Microstructural and Mechanical Property Evaluation of DH-36 and 304L Friction Stir Welds

By M. Posada and J.J. DeLoach, Naval Surface Warfare Center; A.P. Reynolds, University of South Carolina; and J.P. Halpin and M. Skinner, MTS Systems

Steels and stainless steels are structural materials of interest for shipbuilding applications. Two of the most significant challenges in conventional arc welding of steels and stainless steels include weld distortion and generation of hexavalent chromium (Cr^{6+}) in the welding fumes. Friction Stir Welding (FSW) has many characteristics that make it a potentially-attractive alternative to conventional arc welding. Before FSW can be applied to production fabrication of steels and stainless steels, extensive work is needed in tool development, equipment and parameter optimization, as well as mechanical property and microstructural characterization.

The base metals used for the evaluation were ¼ in thick DH-36 steel and 304L stainless steel. Six friction stir welds were fabricated: three single-sided DH-36 weldments, one single-pass 304L weldment, and two double-sided 304L weldments. The microstructures of the welds and base plate were characterized by optical microscopy. Chemical composition of the stir zone and base metal were obtained by conventional bulk chemical analysis. Mechanical property testing included transverse face bend, longitudinal (all-stir-zone) tensile, and transverse tensile testing.

Chemical analyses revealed that the level of alloying and residual elements were similar in base metal and welds. The only significant difference in the base metal and stir zone compositions is that pin tool material was deposited within the stir zone.

Microhardness traverses for the DH-36 weldments, Figure 1, were taken across the four microstructurally-distinct regions observed during optical microscopy. In general, hardness values were highest within the stir zone and decreased as one moves away from the weld centerline.

DH-36 friction stir welds show 4 microstructurally distinct regions; the stir zone along the weld centerline, a swirl region within the stir zone, and 2 heat-affected zones (HAZs) surrounding the stir zone. The stir zone was comprised primarily of coarse-grained bainite with some martensite. No solid-state transformations occurred in 304L during friction stir welding. The stir zone microstructure consisted on irregular austenite grains with small delta ferrite stringers. Shear banding was evident within the swirl region and the delta ferrite stringers were absent.

The microhardness results for the 304L weldments, Figure 2, remained fairly consistent across the weld. In the double-sided welds, hardness values for side 1 were consistently higher than side 2.

All DH-36 weld specimens failed in the base plate, indicating that the weld strength was overmatching. Like the DH-36, 304L specimens failed in the base plate with the exception of Weld 309 that failed in the weld metal due to a defect. Bend tests were acceptable.

All-stir-zone mechanical property results show that the yield and ultimate tensile strengths for DH-36 exceeded base metal properties. The percent elongation of the DH-36 weldments was significantly lower than the base metal.

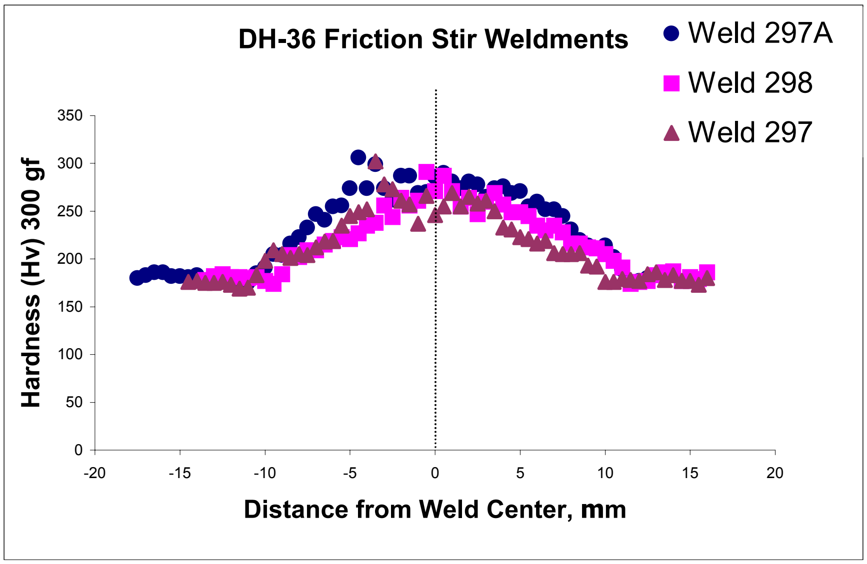

Figure 1. Microhardness results for DH-36 weldments

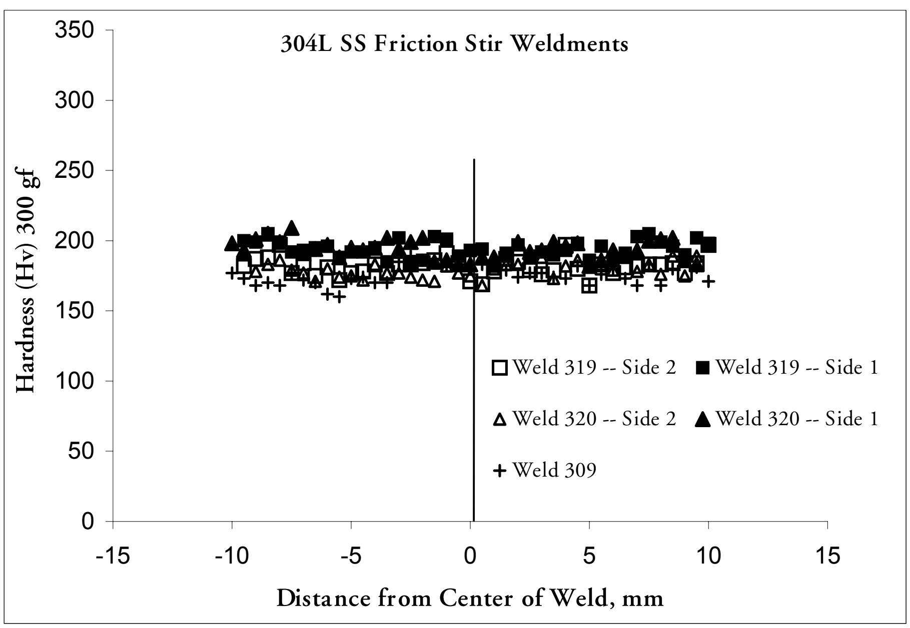

Figure 2. Microhardness results for 304L weldments