

A Classic Aluminum Etch Supporting Development of a New Automotive Joining Process

Introduction

High speed (> 2 m/min) friction stir welding (FSW) has been developed for cost effective mass production of aluminum tailor welded blanks in the automotive industry. Continued exploration of joining various alloy systems for manufacturing a variety of vehicle components is an active area of research. An etching technique that reveals the grain structure, grain flow and also allow defects such as lines of oxides, voids, or other exogenous materials to be identified was needed.

The goal of this work was to develop an etching technique for optical microscopy that revealed all of these microstructural features in one step for 5000 and 6000 series aluminum alloys.

** All samples shown are development samples with non-optimized FSW conditions & significant defects present.*

Significant Findings

Submerging the sample in the etchant for 20 seconds prior to turning on the voltage was the key to this technique. Two significant improvements were realized:

- Improved grain contrast and grain flow contrast.
- Improved oxide stir line contrast.

Figure 1(a) the voltage was applied immediately. Figure 1(b) the sample was submerged for 20 seconds prior to electrolytic etching for 100 seconds. 12.5X optical micrographs of AA5754.

The oxide stir line is a defect the can occur with insufficient mixing. It is highlighted by using this etching method, Fig. 2(a), but stands out even more by reducing the polarization and color tint as shown in Fig. 2(b). 25X optical micrographs of AA5754.

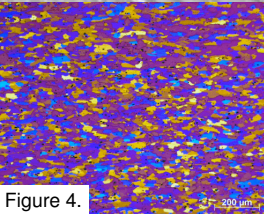
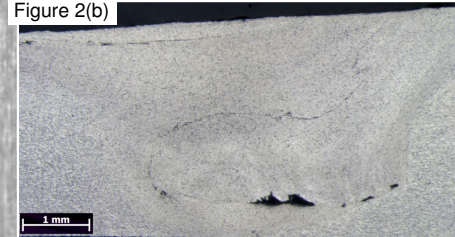
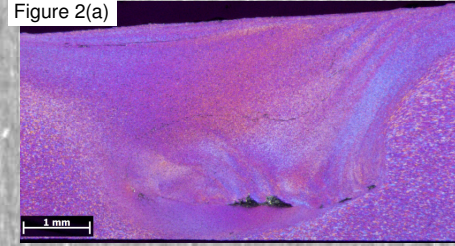
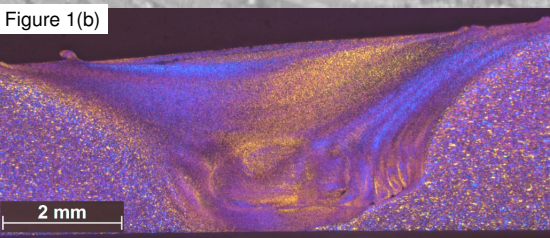
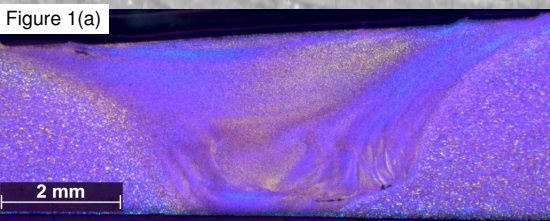


Figure 3 shows a curvilinear FSW in progress with an inset of the FSW tool should mark on the surface (typically the part interior) shown at 10X magnification.

Figure 4 shows a 100X optical micrograph of the AA5754 in the parent metal outside the FSW. The etch slightly pits the surface; however, grains boundaries are clearly highlighted for grain size analysis.

Figure 5(a) shows a 12.5X optical micrograph of a FSW in AA6111 made with a sample that had excessive lubricant on the surface of the Al alloy sheet. Figure 5(b) is a 100X magnification image showing that the lubricant is easily distinguished from the oxide stir line (created due to lack of friction in this joint) in the stir zone.

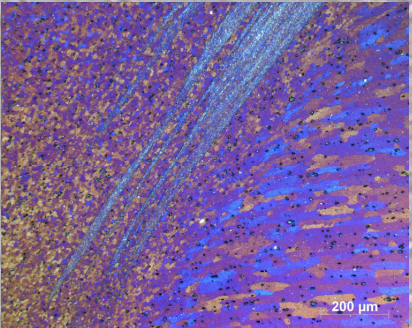
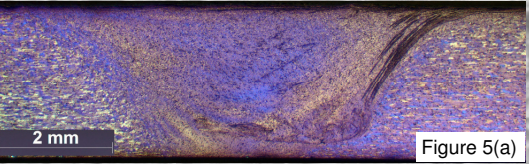


Figure 6 is a 25X micrograph of a limiting dome height (LDH) tested FSW in AA5754. The LDH test was conducted with the bottom (root) of the weld up which was most similar to the intended forming direction on this part. The image was taken with the polarization and color tint reduced to highlight the oxide stir line in this developmental FSW. Voids were present on the advancing side of the weld; however, the oxide stir line was shown to be the location where fracture initiated. It is indicated by the white arrow in the image.

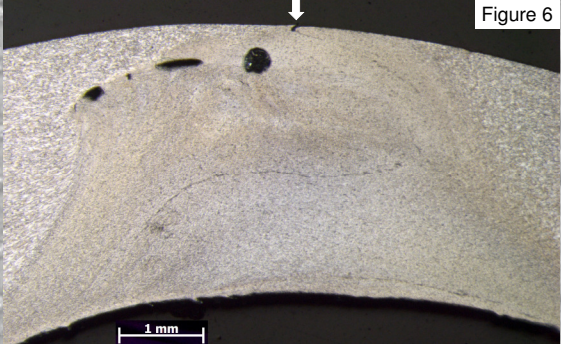
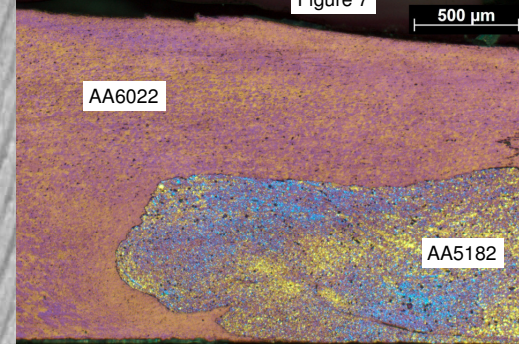


Figure 7 is a 50X micrograph of the bond line in a developmental FSW of AA6022 and AA5182.



Experimental Methods

FSW cross-sections were mounted in epoxy (50 mm diameter mounts). Samples were ground by hand on SiC abrasive paper ending at 1,200 grit. Samples were polished on a felt pad for 3 minutes using 1μm diamond polishing compound. Final polishing with 0.05μm colloidal silica for 30 – 60 seconds was done on a low nap synthetic polishing cloth. Samples were thoroughly washed with a micro-soap prior to etching.

Barker's reagent (4% aqueous HBF) was the etchant. An Al cathode was used and 20V was applied for 100 seconds. Prior to the electrolytic etch, the sample was submerged in the acid solution for 20 seconds with no voltage applied. Optical microscopy was done with polarized light and a sensitive tint filter.

