

Unraveling the processing parameters in friction stir welding

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Introduction

In friction stir welding (FSW), a rotating threaded pin tool is translated along a weld seam, literally stirring the edges of the seam together. To determine optimal processing parameters for producing a defect free weld, a better understanding of the resulting metal deformation flow path or paths is required. In this study, various markers are used to trace the flow paths of the metal. X-ray radiographs record the segmentation and position of the wire. Several variations in the trajectories can be differentiated within the weld zone.

Background

Several FSW flow visualization studies have been reported in the literature using either dissimilar materials or tracer techniques [1-5]. These studies all indicate the flow field around a FSW tool is complicated but orderly. The weld metal appears to flow along defined paths or streamlines. This study offers an extension of previous marker studies to correlate the variation in weld parameters with variations in flow streams in an effort to determine their influence on optimized FSW joints.

Experimental Procedure

Rolled panels, 24" long and 0.25" thick, of 2219 aluminum alloy were used in this study. A tungsten wire marker, 0.001" dia., was used to trace the metal flow path. The tungsten wire was positioned in a 0.001" deep groove scored along the longitudinal seam side of the panels and the plates were tack welded together. Multiple panels were welded with an individual wire placed at the various depths below the surface. The FSWs were made off-centered with the wire located either toward the advancing side or the retreating side of the pin tool. The weld tool consisted of a 1/2-20 UNF LH threaded pin tool with a scrolled shoulder 1.2" in diameter. All welds were terminated using an E-stop on the travel. Tracer positions were recorded using standard x-ray radiography equipment.

Results and Discussion

X-ray radiographs are shown in Figure 1 for 3 different wire placements. All wires were placed in the center of the weld plate thickness. In agreement with 2-D slip line theory of the friction stir process, the wire tracer in Figure 1a is observed to follow the metal flowing around the tool in an arc just inside the shear surface. Using the same weld parameters, but increasing the tool rotation results in a lateral shift in the wire placement as it exits the flow field in Figure 1b. This shift can be understood as a consequence of a radial velocity component around the pin tool due to vortex flow induced by the tool threads (a 3-D extension of theory). Figure 1c uses the same weld parameters as Figure 1a, but introduces the wire on the advancing side. The wire trace

appears to follow a relatively slow induced circumferential flow, entering a much faster flow when a streamline passes sufficiently close to the tool. Under the latter condition scatter occurs. The scatter may be a consequence of imprecise encounters with a sharp change in circumferential velocity or of a radial oscillation of the flow field at the tool shoulder.

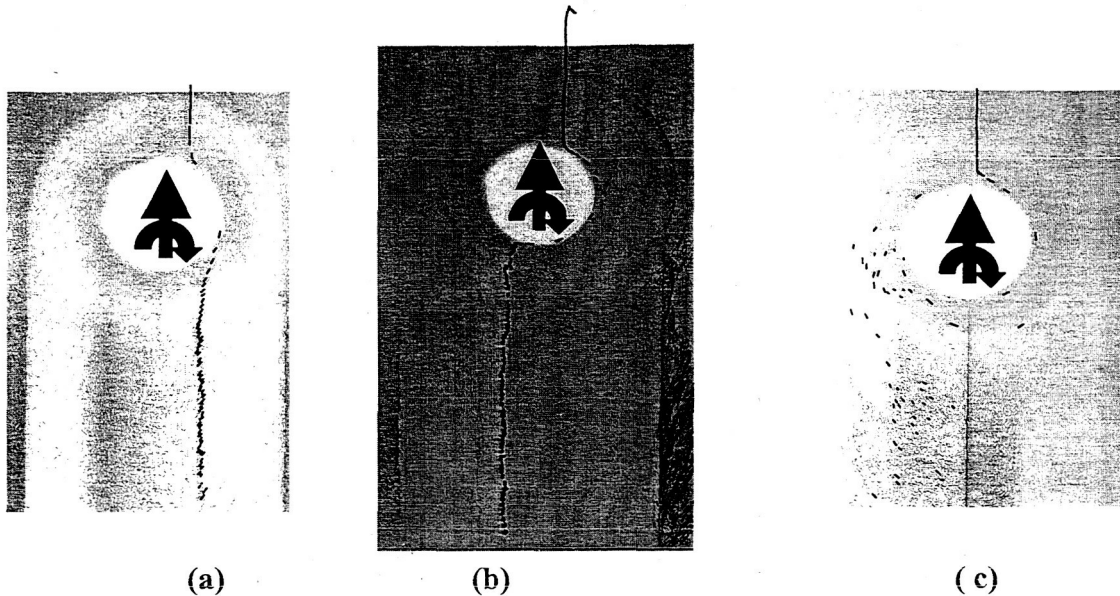


Figure 1. Varying marker traces resulting from tungsten wire marker introduced at center thickness of weld joint. a) wire introduced on retreating side of weld, b) wire introduced on retreating side of weld at slightly higher rpm, c) wire introduced at center line of weld.

Summary and Conclusion

Thin tungsten wire markers can be used to trace the metal flow path during friction stir welding. As the wire is entrained in the shear zone surrounding the weld tool, it segments into uniform lengths. Entrainment of the marker into a downward, vortex flow is observed when the wire is introduced on the retreating side of the weld at a higher weld rpm. Scatter in the post weld marker placement, initially introduced on the advancing side of the weld, suggests high rotating velocities very close to the pin circumference and possible radial oscillations of the flow field.

References

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