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EBSD Texture Analysis as a Measure of Local Flow in Friction Stir Welding

D.J. Rowenhorst[1], K.E. Knipling[1], and R.W. Fonda[1]

[1] U.S. Naval Research Laboratory, Code 6350, Washington, DC 20375

Friction stir welding (FSW) is a relatively new joining process wherein a rotating non-consumable tool is plunged into the joint line where it produces sufficient frictional and adiabatic heat to enable rotational flow, and thus mixing of the material across the joint line. As the tool is traversed along the joint line, a consolidated weld is deposited in the wake of the tool. There has been considerable interest in the exact nature of the complex material flow around the tool as it would provide crucial information for optimizing process models and avoiding defects within the weld. There have been a number of studies that have used either dissimilar metals [1] or tracers within the material to attempt to back out the flow within the weld [2, 3] however, it can be very difficult to correlate the post-processing locations of the tracers to their original placements and there is some evidence that the tracer material itself can have a significant affect on the FSW process [4].

Recent work using Electron Backscatter Diffraction (EBSD) analysis of the wake of FSW in aluminum alloys show that the deformation textures are dominated by pure shear textures [5], which is as expected with the majority of the material being sheared around the tool face and deposited in the wake as it traverses though the material. Proper analysis of these deformation textures requires that the crystallographic orientations be rotated to align the EBSD reference frame with the geometrically determined deformation frame of the spinning tool [6]. In FSW, this deformation reference frame is a strong function of the location within the deposited weld, which is unlike other deformation mechanisms such as rolling or forging where the direction of deformation is constant within the entire sample.

It was observed that even after aligning the textures to the local idealized shear directions determined from the tool geometry, additional small rotations were required of the data to achieve exact alignment with the expected pure shear reference textures. This work recognizes that these small deviations are indicative of the variations of material flow in the wake as the material is deposited, and thus can act as a forensic tool to determine the exact direction of the material flow as a function of position in the wake of the tool.

Figure 1 shows a large area EBSD scan that analyzed seven positions across the wake of a FSW of aluminum alloy 2519-T87, 1-inch plate, welded at 8 inches/minute at 140RPM. The welding tool used was threaded with three flats. The EBSD data was collected on a JEOL JSM-7001F field emission SEM equipped with a EDAX EBSD system. The EBSD step size was 1 μm, and each column of EBSD data is composed of four individual scans that were then stitched together to form a single column of data, each covering an approximate area of 900μm $\times$3500μm. The columns were spaced 2.7 mm, with seven columns evenly spaced across the weld. Using the tangental direction of the texture bands within each column of data, the crystallographic texture was measured in 50μm segments (approximately 60 segments per column) and the strongest shear deformation textures in each column were extracted, as indicated by the white boxes in Fig. 1. The texture of each extracted region was then rotated into the geometrically determined deformation orientation, and then compared to the idealized shear texture. The small rotations needed to bring the measured and ideal shear textures into coincidence are indicative of the deviations from the geometrically predetermined shear flow.

Most notably Fig. 1 shows that that there is an asymmetry in the flow from the retreating to advancing side of the weld, with most of the weld showing a material flow pattern fairly consistent with the idealized shear flow, while the advancing side shows significant deviations. At all the locations in the wake of the weld, there is small yet consistent amount of downward flow (along the tool rotation axis) of the material, which is attributed to the downward flow of the threads on the tool. [7]

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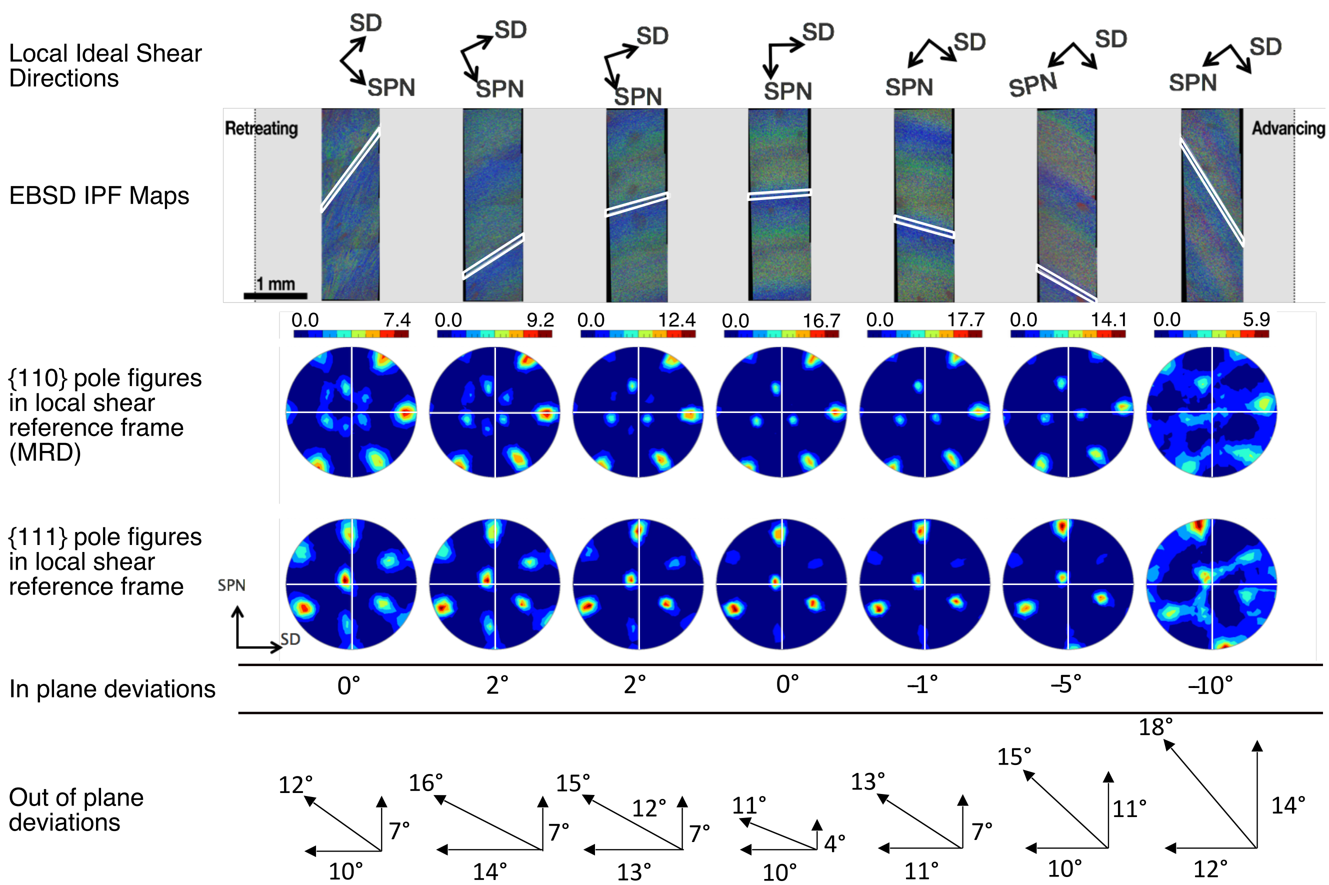

Figure 1: Directional shear texture analysis in the wake of a Friction Stir Weld. Deviations from the idealized shear reference frame indicate the directions of material flow at the time of deposition in the weld.