Investigation of Evolution of Microstructure and Mechanical Properties in metal alloys formed by Friction Stir Welding

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Objective:

As a solid-state joint process, Friction Stir Welding (FSW) joins metals by locally introducing frictional heat and plastic flow by rotation of the welding tool with resulting local microstructure changes. The local microstructure determines the weld mechanical properties. Therefore, it is important to investigate the relationship between the microstructure and the mechanical properties. However, the mechanism of the evolution of microstructure of the process has not been well established, defined and examined by present research. Our research will be based on a comprehensive investigation of the micro-properties, which include stress, strain, strain rate, deformation, dislocation, grain structure, phases, and macro-properties, which include elastic stiffness, yield strength, ductility, toughness, etc. The main thrust of our research is to reveal the relationships of these properties, and develop a fundamental understanding of the mechanism of the evolution of microstructure, which will provide some beneficial information for the optimization of weld qualities of the FSW.

Background:

The FSW has been actively studied as a new solid state welding technique since its invention at The Welding Institute (TWI) in 1991. FSW produces a fine re-crystallized grain structure in the stir zone, and the welds exhibit better tensile, bend, and fatigue properties than fusion welds. Additionally, this process reduces manufacturing costs due to the elimination of some defects, filler materials, shielding gases, and costly weld preparation. Taking advantage of these positive factors, this process has already been applied to the construction of metal structures, e.g. the external fuel tank of rockets, rolling stock of railways, and high-speed vessels.

Many organizations have been trying to optimize FSW processes and to characterize microstructures in friction stir (FS) welds over the past decade. However, no one has successfully revealed the mechanism and process of the evolution of microstructure in detail.

Experimental approach:

1. Using scanning and transmission electron microscopy, orientation image microscopy and optical microscopy to identify the microstructure.
2. Mechanical testing to recover the mechanical properties.
3. Computer modeling to simulate the microstructure evolution during plastic deformation and annealing.

4. Since the previous studies suggest that FSW can cause grain refinement through severe plastic deformation, similar to equal channel angular pressing (ECAP), we will attempt to develop a new method to simulate the early stage of the microstructure evolution of FSW by using various types of ECAP or other novel channel pressing techniques.

Results and Future Work

Our current research has been focused on the microstructure around the hole formed by the pin. The material is Al 7075, with the processing parameter of 300rpm, 6in/min. preliminary work has been performed using OIM and optical microscopy. The picture below was taken by optical microscopy, with the magnification of 100X. It indicates that the fine-grained microstructures surround the hole, except at the leading edge of the tool.

Further exploration of the mechanism of the microstructure evolution and the relationship between the microstructure and mechanical properties of the FSW is on-going.