involved in various machining processes
- Plastic deformation in the workpiece (residual stresses)
- Surface geometry (roughness, cracks, distortion)
- Chemical reactions, especially between the tool and the workpiece

References

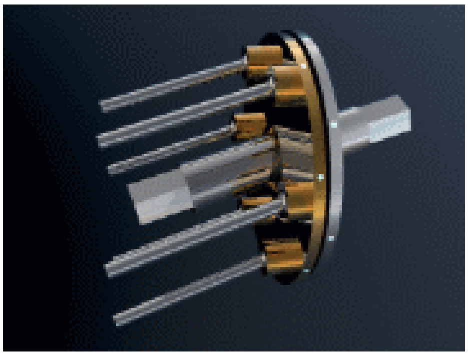
[1] *Dr. Michael Field* (http://www.nae.edu/nae/naepub.nsf/Members+By+UNID/AA719535BA65B8E186257552006B36A1?opendocument), , retrieved 2009-08-28.
[2] Micheal, Field, *John F. Kahles* (http://books.nap.edu/openbook.php?record_id=4779&page=121), , retrieved 2009-08-28.
[3] Degarmo, Black & Kohser 2003, p. 778.
[4] Degarmo, Black & Kohser 2003, p. 779.
[5] Degarmo, Black & Kohser 2003, p. 777.
[6] Degarmo, Black & Kohser 2003, p. 780.

Bibliography

- Degarmo, E. Paul; Black, J T.; Kohser, Ronald A. (2003), *Materials and Processes in Manufacturing* (9th ed.), Wiley, ISBN 0-471-65653-4.

Swashplate

A **swashplate** is a device used in → mechanical engineering to translate the motion of a rotating shaft into → reciprocating motion. Conversely it can translate a reciprocating motion into a rotating one and can be used to replace the crankshaft in engine designs.



Swashplate animation. The rotating shaft and plate are shown in silver. The fixed plate is shown in gold and six shafts each take a reciprocating motion from points on the gold plate. The shafts might be connected to pistons in cylinders. Note the power may be coming from the shaft to drive the pistons as in a pump, or from the pistons to drive the shaft rotation as in an engine.

The swashplate consists of a disk attached to a shaft. If the disk is aligned squarely on the shaft then rotation of the shaft will turn the disk with it and no swashplate effect will be seen. Even a slight displacement of the disk from the square position, however , will cause the disk edge to appear to describe an oscillating linear path when viewed from a non-rotating point of view away from the shaft. The greater the angle of the plate to the shaft the more exaggerated the apparent linear motion will be. The apparent linear motion can be turned into an actual linear motion by having a follower, stationary with respect to the shaft but which presses against the top or bottom edge of the plate. The device has many similarities to the → cam.

The swashplate engine uses a swashplate in place of a crankshaft to translate the motion of a piston into rotary motion. Internal combustion engines and Stirling engines have been built using this mechanism.

The axial piston pump drives a series of pistons aligned coaxially with a shaft through a swashplate to pump a fluid.

A helicopter swashplate is a pair of plates, one rotating and one fixed, that are centered on the main rotor shaft. The rotating plate is linked to the rotor head, and the fixed plate is linked to the operator controls. Displacement of the alignment of the fixed plate is transferred to the rotating plate, where it becomes reciprocal motion of the rotor blade linkages. This type of pitch control, known as cyclic pitch, allows the helicopter rotor to provide selective lift in any direction.

Nutating flowmeters and pumps have similar motions to the wobble of a swashplate, but do not necessarily transform the motion to a reciprocating motion at any time.

YouTube video of a swashplate in action: [1]

References

[1] http://www.youtube.com/watch?v=3Y9MhcRMx4k&feature=related

Swivel

A **swivel** is a connection that allows the connected object, such as a gun or chair to rotate horizontally and/or vertically. A common design for a swivel is a cylindrical rod that can turn freely within a support structure. The rod is usually prevented from slipping out by a nut, washer or thickening of the rod. The device can be attached to the ends of the rod or the center. Another common design is a sphere that is able to rotate within a support structure. The device is attached to the sphere. A third design is a hollow cylindrical rod that has a rod that is slightly smaller than its inside diameter inside of it. They are prevented from coming apart by flanges. The device may be attached to either end.

A swivel joint for a pipe is often a threaded connection in between which at least one of the pipes is curved, often at an angle of 45 or 90 degrees. The connection is tightened enough to be water- or air-tight and then tightened further so that it is in the correct position.

See also

- Fishing Swivel
- Swivel gun
- Swivel (form)

Systematic Hierarchical Approach for Resilient Process Screening (SHARPS)

Systematic Hierarchical Approach for Resilient Process Screening (SHARPS)[1] is a cost screening technique to assist designers achieve a desired investment payback period during preliminary design of water-using systems. Heuristics involving equipment susbtitution and intensification are used to guide process changes. SHARPS method has been used to yield cost effective minimum water network for water-intensive facilities.

See also

- Water management hierarchy
- Cost effective minimum water network

References

[1] Wan Alwi, S. R. and Manan, Z. A. (2006). SHARPS – A New Cost-Screening Technique To Attain Cost-Effective Minimum Water Utilisation Network . AiChe Journal. 11 (52): 3981-3988.

Tail lift

A **tail lift** is a mechanical device permanently fitted to the back of van or lorry, which is designed to facilitate the materials handling of goods from ground level or a loading dock to the level of the load bed of the vehicle, or vice versa.

A hydraulic cantilever tail lift on the back of a truck

The majority of tail lifts are hydraulic or pneumatic in operation, although they can be mechanical, and are controlled by an operator using an electric relay switch.

The use of a tail lift can obviate the need to use machinery such as a forklift truck in order to load heavy items on to a vehicle, or can be used to bridge the difference in height between a loading dock and the vehicle load bed.

Tail lifts are available for many sizes of vehicle, from standard vans to articulated lorries, and standard models can lift anywhere up to 2500kg.[1]

Types

There are two key types of tail lift available to operators these are:


Four stages of deployment on an ambulance tail lift

Column lifts

Column lifts are often mechanical, although they can be hydraulic or pneumatic. They run on 'tracks' fitted to the rear of the vehicle. From the tracks, a folding platform extends, which can be taken up and down.

Column lifts have the advantage of being able to lift to a higher level than the load bed (and are therefore suitable for loads over more than one level in the truck.[2] They are usually the easiest of the lift types to fit, as they require little structural work.

The disadvantages of column lifts include that the platform is only usually able to operate at a 90° angle from the track, meaning that on uneven surfaces, the lift will not meet the ground properly.

Cantilever lifts

The cantilever lift is the type first developed by Zepro. They operate only on a hydraulic or pneumatic system. The system works by a set of rams attached to the chassis of the vehicle. These rams are on hinges, allowing them to move angle as they expand or contract. By using the rams in sequence, the working platform can either be tilted, or raised and lowered.

Control for a tail lift

Cantilever lifts have the advantage of being able to tilt, which means they can often form a ramp arrangement, which may be more appropriate for some applications. It also means that it can be easier to load or unload on uneven ground.

On tuckaway lifts, the ramp can be folded away under the load bed of the vehicle, leaving the option of it not being used when at a loading ramp, and giving access and egress for operatives without the need to operate the lift.

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[2] " Ratcliff Double Tier Lift (http://www.ratcliff.co.uk/palfinger/16461_EN.pdf)". . Retrieved 2007-06-13.

Thermal engineering

Heating or cooling of processes, equipment, or enclosed environments are within the purview of thermal engineering.

One or more of the following disciplines may be involved in solving a particular thermal engineering problem:

- Thermodynamics
- Fluid mechanics
- → Heat transfer
- → Mass transfer

Thermal engineering may be practiced by → mechanical engineers.

One branch of knowledge used frequently in thermal engineering is that of thermofluids.

Applications

- Engineering : HVAC
- Cooling of computer chips [1]
- Boiler design
- Solar heating

External links

- Yahoo directory [2]
- Thermal Engineeing branch at Goddard Space Flight Center [3]
- List of related fields in UNESCO thesaurus [4]

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Thermal efficiency

In thermodynamics, the **thermal efficiency** (η_{th}) is a dimensionless performance measure of a thermal device such as an internal combustion engine, a boiler, or a furnace, for example. The input, Q_{in}, to the device is heat, or the heat-content of a fuel that is consumed. The desired output is mechanical work, W_{out} , or heat, Q_{out} , or possibly both. Because the input heat normally has a real financial cost, a memorable, generic definition of thermal efficiency is[1]

$$\eta_{th} \equiv \frac{\text{What you get}}{\text{What you pay for}}.$$

From the first law of thermodynamics, the output can't exceed what is input, so

$$0 \leq \eta_{th} \leq 1$$

When expressed as a percentage, the thermal efficiency must be between 0% and 100%. Due to inefficiencies such as friction, heat loss, and other factors, thermal engines efficiencies are typically much less than 100%. For example, a typical gasoline automobile engine operates at around 25% efficiency, and a large coal-fueled electrical generating plant peaks at about 46%. The largest diesel engine in the world peaks at 51.7%. In a combined cycle plant, thermal efficiencies are approaching 60%.[2]

Heat engines

When transforming thermal energy into mechanical energy, the thermal efficiency of a heat engine is the percentage of heat energy that is transformed into work. Thermal efficiency is defined as

$$\eta_{th} \equiv \frac{W_{out}}{Q_{in}} = 1 - \frac{Q_{out}}{Q_{in}}$$

Carnot efficiency

The second law of thermodynamics puts a fundamental limit on the thermal efficiency of heat engines. Surprisingly, even an ideal, frictionless engine cannot convert anywhere near 100% of its input heat into work. The limiting factors are the temperature at which the heat enters the engine, T_H, and the temperature of the environment into which the engine exhausts its waste heat, T_C, measured in the absolute Kelvin or Rankine scale. From Carnot's theorem, for any engine working between these two temperatures:

$$\eta_{th} \leq 1 - \frac{T_C}{T_H}$$

This limiting value is called the **Carnot cycle efficiency** because it is the efficiency of an unattainable, ideal, reversible engine cycle called the Carnot cycle. No heat engine, regardless of its construction, can exceed this efficiency.

Examples of T_H are the temperature of hot steam entering the turbine of a steam power plant, or the temperature at which the fuel burns in an internal combustion engine. T_C is usually the ambient temperature where the engine is located, or the temperature of a lake or river that waste heat is discharged into. For example, if an automobile engine burns gasoline at a temperature of $T_H = 1500^{\circ}F = 1089K$ and the ambient temperature is $T_C = 70^{\circ}F = 294K$, then its maximum possible efficiency is given by:

$$\eta_{th} \le 1 - \frac{294K}{1089K} = 73.0\%$$

In practice, because the operating cycles of real engines are nowhere near as efficient as the Carnot cycle, coupled with other irreversibilities such as the combustion process itself and friction, real engines fall far short of the Carnot efficiency. Real automobile engines are only around 25% efficient. Combined cycle power stations efficiencies are higher, approaching 46%, but still fall at least 15 points short of the Carnot value. As Carnot's theorem only applies to heat engines, devices that convert the fuel's energy directly into work without burning it, such as fuel cells, can exceed the Carnot efficiency.

It can be seen that since T_C is fixed by the environment, the only way for a designer to increase the theoretical efficiency of an engine is to increase T_H, the operating temperature of the engine. For this reason the operating temperatures of engines have increased greatly over the long term, and new materials such as ceramics to enable engines to stand higher temperatures are an active area of research.

Energy conversion

For an energy conversion device like a boiler or furnace, the thermal efficiency is

$$\eta_{th} \equiv \frac{Q_{out}}{Q_{in}}.$$

So, for a boiler that produces 210 kW (or 700,000 BTU/h) output for each 300 kW (or 1,000,000 BTU/h) heat-equivalent input, its thermal efficiency is 210/300 = 0.70, or 70%. This means that the 30% of the energy is lost to the environment.

An electric resistance heater has a thermal efficiency of at or very near 100%, so, for example, 1500W of heat are produced for 1500W of electrical input. When comparing heating units, such as a 100% efficient electric resistance heater to an 80% efficient natural gas-fueled furnace, an economic analysis is needed to determine the most cost-effective choice.

Heat pumps and refrigerators

Heat pumps, refrigerators and air conditioners use work to move heat from a colder to a warmer place, so their function is the opposite of a heat engine. Their efficiency is measured by a → coefficient of performance (COP). Heat pumps are measured by the efficiency with which they add heat to the hot reservoir, $COP_{heating}$; refrigerators and air conditioners by the efficiency with which they remove heat from the cold interior, $COP_{cooling}$:

$$\mathrm{COP}_{\mathrm{heating}} \equiv \frac{Q_H}{W}$$

$$\mathrm{COP}_{\mathrm{cooling}} \equiv \frac{Q_L}{W}$$

The reason for not using the term 'efficiency' is that the coefficient of performance can often be greater than 100%. Since these devices are moving heat, not creating it, the amount of heat they move can be greater than the input work. Therefore, heat pumps can be a more efficient way of heating than simply converting the input work into heat, as in an electric heater or furnace.

Since they are heat engines, these devices are also limited by Carnot's theorem. The limiting value of the Carnot 'efficiency' for these processes, with the equality theoretically achievable only with an ideal 'reversible' cycle, is:

$$\mathrm{COP}_{\mathrm{heating}} \le \frac{T_H}{T_H - T_C}$$

$$\mathrm{COP}_{\mathrm{cooling}} \le \frac{T_C}{T_H - T_C}$$

The same device used between the same temperatures is more efficient when considered as a heat pump than when considered as a refrigerator:

$$\mathrm{COP}_{\mathrm{heating}} - \mathrm{COP}_{\mathrm{cooling}} = 1$$

This is because when heating, the work used to run the device is converted to heat and adds to the desired effect, whereas if the desired effect is cooling the heat resulting from the input work is just an unwanted byproduct.

Energy efficiency

The 'thermal efficiency' is sometimes called the **energy efficiency**. In the United States, in everyday usage the SEER is the more common measure of energy efficiency for cooling devices, as well as for heat pumps when in their heating mode. For energy-conversion heating devices their peak steady-state thermal efficiency is often stated, e.g., 'this furnace is 90% efficient', but a more detailed measure of seasonal energy effectiveness is the Annual Fuel Utilization Efficiency (AFUE).[3]

See also

- Electrical efficiency
- → Mechanical efficiency
- Figure of merit

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[3] HVAC Systems and Equipment volume of the *ASHRAE Handbook*, ASHRAE, Inc., Atlanta, GA, USA, 2004

Thermal science

Thermal science is the combined study of thermodynamics, fluid mechanics, → heat transfer, and combustion. This umbrella-subject is typically designed for non-engineering students and functions to provide a general introduction to each of three core heat-related subjects.

Overview

Introductory subjects studied in thermal science generally are focused on thermodynamics. These include studies of properties of pure substances, pressure-volume-temperature diagrams, the ideal gas law, heat and it relationship to work, → heat transfer, the laws of thermodynamics, engine and refrigeration cycles, and combustion.

A second area of concern in thermal science is fluid mechanics. These include fluid statics, fluid flows, i.e. laminar flow vs. turbulent flow, the Bernoulli equation etc. The applicability of this area is piping networks, turbomachineries, airfoils...etc.

The third area is → heat transfer. Applications include, heat exchangers, heat engines, heating, ventilating, and air-conditioning, and cooling of microelectronics.

The fourth area is combustion, which involves both thermal effects and chemical reaction.

Intensive study of thermal sciences requires additional knowledge and experience in other areas such as experimental techniques and numerical or computational methods.

See also

- Thermal physics
- → Mechanical engineering
- Chemical engineering
- Architectural engineering

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External links

- Thermal Science [1] - International Scientific Journal

References

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Thermo-mechanical fatigue

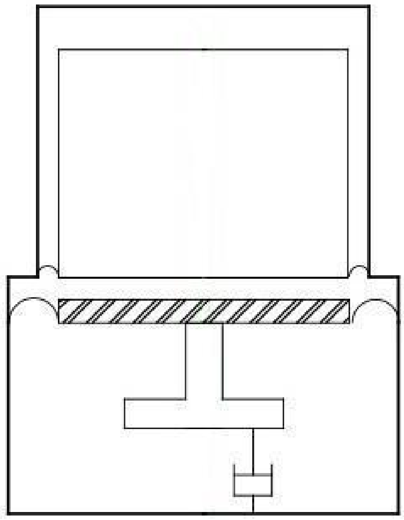
Thermo-mechanical fatigue (short **TMF**) is the overlay of a cyclical mechanical loading, that leads to fatigue of a material, with a cyclical thermal loading. Thermo-mechanical fatigue is an important point that needs to be considered, when constructing turbine engines or gas turbines.

Cyclical mechanical loading applied to a material leads to material fatigue.

When a cyclical thermal load is applied to a material it will fail by thermal fatigue due to induced thermal stresses.

Thermomechanical generator

The **Harwell TMG** Stirling engine, an abbreviation for "Thermo-Mechanical Generator", was invented in 1967 by E. H. Cooke-Yarborough at the Harwell Labs of the United Kingdom Atomic Energy Authority. It was intended to be a remote electrical power source with low cost and very long life, albeit by sacrificing some efficiency. The TMG (model TMG120) was at one time the only Stirling engine sold by a manufacturer, namely HoMach Systems Ltd., England.[1]



Freebody diagram; modeling the interaction of the piston with the case

The engine has near isothermal cylinders because 1) the heater area covers the entire cylinder end, 2) it is a short stroke device, with wide shallow cylinders, yielding a high surface area to volume ratio, 3) the average thickness of the gas space is about 0.1 cm, and 4) the working fluid is Helium, a gas having good thermal properties for Stirling engines.

The engine's displacer also has very low losses. These low-loss operating characteristics simplify the engine analysis, compared to more conventional Stirling engines.[1]

The design has many advantages over conventional Stirling engines. The simplicity of the heater greatly reduces the cost by allowing the TMG to avoid the need for a brazed tubular or finned heater, which can account for 40% of the cost of a conventional Stirling engine. [2] The heat exchangers for the heater and cooler are mechanically trivial. The regenerator is a simple annulus, referred to as a "flat plate". Along with the cylinder wall and the displacer, there are a total of four regenerating surfaces. The TMG is a free piston engine. There are no rolling bearings or sliding seals, thus there is very little friction or wear. The working space is hermetically sealed, allowing it to contain pressurized helium gas for many thousands of hours.

The displacer is a stainless steel can, 27 cm in diameter. It is suspended by a low-loss planer metal spring centered in a 27.4 cm diameter cylinder. The 2 mm radial clearance is

divided into two concentric annular gaps by a thin, open-ended cylinder, which is fixed to the engine's cylinder. This annulus acts as the regenerator, which is much less costly than a wire-mesh type.

The engine is a "free-cylinder" design, in which the entire engine is mounted on springs and allowed to vibrate slightly. This allows the displacer to be driven by positive feedback from the motion of the power piston and the magnets in the linear-alternator magnets, which have a combined weight of 10 kg.

Engine Parameter	HoMach TMG 120 Spec
Indicated power	170 W
Shaft power	150 W
Heat input	1500 W
Thermal to mechanical efficiency	10%
Engine frequency	110 Hz
charge Pressure	0.2 MPa
Displacer diameter	26.0 cm
displacer stroke	0.2 cm
Displacer swept volume	110 cm^3
Power piston diaphragm outer diameter	35.2 cm
Power piston diaphragm stroke	0.152 cm
Power piston diaphragm swept volume	110 cm^3
Phase angle	~90 degrees
Moving mass (Power piston and alternator magnets)	10 kg
Total engine mass	~80 kg
Operating life	over 90000 hours
Helium replenishment (7 liters, at unknown pressure)	every 22500 hours on average

[1]

The unique power piston was invented by Cooke-Yarborough, and is called an "articulated diaphragm". It consists of a stainless steel annulus, with an outer diameter of 35 cm and an inner diameter of 26 cm. This annulus is clamped to the engine on the outer edge by two flexible rubber o-rings, and on the inner edge it is similarly clamped, in this case to a rigid center hub that makes up the piston's center. The o-rings flex but do not slide, thus no lubricant is needed and there is negligible wear in the entire machine.

The compression space is located between the power-piston hub and the displacer, and this space is cooled by direct conduction through the power piston. A developmental model of the TMG contained a double articulated diaphragm containing cooling water, which was pumped by a thermosyphon. The depth of the compression space varies from 0.2 to 2.7 mm, as governed by the 2 mm displacer stroke and the 1.5 mm power piston stroke moving 90 degrees out of phase.

The TMG engine successfully overcomes many of the economic and mechanical difficulties common in conventional Stirling engines. However, there are some limitations of this design. The simple, low-cost annular regenerator is inefficient compared to other types, (and this contributes to this engine's somewhat low thermal efficiency of only 10%). The

mechanical limitations of the articulated diaphragm only allow a maximum stroke of an estimated 3 mm. These properties limit the maximum obtainable power to about 500 - 1000 Watts from an engine of this design.[1] Nevertheless, it is rare for a low-cost Stirling engine to obtain this high level of reliability and operating life, which can only be attributed to the ingenuity of the design.

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Timken OK Load

Timken OK Load is a qualitative measure that indicates the possible performance of extreme pressure additives (EP Additives) in a lubricating grease or oil. The units of measure are pounds-force or kilograms-force and are determined using a special test machine.

The test machine is based on a machine manufactured by the Timken Company from 1935 to 1972. It is now an industry standard test though the meaning of the qualitative measure has become less useful as the science of tribology has advanced.

The test machine consists of a bearing race mounted on a tapered arbor rotating at high speed. The race is brought into contact with a square steel test block under load. The contact area is flooded with the lubricant being tested. The Timken OK Load is the load at which the spinning bearing race produces a score mark on the test block.

Timken no longer manufactures the test machine, but it is commercially manufactured by the Falex Corporation. Timken OK Loads are still listed on grease and oil property charts. It was once generally assumed that the measure and the film strength of the lubricant were directly related. Today, the primary purpose of the test is to determine whether EP additives are present and functioning. A measure of 35 pounds-force (16 kilograms-force or 155 newtons) or more means that EP additives are present and working.

The Timken OK Load test specification is ASTM D-2509.

Falex Corporation can be reached here : [1]

References

[1] http://www.falex.com

Tip clearance

Tip clearance is the distance between the tip of a rotating airfoil and a non moving part.

- Gas turbine: Rotor blade and casing[1]
- Propeller (Ship or aircraft): Propeller and structure[2]
  - Ground tip clearance [3]
- Wind turbine: Blade and tower [4]

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Tolerance stacks

Tolerance analysis is the general term for all activities related to the study of accumulated variation in mechanical parts and assemblies, and may be used on other types of systems subject to accumulated variation, such as mechanical and electrical systems.

Tolerance stacks, **tolerance stackups** or **tolerance stack-ups** are terms used to describe the problem-solving process in → mechanical engineering of calculating the effects of the accumulated variation that is allowed by specified dimensions and tolerances. Typically these dimensions and tolerances are specified on an engineering drawing. Arithmetic tolerance stackups use the worst-case maximum or minimum values of dimensions and tolerances to calculate the maximum and minimum distance (clearance or interference) between two features or parts. Statistical tolerance stackups evaluate the maximum and minimum values based on the absolute arithmetic calculation combined with some method for establishing likelihood of obtaining the maximum and minimum values, such as Root Sum Square (RSS) or Monte-Carlo methods.

While no official engineering standard covers the process or format of tolerance analysis, tolerance analysis and tolerance stackups are essential components of good product design. Tolerance stackups should be used as part of the mechanical design process, both as a predictive tool and as a problem-solving tool. The methods used to conduct a tolerance stackup depend somewhat upon the engineering dimensioning and tolerancing standards that are referenced in the engineering documentation, such as → ASME Y14.5, ASME Y14.41, or the relevant ISO dimensioning and tolerancing standards. Understanding the tolerances, concepts, and boundaries created by these standards is vital to performing accurate calculations.

Tolerance stackups serve engineers by:

- helping engineers and designers study dimensional relationships within an assembly
- giving designers a means of calculating part tolerances
- helping engineers compare design proposals
- helping designers produce complete drawings

Concerns with tolerance stackups

A safety factor is often included in designs because of concerns about:

- Operational temperature of the parts or assembly
- Wear
- Deflection of components after assembly
- The possibility or probability that the parts are slightly out of specification (but passed inspection)
- The sensitivity or importance of the stack (what happens if the design conditions are not met)

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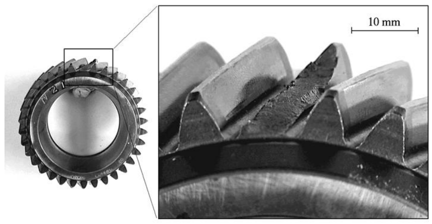
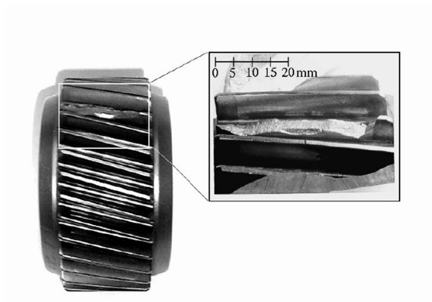
Tooth Interior Fatigue Fracture

Tooth Interior Fatigue Fracture, (TIFF), is a type of gear failure. The failure is characterised by a fracture at approximately mid-height on the tooth of the gear. This distinguishes it from a tooth root fatigue failure. The crack for a TIFF is initiated in the interior of the tooth. This distinguishes TIFF from other fatigue failures of gears. TIFF has been observed in case-hardened → idlers (i.e. gear wheels loaded on both flanks during each revolution).



Tooth Interior Fatigue Fracture (TIFF) on intermediate gear

The TIFF fracture surface has a distinct plateau in the central part along the tooth width and approximately mid-height of the tooth. In a close-up of the cross-section of the TIFF small wing cracks are observed. The presence of the wing crack indicates that the main crack has propagated from the centre of the tooth toward the tooth flank.



The TIFF fracture surface has a distinct plateau in the central part along the tooth width and approximately mid-height of the tooth.

The crack-producing stresses of TIFF are twofold: i) constant residual tensile stresses in the interior of the tooth due to case hardening; and ii) alternating stresses due to the idler usage of the gear wheel.

Contact fatigue begins with surface distress, which can grow to spalling. In severe cases a secondary crack can grow from a spalling crater through the tooth thickness and a part of the tooth can fall off. In contrast to the fracture of severe contact fatigue, spalling craters are not necessary at the flank surface for a TIFF.

See also

Fracture mechanics

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Torque density

Torque density is a measure of the torque-carrying capability of a mechanical component. It is the ratio of torque capability to volume and is expressed in units of torque per volume. Torque density is a system property since it depends on the design of each element of the component being examined and their interconnection.

Torque density is useful during the concept evaluation stage of mechanical designs, especially in power train design problems. Typically, it will be one of many factors used to assign potential success measures to each concept. For example, in the upgrade of a drive train for a set of rolls in a rolling mill, space is often dictated by the configuration of current components. There may be several types of devices that can perform the function of an existing component that must be replaced. The relative torque densities of the devices may be an important determinant for which design is ultimately selected, although it will often compete with other factors such as cost, ease of maintenance, time to install, operating costs and potential failure modes.

Units

In SI units, torque density is expressed in joules per cubic metre or equivalently newton-metres per cubic metre (though dimensionally equivalent to the pascal, that is usually not used for this purpose). Small amounts can be expressed in newton-millimetres per cubic millimetre.

In U.S. customary units, torque density is expressed in foot-pounds force per cubic foot, or inch-pounds force per cubic inch or ounce-force inches per cubic inch.

Treadle


A sheep or dog treadle

A **treadle** [from OE *tredan* = to tread] is a part of a machine which is operated by the foot to produce reciprocating or rotary motion in a machine such as a weaving loom (reciprocating) or grinder (rotary). Treadles can also be used to power water pumps (treadle pump)

Railways

On a railway, a treadle or treatle is a device that detects the passing of a train, a bit like a track circuit and might be used to put a signal to 'stop'. Treadles are also used to start the sequence of automatic level crossings.

Sewing machines

Many of the early sewing machines were operated by a treadle mechanism linked to the machine by a leather belt.

See also

- Pedal
- Treadle pump
- Treadle (railway)

Trunnion

A **trunnion** is a cylindrical protrusion used as a mounting and/or pivoting point.

The trunnions are the protrusions from the side of the barrel that rest on the carriage.

Usages

In weapons

- In a cannon, the trunnions are the two projections on the side of the barrel which mount the barrel in the carriage. As they allowed the muzzle to be raised and lowered easily, and made it easier to fix it to a movable carriage, the integral casting of trunnions is seen by military historians as one of the most important advances in early field artillery.[1]
- On firearms, the barrel is sometimes mounted in a trunnion, which in turn is mounted to the receiver. This usage is common for tubular or pressed metal frame guns, such as the Kalashnikov, PPSh, Uzi, Sten, and others.

In vehicles

- In older cars, especially those by the Triumph Motor Company, the trunnion is part of the suspension and either allows free movement of the rear wheel hub in relation to the chassis or allows the front wheel hub to rotate with the steering. On many cars the trunnion is machined from a brass or bronze casting and is prone to failure.
- In aviation, the term refers to the structural component that attaches the landing gear to the airframe. For aircraft equipped with retractable landing gear, the trunnion is pivoted to permit rotation of the entire gear assembly.
- In heavy equipment, such as a bulldozer, the term refers to the protrusions on the vehicle frame on which the blade frame attaches and hinges allowing vertical movement.
- In Chevrolet GMC C/K pickup trucks, the term refers to the tailgate attachment points. Rather than using conventional tailgate hinges, trunnions are used to permit quick toolless removal and installation of the pickup tailgate.
- In Trailers,Murray Trailer [2] The term refers to the type of suspension used on a two axle configuration with eight tires, i.e. four tires per axle. This type of trailer suspension is commonly used in the western United States and is allowed 60000 pounds (27000 kg) to be loaded on that axle group.

In other technology

- In steam engines, they are supporting → gudgeon pins on either side of an oscillating steam cylinder. They are usually tubular and convey steam.
- On communication satellites, the antennas are usually mounted on a pair of trunnions to allow the beam pattern to be correctly pointed on the Earth from the geostationary orbit.
- On stage lighting instruments, a trunnion is a bracket attached to both ends of a striplight that allows the striplight to be mounted on the floor. Sometimes trunnions are also equipped with casters to allow the striplight to be moved easily.
- In woodworking, they are the assembly that holds a saw's arbor to the underside of the saw table.
- In Waste Collection the trunnion is the bar on the front of a Dumpster that connects to the back of a garbage truck.
- On the Space Shuttle, trunnion pins are affixed to the sides of payload items allowing them to be secured to receivers mounted on the sills of the payload bay. These receivers can be remotely commanded to secure and release selected items. Similar keel pins protrude from the nadir side of payload items, into matching holes in the bottom of the payload bay.

Trunnion bearings

In avionics, these are self-contained concentric bearings that are designed to offer fluid movement in a critical area of the steering.

The term is also used to describe the wheel that a rotating cylinder runs on. For example, a lapidiary (stone-polishing) cylinder runs on a pair of rollers, similar to trunnions. The sugar industry uses rotating cylinders up to 6.7 meters in diameter and 40 meters long weighing around 1000 tonnes. These rotate at around 30 revolutions per hour. They are supported on a pathring which runs on trunnions. Similar devices called rotary kilns are used in cement manufacture.

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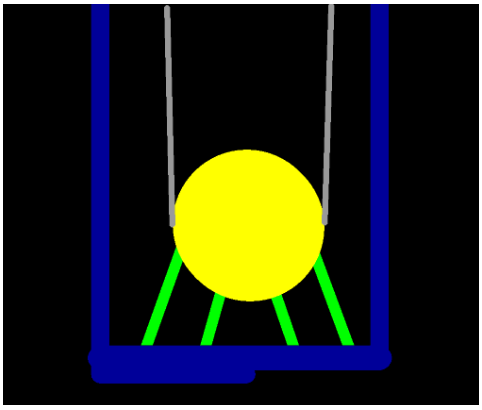
Tuned mass damper

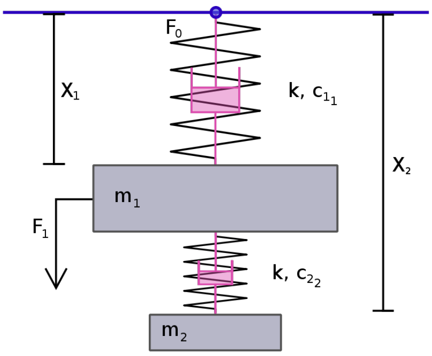
A **tuned mass damper**, also known as an **active mass damper** (**AMD**) or **harmonic absorber**, is a device mounted in structures to prevent discomfort, damage, or outright structural failure caused by vibration. They are frequently used in power transmission, automobiles, and buildings.



An animation showing the movement of a skyscraper mass damper. The green indicates the hydraulic cylinders used to push the yellow weight.

Example

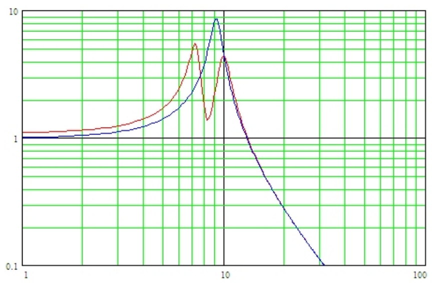
Tuned mass dampers stabilize against violent motion caused by harmonic vibration. A tuned damper balances the vibration of a system with comparatively lightweight component so that the worst-case vibrations are less intense.



A schematic of a simple spring–mass–damper system used to demonstrate the tuned mass damper system.

Consider a motor with mass m_1 attached via motor mounts to the ground. The motor vibrates as it operates and the soft motor mounts act as a parallel spring and damper, k_1 and c_1. The force on the motor mounts is F_0; suppose we wish to reduce the maximum force on the motor mounts as the motor operates over a range of speeds.

Let F_1 be the effective force on the motor due to its operation. We will add a smaller mass, m_2, connected to m_1 by a spring and a damper, k_2 and c_2.

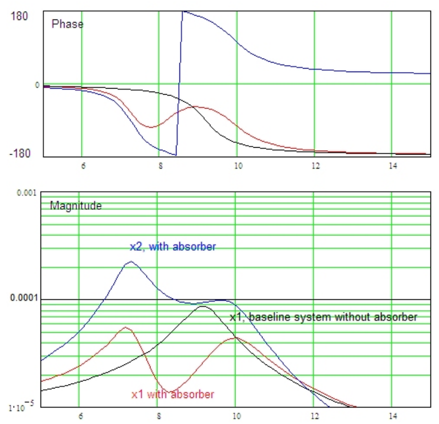


Response of the system excited by one unit of force, with (red) and without (blue) the 10% tuned mass. The peak response is reduced from 9 units down to 5.5 units. While the maximum response force is reduced, there are some operating frequencies for which the response force is increased.

The graph shows the effect of a tuned mass damper on a simple spring–mass–damper system, excited by vibrations with an amplitude of one unit of force applied to the main mass, m_1. An important measure of performance is the ratio of the force on the motor mounts to the force vibrating the motor, F_0/F_1. (We are assuming the system is linear, so if the force on the motor were to double, so would the force on the motor mounts.) The blue line represents the baseline system, with a maximum response of 9 units of force at around 9 units of frequency. The red line shows the effect of adding a tuned mass of 10% of the baseline mass. It has a maximum response of 5.5, at a frequency of 7. as a side effect, it also has a second normal mode and will vibrate somewhat more than the baseline system at frequencies below about 6 and above about 10.

The heights of the two peaks can be adjusted by changing the stiffness of the spring in the tuned mass damper. Changing the damping also changes the height of the peaks, in a complex fashion. The split between the two peaks can be changed by altering the mass of the damper (m_2).

The Bode plot is more complex, showing the phase and magnitude of the motion of each mass, for the two cases, relative to F1.



A Bode plot of displacements in the system with (red) and without (blue) the 10% tuned mass.

In the plots at right, the black line shows the baseline response ($m_2 = 0$). Now considering $m_2 = m_1/10$, the blue line shows the motion of the damping mass and the red line shows the motion of the primary mass. The amplitude plot shows that at low frequencies, the damping mass resonates much more than the primary mass. The phase plot shows that at low frequencies, the two masses are in phase. As the frequency increases m_2 moves out of phase with m_1 until at around 9.5 Hz it is 180° out of phase with m_1, maximizing the damping effect by maximizing the amplitude of $x_2 - x_1$, this maximizes the energy dissipated into c_2 and simultaneously pulls on the primary mass in the same direction as the motor mounts.

Mass dampers in automobiles

Motorsport

The tuned mass damper was introduced as part of the suspension system by Renault, on its 2005 F1 car (the R25), at the 2005 Brazilian Grand Prix. It was deemed to be legal at first, and it was in use up to the 2006 German Grand Prix.

At Hockenheim, the mass damper was deemed by the FIA to be a moveable aerodynamic device due to the influence it had on the pitch attitude of the car, and hence, as a consequence, the performance of the aerodynamics.

The Stewards of the meeting deemed it legal, but the FIA appealed against that decision. Two weeks later, the FIA International Court of Appeal deemed the mass damper illegal.

Production cars

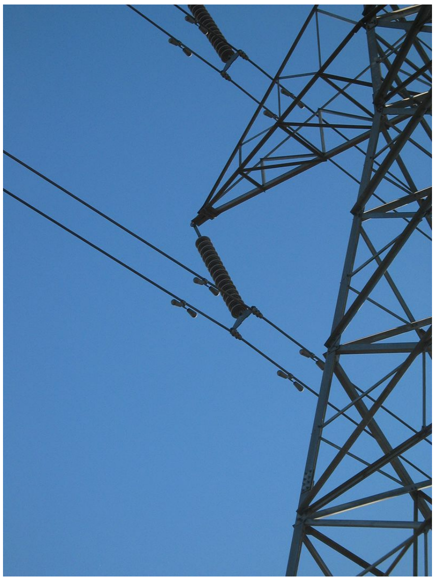
Tuned mass dampers are widely used in production cars, typically on the crankshaft pulley to control torsional vibration and bending modes of the crankshaft, on the driveline for gearwhine, and other noises. They are also used on the exhaust, on the body and on the suspension, as in the 2CV example above. Almost all cars will have one mass damper, some may have 10 or more.

Mass dampers in spacecraft

NASA's Ares uses 16 spring/mass absorbers as part of a design strategy to reduce peak loads from 6g to 0.25 g. The spring/mass system is responsible for reducing the vibration from 1g to 0.25g.[1]

Dampers in power transmission lines

High-tension lines often have small barbell-shaped Stockbridge dampers hanging from the wires to reduce the high-frequency, low-amplitude oscillation termed flutter.[2] [3]



Stockbridge dampers on power lines.

Dampers in buildings and related structures


Tuned mass damper atop the Taipei 101.

Typically, the dampers are huge concrete blocks or steel bodies mounted in skyscrapers or other structures, and moved in opposition to the resonance frequency oscillations of the structure by means of springs, fluid or pendulums.

Sources of vibration and resonance

Unwanted vibration may be caused by environmental forces acting on a structure, such as wind or earthquake, or by a seemingly innocuous vibration source causing resonance that may be destructive, unpleasant or simply inconvenient.

Earthquakes

The seismic waves caused by an earthquake will make buildings sway and oscillate in various ways depending on the frequency and direction of ground motion, and the height and construction of the building. Seismic activity can cause excessive oscillations of the building which may lead to structural failure. To enhance the building's seismic performance, a proper building design is performed engaging various seismic vibration control technologies.

Mechanical human sources

Masses of people walking up and down stairs at once, or great numbers of people stomping in unison, can cause serious problems in large structures like stadiums if those structures lack damping measures. Vibration caused by heavy industrial machinery, generators and diesel engines can also pose problems to structural integrity, especially if mounted on a steel structure or floor. Large ocean going vessels may employ tuned mass dampers to isolate the vessel from its engine vibration.


Dampers on a pedestrian bridge - the Millennium Bridge, London (the disk is not part of the damper)

Wind

The force of wind against tall buildings can cause the top of skyscrapers to move more than a metre. This motion can be in the form of swaying or twisting, and can cause the upper floors of such buildings to move. Certain angles of wind and aerodynamic properties of a building can accentuate the movement and cause motion sickness in people.

Examples of buildings and structures with tuned mass dampers

- Bally’s to Bellagio, Bally’s to Caesars Palace, and Treasure Island to The Venetian Pedestrian Bridges in Las Vegas
- Berlin Television Tower (Fernsehturm) — tuned mass damper located in the spire.
- Bloomberg Tower/731 Lexington in New York
- Burj al-Arab in Dubai — 11 tuned mass dampers.
- Citigroup Center in New York City — Designed by William LeMessurier and completed in 1977, it was one of the first skyscrapers to use a tuned mass damper to reduce sway. Uses a concrete version.
- Comcast Center in Philadelphia, PA — Contains the largest Tuned Liquid Column Damper (TLCD) in the world at 1,300 tons. [4]
- Dublin Spire in Dublin, Ireland — This narrow slender structure was designed with a tuned mass damper to ensure aerodynamic stability during a wind storm.
- Grand Canyon Skywalk
- John Hancock Tower in Boston — A tuned mass damper was added to it after it was built.
- London Millennium Bridge — 'The Wobbly Bridge'
- One Rincon Hill South Tower — First building in California to have a liquid tuned mass damper
- One Wall Centre in Vancouver — It employs tuned liquid column dampers, at the time of its installation, a unique form of tuned mass damper.
- Park Tower in Chicago — The first building in the United States to be designed with a tuned mass damper from the outset.
- Random House Tower Uses two liquid filled dampers in New York City
- Sakhalin-I — An offshore drilling platform
- Shanghai World Financial Center in Shanghai, China
- Taipei 101 skyscraper — Contains one of the world's largest tuned mass damper at 730-tons.[5]
- Trump World Tower in New York
- Yokohama Landmark Tower

External links

- Video of the TMD in Taipei 101 in action [6]
- Structures Incorporating Tuned Mass Dampers [7]
- GERB Vibration Control [8]
- Adjustable tuned mass dampers [9]
- Motioneering Inc [10]

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[3] Item in *New Scientist* (http://www.newscientist.com/backpage.ns?id=mg19626273.000) accessed 7 Nov 2007
[4] http://www.rwdi.com/cms/publications/84/pp_comcast_center.pdf
[5] Taipei 101's 730-Ton Tuned Mass Damper (http://www.popularmechanics.com/technology/industry/1612252.html), *Popular Mechanics*, May 2005.
[6] http://www.youtube.com/watch?v=NYSgd1XSZXc
[7] http://nisee.berkeley.edu/prosys/tuned.html
[8] http://gerb.com/en/arbeitsgebiete/arbeitsgebiete.php?ID=140&kategorie=15
[9] http://www.esm-gmbh.de/eng/Products/tuned_mass_dampers
[10] http://www.motioneering.ca

Turboexpander

A **turboexpander**, also referred to as a **turbo-expander** or an **expansion turbine**, is a centrifugal or axial flow turbine through which a high pressure gas is expanded to produce work that is often used to drive a compressor.[1] [2] [3]

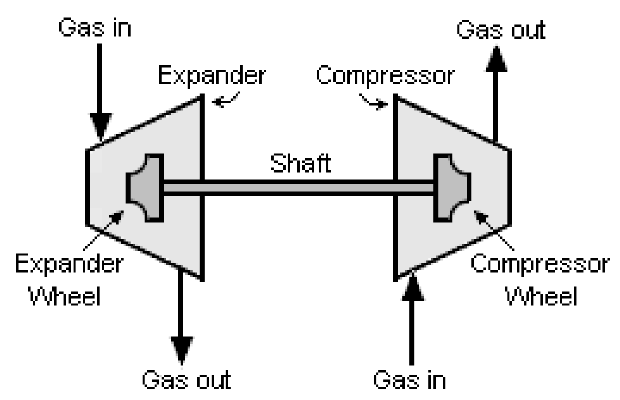

Figure 1: Schematic diagram of a turboexpander driving a compressor.

Because work is extracted from the expanding high pressure gas, the expansion is an isentropic process (i.e., a constant entropy process) and the low pressure exhaust gas from the turbine is at a very low temperature, sometimes as low as −90 °C or less.

Turboexpanders are very widely used as sources of refrigeration in industrial processes such as the extraction of ethane and natural gas liquids (NGLs) from natural gas,[4] the liquefaction of gases (such as oxygen, nitrogen, helium, argon and krypton)[5] [6] and other low-temperature processes.

Turboexpanders currently in operation range in size from about 750 W to about 7.5 MW (1 hp to about 10,000 hp).

Applications

Although turboexpanders are very commonly used in low-temperature processes, they are used in many other applications as well. This section discusses one of the low temperature processes as well as some of the other applications.

Extracting hydrocarbon liquids from natural gas

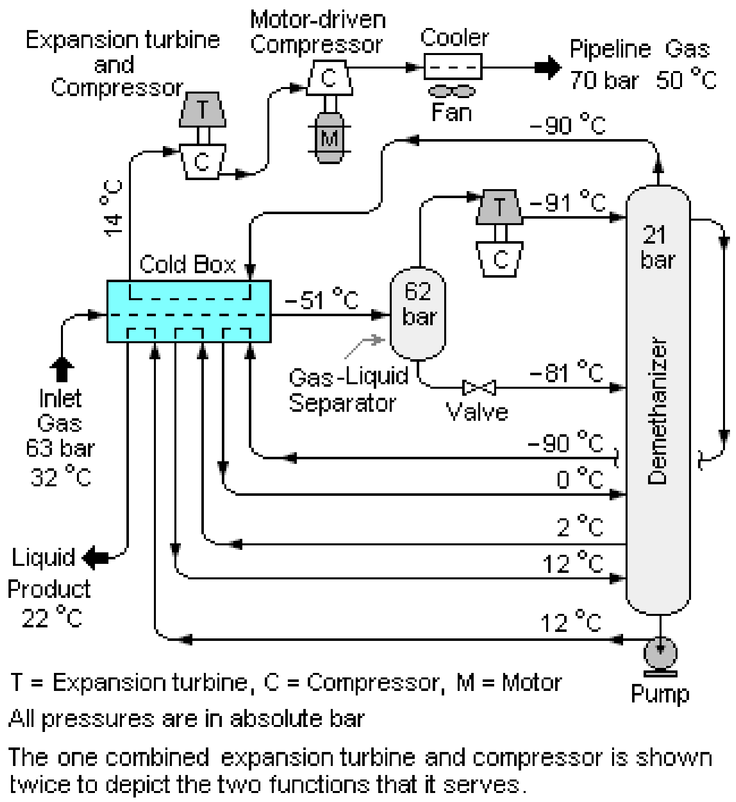

Figure 2: A schematic diagram of a demethanizer extracting hydrocarbon liquids from natural gas.

Raw natural gas consists primarily of methane (CH_4), the shortest and lightest hydrocarbon molecule, as well as various amounts of heavier hydrocarbon gases such as ethane (C_2H_6), propane (C_3H_8), normal butane (n-C_4H_{10}), isobutane (i-C_4H_{10}), pentanes and even higher molecular weight hydrocarbons. The raw gas also contains various amounts of acid gases such as carbon dioxide (CO_2), hydrogen sulfide (H_2S) and mercaptans such as methanethiol (CH_3SH) and ethanethiol (C_2H_5SH).

When processed into finished by-products (see Natural gas processing), these heavier hydrocarbons are collectively referred to as NGL (natural gas liquids). The extraction of the NGL often involves a turboexpander[7] and a low-temperature distillation column (called a *demethanizer*) as shown in Figure 2. The inlet gas to the demethanizer is first cooled to about −51 °C in a heat exchanger (referred to as a *cold box*) which partially condenses the inlet gas. The resultant gas-liquid mixture is then separated into a gas stream and a liquid stream.

The liquid stream from the gas-liquid separator flows through a valve and undergoes a *throttling expansion* from an absolute pressure of 62 bar to 21 bar (6.2 to 2.1 MPa), which is an enthalpic process (i.e., a constant enthalpy process) that results in lowering the temperature of the stream from about −51 °C to about −81 °C as the stream enters the demethanizer.

The gas stream from the gas-liquid separator enters the turboexpander where it undergoes an isentropic expansion from an absolute pressure of 62 bar to 21 bar (6.2 to 2.1 MPa) that lowers the gas stream temperature from about −51 °C to about −91 °C as it enters the demethanizer to serve as distillation reflux.

Liquid from the top tray of the demethanizer (at about −90 °C) is routed through the cold box where it is warmed to about 0 °C as it cools the inlet gas, and is then returned to the lower section of the demethanizer. Another liquid stream from the lower section of the demethanizer (at about 2 °C) is routed through the cold box and returned to the demethanizer at about 12 °C. In effect, the inlet gas provides the heat required to "reboil" the bottom of the demethanizer and the turboexpander removes the heat required to provide reflux in the top of the demethanizer.

The overhead gas product from the demethanizer at about −90 °C is processed natural gas that is of suitable quality for distribution to end-use consumers by pipeline. It is routed through the cold box where it is warmed as it cools the inlet gas. It is then compressed in the gas compressor which is driven by the turbo expander and further compressed in a second-stage gas compressor driven by an electrical motor before entering the distribution pipeline.

The bottom product from the demethanizer is also warmed in the cold box, as it cools the inlet gas, before it leaves the system as NGL.

Power generation

Figure 3 depicts an electric power generation system that uses a heat source, a cooling medium (air, water or other), a circulating working fluid and a turboexpander. The system can accommodate a wide variety of heat sources such as:

- Geothermal hot water
- Exhaust gas from internal combustion engines burning a variety of fuels (natural gas, landfill gas, diesel oil, or fuel oil)
- A variety of waste heat sources (in the form of either gas or liquid)

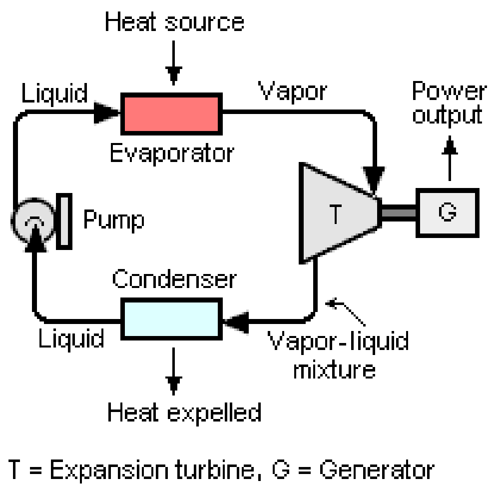

Figure 3: Schematic diagram of power generation system using a turboexpander.

Referring to Figure 3, the circulating working fluid (usually an organic compound such as R-134a) is pumped to a high pressure and then vaporized in the evaporator by heat exchange with the available heat source. The resulting high-pressure vapor flows to the turboexpander where it undergoes an isentropic expansion and exits as a vapor-liquid mixture which is then condensed into a liquid by heat exchange with the available cooling medium. The condensed liquid is pumped back to the evaporator to complete the cycle.

The system in Figure 3 is a Rankine cycle as is used in fossil fuel power plants where water is the working fluid and the heat source is derived from the combustion of natural gas, fuel oil or coal used to generate high-pressure steam. The high-pressure steam then undergoes an isentropic expansion in a conventional steam turbine. The steam turbine exhaust steam is next condensed into liquid water which is then pumped back to steam generator to complete the cycle.

When an organic working fluid such as R-134a is used in the Rankine cycle, the cycle is sometimes referred to as an Organic Rankine Cycle (ORC). [8] [9] [10]

Refrigeration system

Figure 4 depicts a refrigeration system with a capacity of about 100 to 1000 tons of refrigeration (i.e., 352 to 3,520 kW). The system utilizes a compressor, a turboexpander and an electric motor.

Depending on the operating conditions, the turboexpander reduces the load on the electric motor by some 6 to 15% as compared to a conventional vapor-compression refrigeration system that uses a *throttling expansion* valve rather than a turboexpander.[11]

The system employs a high-pressure refrigerant (i.e., one with a low normal boiling point) such as:[11]

- Chlorodifluoromethane ($CHClF_2$) known as R-22, with a normal boiling point of −47 °C
- 1,1,1,2 Tetrafluoroethane ($C_2H_2F_4$) known as R-134a, with a normal boiling point of −26 °C.

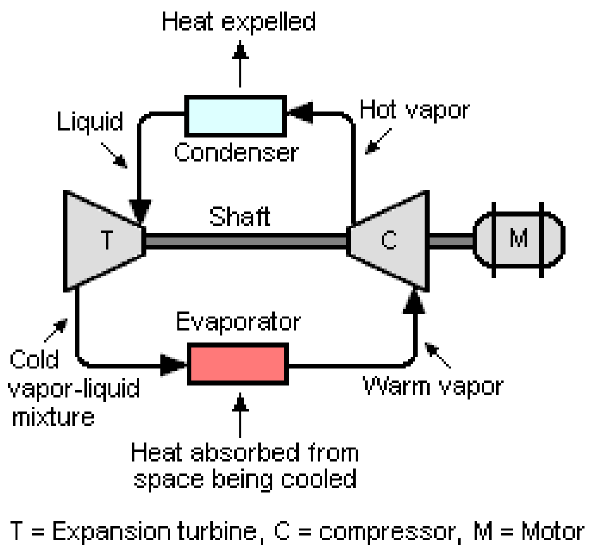

Figure 4: Schematic diagram of a refrigeration system using a turboexpander, compressor and a motor.

As shown in Figure 4, refrigerant vapor is compressed to a higher pressure resulting in a higher temperature as well. The hot, compressed vapor is then condensed into a liquid. The condenser is where heat is expelled from the circulating refrigerant and is carried away by whatever cooling medium is used in the condenser (air, water, etc.).

The refrigerant liquid flows through the turboexpander where it is vaporized and the vapor undergoes an isentropic expansion which results in a low-temperature mixture of vapor and liquid. The vapor-liquid mixture is then routed through the evaporator where it is vaporized by heat absorbed from the space being cooled. The vaporized refrigerant flows to the compressor inlet to complete the cycle.

Power recovery in fluid catalytic cracker

The combustion flue gas from the catalyst regenerator of a fluid catalytic cracker is at a temperature of about 715 °C and at a pressure of about 2.4 barg (240 kPa gauge). Its gaseous components are mostly carbon monoxide (CO), carbon dioxide (CO_2) and nitrogen (N_2). Although the flue gas has been through two stages of cyclones (located within the regenerator) to remove entrained catalyst fines, it still contains some residual catalyst fines.

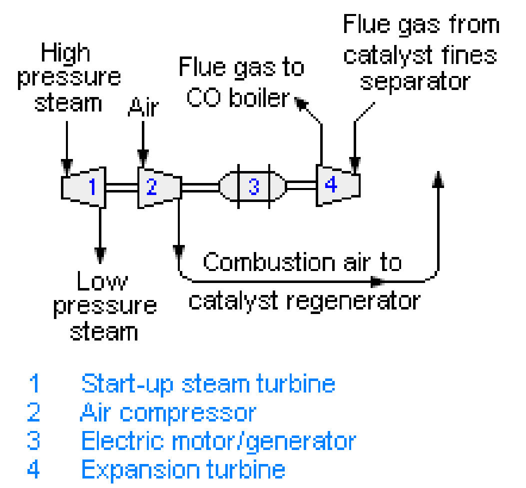

Figure 5: A schematic diagram of the power recovery system in a fluid catalytic cracking unit.

Figure 5 depicts how power is recovered and utilized by routing the regenerator flue gas through a turboexpander. After the flue gas exits the regenerator, it is routed through a secondary catalyst separator containing *swirl tubes* designed to remove 70 to 90 percent of the residual catalyst fines.[12] This is required to prevent erosion damage to the turboexpander.

As shown in Figure 5, expansion of the flue gas through a turboexpander provides sufficient power to drive the regenerator's combustion air compressor. The electrical motor-generator in the power recovery system can consume or produce electrical power. If the expansion of the flue gas does not provide enough power to drive the air compressor, the electric motor-generator provides the needed additional power. If the flue gas expansion provides more power than needed to drive the air compressor, than the electric motor-generator converts the excess power into electric power and exports it to the refinery's electrical system.[13] The steam turbine shown in Figure 5 is used to drive the regenerator's combustion air compressor during start-ups of the fluid catalytic cracker until there is sufficient combustion flue gas to take over that task.

The expanded flue gas is then routed through a steam-generating boiler (referred to as a *CO boiler*) where the carbon monoxide in the flue gas is burned as fuel to provide steam for use in the refinery.[13]

The flue gas from the CO boiler is processed through an electrostatic precipitator (ESP) to remove residual particulate matter. The ESP removes particulates in the size range of 2 to 20 micrometers from the flue gas.[13]

History

The possible use of an expansion machine for isentropically creating low temperatures was suggested by Carl Wilhelm Siemens (Siemens cycle), a German engineer in 1857. About three decades later, in 1885, Ernest Solvay of Belgium attempted to use a reciprocating expander machine but could not attain any temperatures lower than −98 °C because of problems with lubrication of the machine at such temperatures.[2]

In 1902, Georges Claude, a French engineer, successfully used a reciprocating expansion machine to liquefy air. He used a degreased, burnt leather packing as a piston seal without any lubrication. With an air pressure of only 40 bar (4 MPa), Claude achieved an almost

isentropic expansion resulting in a lower temperature than had before been possible.[2]

The first turboexpanders seem to have been designed in about 1934 or 1935 by Guido Zerkowitz, an Italian engineer working for the German firm of Linde AG.[14] [15]

In 1939, the Russian physicist Pyotr Kapitsa perfected the design of centrifugal turboexpanders. His first practical prototype was made of Monel metal, had an outside diameter of only 8 cm (3.1 in), operated at 40,000 revolutions per minute and expanded 1,000 cubic metres of air per hour. It used a water pump as a brake and had an efficiency of 79 to 83 percent.[2] [15] Most turboexpanders in industrial use since then have been based on Kapitsa's design and centrifugal turboexpanders have taken over almost 100 percent of the industrial gas liquefaction and low temperature process requirements.[2] [15]

In 1978, Pyotr Kapitsa was awarded a Nobel physics prize for his body of work in the area of low-temperature physics.[16]

See also

- Flash evaporation
- Gas
- Gas compressor
- Joule-Thomson effect
- Liquefaction of gases
- Rankine cycle
- Steam turbine
- Vapor-compression refrigeration

External links

- Use of Expansion Turbines in Natural Gas Pressure Reduction Stations [17]
- Full load, full speed test of turboexpander-compressor with active magnetic bearings [18]
- Low-Temperature Geothermal Power Generation with HVAC Hardware [19]
- R&D Dynamics foil bearing turboexpander [20]
- S2M magnetic bearing turboexpander [21]

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[19] http://www.smu.edu/geothermal/Oil&Gas/2007/Dickey_Halley%20Future%20of%20Field%20Installations%20UTC%20Power.pdf

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Turbomachinery

In → mechanical engineering, **turbomachinery** describes machines that transfer energy between a rotor and a fluid, including both turbines and compressors. While a turbine transfers energy from a fluid to a rotor, a compressor transfers energy from a rotor to a fluid. The two types of machines are governed by the same basic relationships including Newton's second law of motion and Euler's energy equation for compressible fluids. Centrifugal pumps are also turbomachines that transfer energy from a rotor to a fluid, usually a liquid, while turbines and compressors usually work with a gas.

Translated from German wikipedia by google translate

A flow machine is generally a fluid energy machine, which operates continuously, ie a static pressure difference between inlet and outlet on or degrades. At any point in the engine exists regardless of the time a thermodynamic state. It differs from the piston machine in which this pressure difference changes periodically. Strömungsmaschinen are usually Turbomaschinen. A flow machine, which operates discontinuously, the Savonius rotor.

Classification of Fluid Machinery in species and groups

Machine type → Group ↓	**Machinery**	**Combinations of Power and machinery**	**Engines**
Housing turbomachine	Propeller		Repeller
Hydraulic Fluid Machinery (≈ incompressible Fluids)	Centrifugal Pumps Turbopumps and Fans	Foettinger converters and clutches (hydrodynamic gearbox) or Pump-turbines (In a pumped storage)	Water turbines
Thermal Turbomachinery (compressible Fluid)	Compressors	(Gas turbines) (Receipt of GT consists of a compressor)	Steam Turbines ← Turbine Jet engines

Note: Known colloquially as the "fan" named Appliances are in the above table as a prop to find because they are out of a grid (as a protection against injury) does not have housing. Stand or tower fans are centrifugal fans, however, with housing and therefore in the table as fans to find.

Dimensionless ratios to describe turbomachinery

The following dimensionless ratios are often used for the characterization of fluid machines. They allow a comparison of flow machines with different dimensions and boundary conditions.

1. Pressure range ψ
2. Flow number φ (including delivery or volume number called)
3. Performance numbers λ
4. Run number σ
5. Diameter Number δ

See also

- Secondary flow in turbomachinery

External links

- Hydrodynamics of Pumps [1]
- Turbomachinery design and development [1]
- Designing Turbomachinery Flow Path [2]

[3] ==References==

[1] http://caltechbook.library.caltech.edu/22/01/pumps.htm
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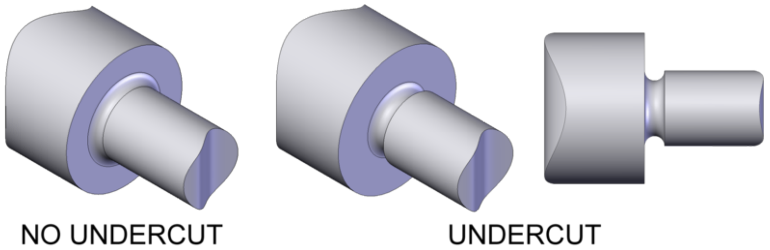
Undercut (manufacturing)

In manufacturing, an **undercut** is a special type of recessed surface. In turning it refers to a recess in a diameter. In machining it refers to a recess in a corner. In molding it refers to a feature that cannot be molded using only a single pull mold. In printed circuit board construction it refers to the portion of the wafer that is etched away under the photoresist.

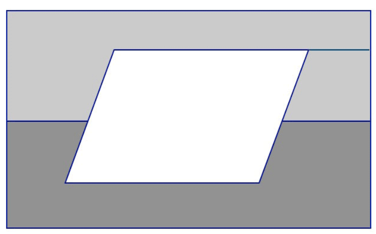
Turning



An example of a turned part with and without an undercut

On turned parts an undercut is also known as a *neck*. They are often used at the end of the threaded portion of a shaft or screw to provide clearance for the cutting tool. For proper usage the undercut should be at least 1.5 threads long and the diameter should be at least 0.015 in (0.38 mm) smaller than the minor diameter of the thread.[1] They are also often used on shafts that have diameter changes so that a mating part can seat against the shoulder. If an undercut is not provided there is always a small radius left behind even if a sharp corner is intended. These type of undercuts are called out on technical drawings by stating the width and either the depth or the diameter of the bottom of the neck.[2]

Molding

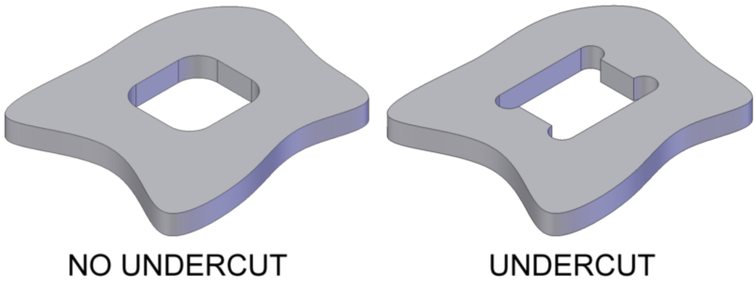

A simple example of molding an external undercut

Undercuts on molded parts are features that prevent the part from being directly ejected from the injection molding machine. They are categorized into *internal* and *external* undercuts, where external undercuts are on the exterior of the part and interior undercuts are on the inside of the part. Undercuts can still be molded, but require a *side action* or *side pull*.[3] This is an extra part of the mold that moves separately from the two halves. These can add 15 to 30% to the cost of the mold and also increase the cost of the molded part.[3] [4]

If the size of the undercut is small enough and the material is flexible enough a side action is not always required. In these cases the undercut is stripped or snapped out of the mold. When this is done usually a stripping plate or ring is used instead of stripper pins so that the part is not damaged. This technique can be used on internal and external undercuts.[3]

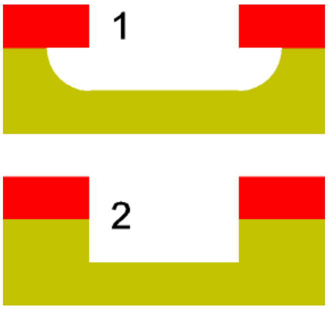
Machining

In machining the corners may be undercut to remove the radius that is usually left by the milling cutter. Examples of this use are linear bearings for square shafts (i.e. racks) and machined hexalobular sockets.



An example of a machining undercut

Etching



1. An isotropic etchant that creates an undercut
2. An anisotropic etchant leaves no undercut

Undercuts from etching are somewhat different than the undercuts explained above, because it is a side effect, not an intentional feature. Undercuts from etching can occur from two common causes. The first is over etching, which means the etchant was applied too long. The second is due to an isotropic etchant, which means the etchant etches in all directions equally. To overcome this problem an anisotropic etchant is used.[5]

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[1] " Thread relief and chamfers (http://www.pmpa.org/technology/design/threadrelief.htm)". *PMPA's Designer's Guide*. Precision Machined Products Assocation. . Retrieved 2009-07-19.
[2] Taylor 2004, p. 194.
[3] Berins & Society of the Plastics Industry 1991, pp. 325–326.
[4] Rosato et al. 2001, pp. 1405–1406.
[5] Degarmo, Black & Kohser 2003, p. 897.

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Units conversion by factor-label

Many, if not most, parameters and measurements in the physical sciences and engineering are expressed as a numerical quantity and a corresponding dimensional unit; for example: 1000 kg/m³, 100 kPa/bar, 50 miles per hour, 1000 Btu/lb. Converting from one dimensional unit to another is often somewhat complex and being able to perform such conversions is an important skill to acquire. The **factor-label method**, also known as the **unit-factor method** or **dimensional analysis**, is a widely used approach for performing such conversions.[1] [2] [3] It is also used for determining whether the two sides of a mathematical equation involving dimensions have the same dimensional units.

The factor-label method for converting units

The factor-label method is the sequential application of conversion factors expressed as fractions and arranged so that any dimensional unit appearing in both the numerator and denominator of any of the fractions can be cancelled out until only the desired set of dimensional units is obtained. For example, 10 miles per hour can be converted to meters per second by using a sequence of conversion factors as shown below:

```
10 mile   1609 meter      1 hour           meter
-- ---- × ---- ----- × ---- ------  = 4.47 ------
 1 hour      1 mile    3600 second         second
```

It can be seen that each conversion factor is equivalent to the value of one. For example, starting with 1 mile = 1609 meters and dividing both sides of the equation by 1 mile yields 1 = 1609 meters / 1 mile.

So, when the units *mile* and *hour* are cancelled out and the arithmetic is done, 10 miles per hour converts to 4.47 meters per second.

As a more complex example, the concentration of nitrogen oxides (i.e., NOx) in the flue gas from an industrial furnace can be converted to a mass flow rate expressed in grams per hour (i.e., g/h) of NOx by using the following information as shown below:

NOx concentration

= 10 parts per million by volume = 10 ppmv = 10 volumes/10^6 volumes

NOx molar mass

= 46 kg/kgmol (sometimes also expressed as 46 kg/kmol)

Flow rate of flue gas

= 20 cubic meters per minute = 20 m³/min

The flue gas exits the furnace at 0 °C temperature and 101.325 kPa absolute pressure.

The molar volume of a gas at 0 °C temperature and 101.325 kPa is 22.414 m³/kgmol.

```
10  m³ NOx   20 m³ gas   60 minute   1      kgmol NOx   46 kg NOx
1000 g          g NOx
--- ------ × -- ------ × -- ------ × ------ --------- × -- --------- ×
---- -- = 24.63 -----
10^6 m³ gas    1 minute    1 hour     22.414 m³ NOx       1 kgmol NOx
      1 kg         hour
```

After cancelling out any dimensional units that appear both in the numerators and denominators of the fractions in the above equation, the NOx concentration of 10 ppm_v converts to mass flow rate of 24.63 grams per hour.

Checking equations that involve dimensions

The factor-label method can also be used on any mathematical equation to check whether or not the dimensional units on the left hand side of the equation are the same as the dimensional units on the right hand side of the equation. Having the same units on both sides of an equation does not guarantee that the equation is correct, but having different units on the two sides of an equation does guarantee that the equation is wrong.

For example, check the Universal Gas Law equation of $P \cdot V = n \cdot R \cdot T$, when:

- the pressure P is in pascals (Pa)
- the volume V is in cubic meters (m^3)
- the amount of substance n is in moles (mol)
- the universal gas law constant R is 8.3145 Pa·m^3/(mol·K)
- the temperature T is in kelvins (K)

(Pa) (m^3) = (~~mol~~) [(Pa·m^3) / (~~mol~~ · ~~K~~)] (~~K~~)

As can be seen, when the dimensional units appearing in the numerator and denominator of the equation's right hand side are cancelled out, both sides of the equation have the same dimensional units.

Limitations

The factor-label method can convert only unit quantities for which the units are in a linear relationship intersecting at 0. Most units fit this paradigm. An example for which it cannot be used is the conversion between degrees Celsius and kelvins (or Fahrenheit). Between degrees Celsius and kelvins, there is a constant difference rather than a constant ratio, while between Celsius and Fahrenheit there is both a constant difference and a constant ratio. Instead of multiplying the given quantity by a single conversion factor to obtain the converted quantity, it is more logical to think of the original quantity being divided by its unit, being added or subtracted by the constant difference, and the entire operation being multiplied by the new unit. Mathematically, this is an affine transform ($ax + b$), not a linear transform (ax). Formally, one starts with a displacement (in some units) from one point, and ends with a displacement (in some other units) from some other point.

For instance, the freezing point of water is 0 in Celsius and 32 in Fahrenheit, and a 5 degrees change in Celsius correspond to a 9 degrees change in Fahrenheit. Thus to convert from Fahrenheit to Celsius one subtracts 32 (displacement from one point), divides by 9 and multiplies by 5 (scales by the ratio of units), and adds 0 (displacement from new point). Reversing this yields the formula for Celsius; one could have started with the equivalence between 100 Celsius and 212 Fahrenheit, though this would yield the same formula at the end.

See also

- Conversion of units
- Dimensional analysis
- ISO 31
- Units of measurement

External links

- Unicalc Live web calculator doing units conversion by dimensional analysis [4]
- Math Skills Review [5]
- U.S. EPA tutorial [6]
- A Discussion of Units [7]
- Short Guide to Unit Conversions [8]
- Cancelling Units Lesson [9]
- Chapter 11: Behavior of Gases [10] *Chemistry: Concepts and Applications*, Denton Independent School District
- Air Dispersion Modeling Conversions and Formulas [11]

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[2] James Ogden (1999). *The Handbook of Chemical Engineering*. Research & Education Association. ISBN 0-87891-982-1.
[3] Dimensional Analysis or the Factor Label Method (http://www.kentchemistry.com/links/Measurements/dimensionalanalysis.htm)
[4] http://www.calchemy.com/uclive.htm
[5] http://www.chem.tamu.edu/class/fyp/mathrev/mr-da.html
[6] http://www.epa.gov/eogapti1/toc/full_toc.htm
[7] http://www.ncsu.edu/felder-public/kenny/papers/units.html
[8] http://www.astro.yale.edu/astro120/unitconv.pdf
[9] http://www.purplemath.com/modules/units.htm
[10] http://www.dentonisd.org/512125919103412/lib/512125919103412/_files/chemChap11.pdf
[11] http://www.air-dispersion.com/formulas.html

VOICED

Virtual Organization for Innovative Conceptual Engineering Design (**VOICED**) is a virtual organization that promotes innovation in engineering design. This project is the collaborative work of researchers at five universities across the United States, and is funded by the National Science Foundation. The goal of this virtual organization is to facilitate the sharing of design information between often geographically dispersed engineers and designers through the use of a robust and sophisticated design repository. Additionally, functional data can be mapped to historical failure data[1] and possible components[2] to create a conceptual design.

The end goal is to turn VOICED into a tool that allows engineers to create conceptual designs based on archived designs and detect failures in those design through an open design repository (Tumer & Stone, n.d.). VOICED is a fairly new organization, being about 3–4 years old, however the concepts that underlie the organization have been under development for much longer[3] .

Universities

- Oregon State University
- Missouri University of Science and Technology
- Penn State
- University of Texas
- Texas A&M University

Software

- Design Engineering Lab [4]
- FunctionCAD [5] is an open source application used for the visual representation of functional models.

See also

- Open Design

References

[1] R.B. Stone, I.Y. Tumer, and M.E. Stock, “Linking product functionality to historic failures to improve failure analysis in design,” Research in Engineering Design, vol. 16, 2005, pp. 96-108.
[2] *R.B. Stone and K.L. Wood, “Development of a Functional Basis for Design,” Journal of Mechanical Design, vol. 122, Dec. 2000, pp. 359-370.
[3] http://voiced.device.mst.edu
[4] http://designengineeringlab.org
[5] http://function.device.mst.edu:16080/FunctionCAD/

- http://www.p2pfoundation.net/VOICED

Variable air volume

Variable air volume (**VAV**) is a technique for controlling the capacity of a heating, ventilating, and/or air-conditioning (HVAC) system. The simplest VAV system incorporates one supply duct that, when in cooling mode, distributes approximately 55 °F (13 °C) supply air. Because the supply air temperature, in this simplest of VAV systems, is constant, the air flow rate must vary to meet the rising and falling heat gains or losses within the thermal zone served.

There are two primary advantages to VAV systems. The fan capacity control, especially with modern electronic variable speed drives, reduces the energy consumed by fans which can be a substantial part of the total cooling energy requirements of a building. Dehumidification is greater with VAV systems than it is with constant volume system which modulate the discharge air temperature to attain part load cooling capacity.

The air blower's flow rate is variable. For a single VAV → air handler that serves multiple thermal zones, the flow rate to each zone must be varied as well.

A VAV **terminal unit**[1] , often called a *VAV box*, is the zone-level flow control device. It is basically a quality, calibrated air damper with an automatic actuator. The VAV terminal unit is connected to either a local or a central control system. Historically, pneumatic control was commonplace, but electronic *direct digital control systems* are popular especially for mid-to-large size applications. Hybrid control, for example having pneumatic actuators with digital data collection, is popular as well.

Control of the system's fan capacity is critical in VAV systems. Without proper and rapid flow rate control, the system's ductwork, or its sealing, can easily be damaged by overpressurization.

While invented earlier, Tempmaster Corporation of Kansas City, Missouri is credited with perfecting early VAV technology. The VAV flow control loop (actuator, flow control loop, and differential pressure sensor) is the heart of the technology and several product innovations were introduced by Kreuter Manufacturing Corp., now KMC Controls [2].

See also

- HVAC
- ASHRAE
- SMACNA
- BACnet
- LonWorks
- → Constant air volume
- Intelligent buildings

References

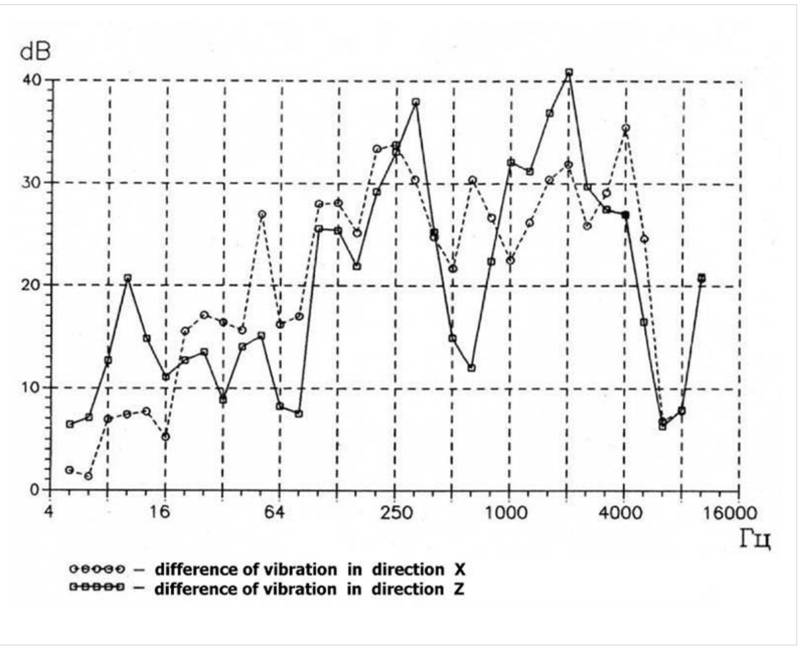
[1] Systems and Equipment volume of the *ASHRAE Handbook*, ASHRAE, Inc., Atlanta, GA, 2004
[2] http://www.kmccontrols.com

Vibration isolation

Vibration isolation is the process of isolating an object, such as a piece of equipment, from the source of vibrations.

Passive isolation

Passive vibration isolation systems consist essentially of a mass, spring and damper (dash-pot).



The equipment and gears have joint with surrounding objects (the supporting joint - with the support; the unsupporting joint - the pipe duct or cable).

Vibration-isolation of supporting joint

Vibration-isolation of supporting joint is realized in the device named vibration-isolator (absorber). On an illustration presented dependence of difference is levels of vibrations which are measured before installation of the functioning gear on vibration-isolator and after installation in a wide range of frequencies.

Vibration-isolator

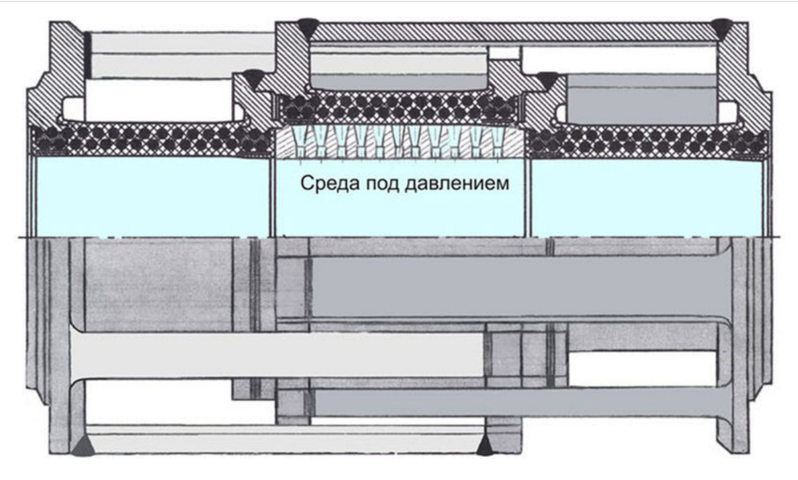
Vibration-isolator – vibration- isolating device for reflection and absorption of waves of oscillatory energy, extending from the working gear or an electrical equipment, with the aid of effect of a vibration insulation. Vibration-isolator is established between a body transferring fluctuations and a body which defend (for example, between the gear and the foundation). On an illustration is presented the

image vibration-isolator a series "ВИ" which are applied in shipbuilding of Russia. Shown "ВИ" allow loadings 5, 40 and 300 kg. They differ in the sizes, but have a similar structure . In a structure is used the rubber envelope, which is reinforced by a spring. Rubber and a spring are strongly connected during transformation of crude rubber into rubber envelope by a method of vulcanization. Under action of weight loading of the gear the rubber envelope is of deformation , and a spring are compressed or stretch. Thus, in springs cross section, occurs the twig twist with a material of rubber envelope, causing deformation of shift in rubber envelope. It is known, that the vibration insulation basically cannot be carried out without presence of vibration absorption . The size of deformation of shift in elastic material of isolator- vibration it basis for definition of size of absorption of fluctuations. At action of vibration or shock loadings of deformation increase. Being thus cyclic, it considerably strengthens efficiency of the given device. In the upper part of a design the sleeve, and in the lower part a flange by means of which the vibration-isolator fastens to the gear and the foundation.

Vibration-isolation of unsupporting joint

Vibration-isolation of unsupporting joint is realized in the device named branch pipe a of vibration-isolating.

A vibration-isolating branch pipe



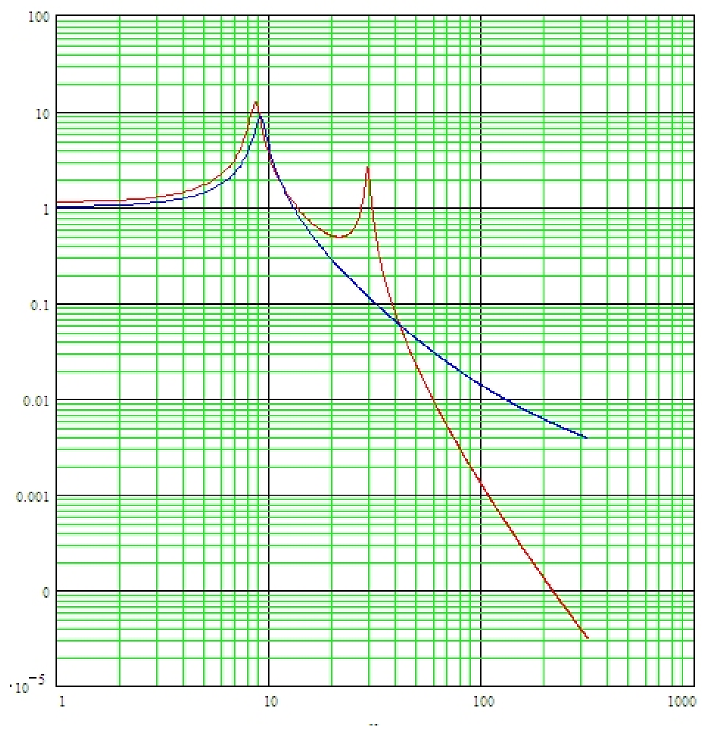
A vibration-isolating branch pipe is a part of a tube with elastic walls for reflection and absorption of waves of the oscillatory energy extending from the working pump over wall of the pipe duct. Is established between the pump and the pipe duct. On an illustration is presented the image a vibration-isolating branch pipe of a series "ВИПБ" . In a structure is used the rubber envelope, which is reinforced by a spring. Properties of a envelope are similar envelope to a vibration-isolator. Has the device reducing axial effort from action of internal pressure up to zero.

Active isolation

Active vibration isolation systems contain, along with the spring, a feedback circuit which consists of a piezoelectric accelerometer, a controller, and an electromagnetic transducer. The acceleration (vibration) signal is processed by a control circuit and amplifier. Then it feeds the electromagnetic actuator, which amplifies the signal. As a result of such a feedback system, a considerably stronger suppression of vibrations is achieved compared to ordinary damping.

Subframe isolation

Another technique used to increase isolation is to use an isolated subframe. This splits the system with an additional mass/spring/damper system. This doubles the high frequency attenuation rolloff, at the cost of introducing additional low frequency modes which may cause the low frequency behaviour to deteriorate. This is commonly used in the rear suspensions of cars with Independent Rear Suspension (IRS), and in the front subframes of some cars. The graph *(see illustration)* shows the force into the body for a subframe that is rigidly bolted to the body compared with the red curve that shows a compliantly mounted subframe. Above 42 Hz the compliantly mounted subframe is superior, but below that frequency the bolted in subframe is better.



Subframe vibration isolation graph: force transmission on suspended body vs. frequency for rigidly and compliantly mounted subframes.

See also

- Shock absorber
- Vibration
- Noise, Vibration, and Harshness
- Base isolation
- Vibration control
- Oscillation

References

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- A.Kolesnikov «Noise and vibration». Russia. Leningrad. Publ.«Shipbuilding». 1988

External links

- "Selecting a vibration/shock isolator" [1]PDF (372 KiB) at Lord Corporation
- "Vibration isolation is the key to accuracy" [2] article at EngineeringTalk.com

References

[1] http://www.lord.com/Portals/0/VibrationMotionNoise/selecting_a_vibration_shock_isolator.pdf
[2] http://www.engineeringtalk.com/news/mqp/mqp100.html

Victaulic

Victaulic is the world's largest developer and producer of mechanical pipe joining systems. They offer a wide range of products including couplings, fittings, sprinklers, fire safety devices, and pipe preparation tools.

Victaulic was founded in 1925 in New York City. The company is currently headquartered in Easton, PA and employs more than 3500 people world-wide. They operate the largest non-ferrous foundry in Canada, producing bronze, brass, aluminum, nickel-copper, high conductivity copper, and other metals.

In 2008, Victaulic was awarded a bronze medal in Plant Engineering's "2008 Product of the Year" contest for its Vortex Fire Suppression System.[1]

See also

- Active fire protection
- Mechanical Engineering
- Plumbing

References

http://www.victaulic.com/content/CorporateHistory.htm

[1] http://www.plantengineering.com/article/191096-Orion_Energy_Systems_wins_Product_of_the_Year_Grand_Award.php

External links

- Official homepage (http://www.victaulic.com/)

Water Pinch

Water Pinch Analysis (WPA) originates from the concept of heat → pinch analysis. WPA is a systematic technique for reducing water consumption and wastewater generation through integration of water-using activities or processes. WPA was first introduced by Wang and Smith[1] . Since then, it has been widely used as a tool for water conservation in industrial process plants. Water Pinch Analysis has recently been applied for urban/domestic buildings[2] .

Techniques for setting targets for maximum water recovery capable of handling any type of water-using operation including mass-transfer-based and non-mass-transfer based systems include the source and sink composite curves and water cascade analysis[3] . The source and sink composite curves is a graphical tool for setting water recovery targets as well as for design of water recovery networks [4] .

See also

- Cost effective minimum water network
- Water management hierarchy
- Reclaimed water

References

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[2] Manan, Z. A., Wan Alwi, S. R. and Ujang Z. (2006). Water pinch analysis for urban system: a case study on the Sultan Ismail Mosque at Universiti Teknologi Malaysia (UTM) . Desalination. 194: 52-68.
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[4] Wan Alwi, S. R. and Manan, Z. A. (2008). Generic Graphical Technique for Simultaneous Targeting and Design of Water Networks . Ind. Eng. Chem. Res. 47 (8): 2762-2777. DOI:10.1021/ie071487o.

Water chiller

A **water chiller**[1] is a mechanical device used to facilitate heat exchange from water to a refrigerant in a closed loop system. The refrigerant is then pumped to a location where the waste heat is transferred to the atmosphere.

In hydroponics, pumps, lights and ambient heat can warm the reservoir water temperatures, leading to plant root and health problems. For ideal plant health, a chiller can be used to lower the water temperature below ambient level; 68°F (20°C) is a good temperature for most plants. This results in healthy root production.

In air conditioning, → chilled water is often used to cool a building's air and equipment, especially in situations where many individual rooms must be controlled separately, such as a hotel. A chiller lowers water temperature to between 40° and 45°F before the water is pumped to the location to be cooled.[2]

See also

- Gardening

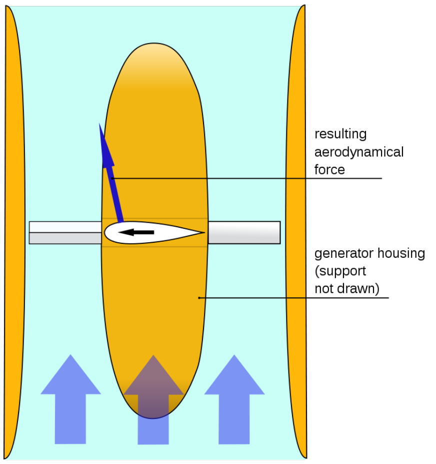
References

External links

References

[1] Birnbaum H, 2007. Homegrown Hydroponics
[2] How Stuff Works: How Air Conditioners Work-Chilled-water and Cooling-tower AC Units (http://home.howstuffworks.com/ac4.htm)

Wells turbine



Wells Turbine, Schematic Diagram

The **Wells turbine** is a low-pressure air turbine developed for use in oscillating-water-column wave power plants to avoid the need to rectify the air stream by delicate and expensive valve systems.

It keeps its sense of rotation in spite of the changing direction of the air stream, which is driven by the rising and falling water surface in a compression chamber. Its blades feature a symmetrical airfoil with its plane of symmetry in the plane of rotation and perpendicular to the air stream.

Its efficiency is lower than that of a turbine with constant air stream direction and asymmetric airfoil. One reason is that symmetric airfoils have a higher drag coefficient than asymmetric ones, even under optimal conditions. Also, in the Wells turbine, the symmetric airfoil is used with a high angle of attack (i.e., low blade speed / air speed ratio), as it occurs during air velocity maxima in volatile flow. Then the air stream stalls and lift collapses. The efficiency of the Wells turbine in oscillating flow reaches values between 0.4 and 0.7.

Another disadvantage is the absence of self-starting capability. For starting, the generator has to be used as a motor, which consumes energy.

This simple but ingenious device was developed by Prof. Alan Wells of Queen's University Belfast in the late 1980s.

Annotation

Another solution of the problem of stream direction independent turbine is the Darrieus rotor.

See also

- Siadar Wave Energy Project

External links

- about wave power generation in general with part on wells turbine [1] **(German)**
- Animation showing OWC wave power plant" [2]

References

[1] http://www.uni-leipzig.de/~grw/lit/texte_099/59__1999/59_1999_hansa.htm
[2] http://www.archipelago.co.uk/our-work/wave-power-animation

West number

The **West number** is an empirical parameter used to characterize the performance of **Stirling engines**, and other Stirling systems. It is very similar to the → Beale number where a larger number indicates higher performance; however, the West number includes temperature compensation. The West number is often used to approximate of the power output of a Stirling engine. The average value is (0.25) [2] for a wide variety of engines, although it may range up to (0.35) [1], particularly for engines operating with a high temperature differential.

The West number may be defined as:

$$W_n = \frac{Wo}{PVf}\frac{(T_H + T_K)}{(T_H - T_K)} = B_n\frac{(T_H + T_K)}{(T_H - T_K)}$$

where:

- $\mathbf{W_n}$ is the West number
- $\mathbf{W_o}$ is the power output of the engine (watts)
- **P** is the mean average gas pressure (Pa) or (MPa, if volume is in cm^3)
- **V** is swept volume of the expansion space (m^3) or (cm^3, if pressure is in MPa)
- **f** is the engine cycle frequency (Hz)
- $\mathbf{T_H}$ is the absolute temperature of the expansion space or heater (kelvin)
- $\mathbf{T_K}$ is the absolute temperature of the compression space or cooler (kelvin)
- $\mathbf{B_n}$ is the → Beale number for an engine operating between temperatures T_H and T_K

When the Beale number is known, but the West number is not known, it is possible to calculate it. First calculate the West number at the temperatures T_H and T_K for which the Beale number is known, and then use the resulting West number to calculate output power for other temperatures.

To estimate the power output of a new engine design, nominal values are assumed for the West number, pressure, swept volume and frequency, and the power is calculated as follows:

$$W_o = W_n PVf\frac{(T_H - T_K)}{(T_H + T_K)}$$ [1]

For example, with an absolute temperature ratio of 2, the portion of the equation representing temperature correction equals 1/3. With a temperature ratio of 3, the temperature term is 1/2. This factor accounts for the difference between the West equation, and the Beale equation in which this temperature term is taken as a constant. Thus, the Beale number is typically in the range of 0.10 to 0.15, which is about 1/3 to 1/2 the value of the West number.

External links

- Stirling Engine Performance Calculator [1]

References

[1] ornl-tm-10475 (http://www.ornl.gov/~webworks/cppr/y2001/rpt/27113.pdf)

Woodruff key

A **Woodruff key** or half-moon key, is a semicircular shaped, removable key that fits into a matching keyway cut into a shaft, leaving a protruding tab. The tab mates with a matching slot on a device mounted flush upon the shaft e.g. a pulley, thus preventing the device from freely rotating about the shaft. It is widely used in machine tools and in the automotive industry.

The main advantage of the Woodruff key is that avoids the milling of a keyslot near stress-concentration prone shaft shoulders. [1]

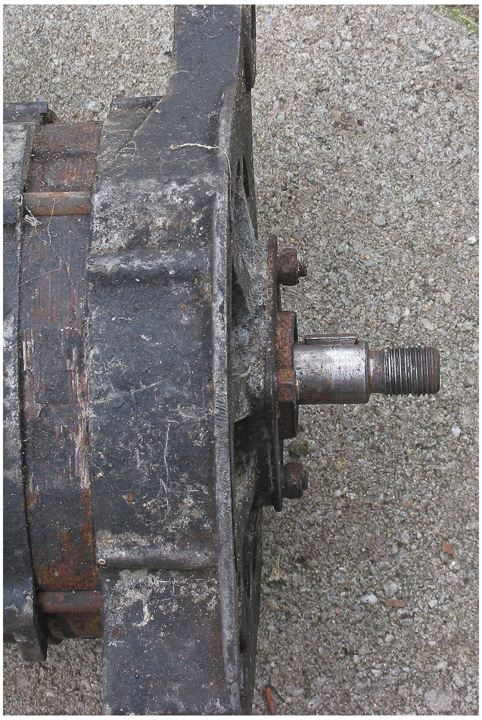
This type of key was developed by W.N Woodruff of Connecticut, who was presented in 1888 with the John Scott Medal by the Franklin Institute for the invention.[2]

See also

- Keyway (engineering)
- Rotating spline

External links

- Illustration of a typical automotive woodruff key application [3] mating a gear to a camshaft.



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[3] http://www.google.co.uk/books?id=G95OZImrmZQC&pg=PT210&dq=%22woodruff+key%22&as_brr=1&sig=xJBVazM1guxlYEpBXDop6Elsxd8

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