Jian-Qing Su, Ph.D.
Postdoctoral Fellow
Department of Mechanical Engineering
Brigham Young University
435 CTB
Provo, UT 84602

E-mail: jqs@et.byu.edu
Tel: (801)422-2059
Fax: (801)422-0516

RESEARCH DESCRIPTION

1. Microstructural Evolution of Friction Stir Welded Aluminum Alloys

Background: Friction stir welding (fsw), a new joining process developed by TWI in Cambridge England, has emerged as a promising solid state process with the potential to join aluminum alloys traditionally considered unweldable. This technique achieves solid phase joining by locally introducing frictional heat and plastic flow by rotation of the welding tool with resulting local microstructure changes in Al alloys. However, The local microstructures, which determine the weld mechanical properties, are not well-understood. The objective of this research is to investigate the details of microstructural evolution during the severe thermomechanical conditions imposed by FSW.

Experimental approach: The grain structure, dislocation density and second phase particles in various regions (Fig. 1) including the dynamically recrystallized zone (DXZ), thermo-mechanically affected zone (TMAZ), and heat affected zone (HAZ) of a friction stir weld aluminum alloy 7050-T651 were investigated by using TEM.

Figure 1. Cross section of the 7050 friction stir weld, showing the different region from base metal to DXZ.

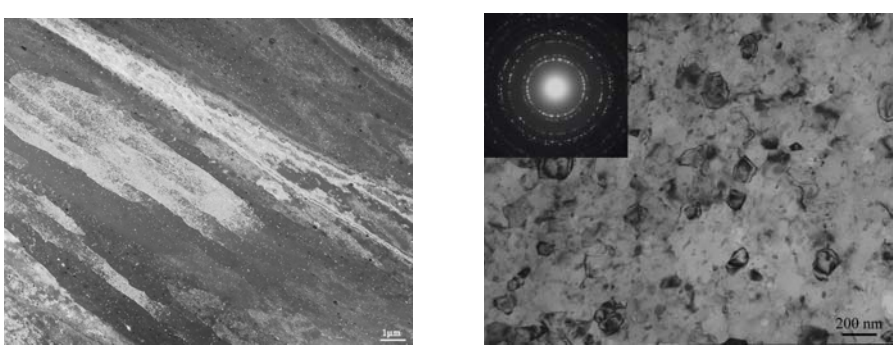
Results and discussion: The FSW process has little effect on the grain structure in the HAZ. In the TMAZ, a recovered structure with subgrains 1-2 μm in size was formed. The DXZ consisted of recrystallized, fine equiaxed grains on the order of 1-4 μm in diameter. Most of the DXZ grains contained a high dislocation density with various degrees of recovery from grain to grain. Precipitates in the 7050-T651 base alloy are predominantly intragranular fine η' with coarser η precipitates along grain boundaries. Following FSW, the precipitates coarsen and more η phase forms in the HAZ. In TMAZ, strengthening precipitates were severely coarsened and partly dissolved while a small amount of very fine η particles were re-precipitated. Strengthening precipitates in the DXZ go into solution and re-precipitate heterogeneously on dislocations and on matrix Al_3Zr particles. The microstructural development in each region was a strong function of the local thermo-mechanical cycle experienced during welding.

2. Fabrication of Nanocrystalline Materials through Friction Stir Processing

Background: One of the most exciting recent events in the materials science community has been the development of metals and alloys possessing nanoscale microstructures because of their superior mechanical properties, including high strength, high toughness, and excellent superplasticity at high strain rate and low temperature. The major roadblock to their structure applications is the difficulty in fabricating them into bulk form. Therefore, development of processing techniques which enable the production of bulk nanostructured materials large enough for many engineering applications is essential. Combining friction stir processing (FSP) technique with rapid cooling, we have developed a new method to refine grain size to a nanoscale.

Experimental approach: FSP was performed on a 2 mm thick commercial 7075 Al sheet. The tool travel speed and rotational speed are 10 cm/min and 800 rpm, respectively. A mixture of water, methanol, and dry ice, was used to quench the plate immediately behind the FSP tool.

Results and discussion: Nanocrystalline 7075 Al with an average grain size of 100 nm was successfully obtained using FSP (Figure 2). In principle, by application of multiple overlapping passes, it is possible to produce any desired size thin sheet to nanostructure using this technique. The objective of the present research is to: 1) optimize the processing parameters to obtain desired microstructures, 2) study microstructural evolution and mechanical behavior of nanostructured materials processed by FSP, and 3) produce parts large enough for most engineering applications.



Parent material After FS Processing

Figure 2. Microstructure of 7075 Al Alloy