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Examination of 3D Manufactured Alloys and Materials for High-performance Drilling and Oilfield Service Tools

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Additive manufacturing or 3D printing is a quickly maturing area that has shown rapid progress over the past few years. It is now possible to produce 3D printed objects directly from a computer aided design (CAD) file, with exceptionally high fidelity and precision. While the process is improving, there is no guarantee that a printed model is structurally sound. We have evaluated resulting microstructures of the produced alloys to show some of the abnormalities present.

This presentation will cover examination by optical microscopy (OM), scanning electron microscopy (SEM) and other non-destructive analytical techniques such as color 3D laser scanning confocal microscopy (LSCM)) as investigative tools for 3D alloy development. The results of these studies will assist in the development of materials for innovative tools as well as continuous improvements in manufacturing and drilling. We have examined the Ti6Al-4V alloy development using 3D printing technology.

Figure 1 illustrates the pre-alloyed powder utilized in this study for laser sintering showing the sizes and distributions. As-received laser sintered and secondary processed (such as hot isostatic pressing) components, see Figure 2, are examined under microscope to evaluate the whole development process.

The results show that, for as-laser sintered material, some areas of the samples had void regions of partially "melted" and structurally weak bonds. Porosity and inclusions are present in all direction of produced materials [1-4]. It also shows the directional grain of the as-laser sintered microstructure. The porosity is significantly reduced by hot isostatic pressing (HIP). HIP also produces the desired microstructure of the alloy. The details of our investigation will be discussed.

OM requires the artful polishing and selective (chemical or electrochemical) etching of microstructures. This is illustrated in Figures 3-5 as progression from high porosity toward low porosity and high-quality etched alloy structure. SEM examination of alloy surface microstructures generally does not require any special specimen preparation except for cutting representative sections to fit within the imaging constraints (size limitations) in the SEM.

Defect characterization of produced parts is another key factor in quality manufacturing. The laser scanning confocal microscope (LSM) provides non-destructive, non-contact high-accuracy measurements with a pinhole confocal optical system, enabling automated dimensional measurements. This system can be used to perform height, profile, area, 3D image, and surface topography measurements, see Figure 6.

Optical, SEM, and associated techniques along with non-contact metrology are valuable tools to gain information on the character and properties of materials being developed for high-performance drilling and oilfield service tools.

References

[1] Loeber.L., et al., SSF Conference Proceedings (2011) p. 1.
[2] Hrabe N, et al., IFF Conference Proceedings 2012-79, 1045-1058.
[3] Kenzari S., et al., Sci. Technol. Adv. Mater. 15 (2014), 024802.
[4] Murr L.; Metallurgy of Additive Manufacturing (2014), 1074-1080.
[5] The authors acknowledge Wes Bodenhamer for his many useful discussions and contributions to this work.

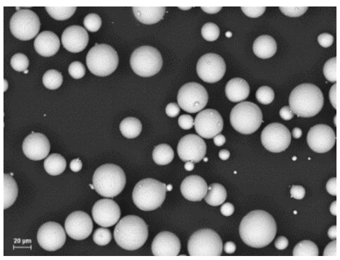

Fig 1

Fig 2

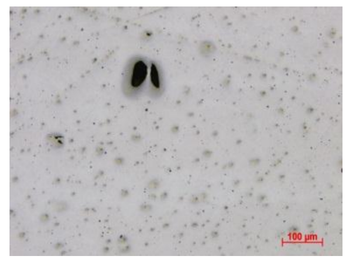

Fig 3

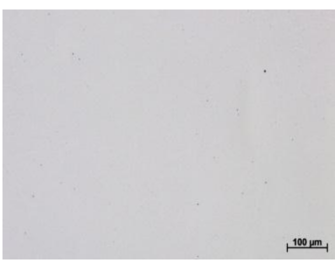

Fig 4

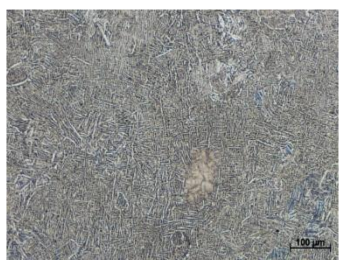

Fig 5

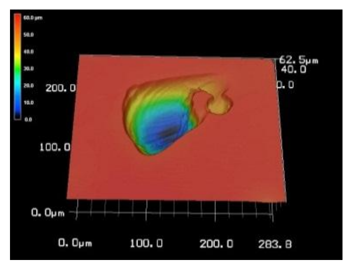

Fig 6

FIG 1. Backscatter electron image of Ti-6Al-4V powder, note microdendritic structure.
FIG. 2. Macro image of printed part with sections removed for optical and SEM examination.
FIG 3. Optical image of unetched Ti6Al-4V material before HIP illustrating defects and sub-surface imperfections.
FIG 4. Unetched HIP sample. Note material has less porosity.
FIG 5. OM image of etched sample after HIP with fine microstructure.
FIG 6. 3D image produced by Laser Scanning Confocal Microscope illustrating non-contact porosity void depth.