Neutron Diffraction Mapping (NDM) for Residual Stresses in Resistance Spot Welding (RSW) of 6061-T6 Aluminum Alloy Sheets

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Acknowledgment: The authors would like to thank U.S. Army-TARDEC for supporting this work. This material is based upon work supported by the U.S. Army under Contract No. W56HZV-08-C-0236, through a subcontract with MSU. High Temperature Materials Laboratory at ORNL provided the opportunity to use the equipment required for this work via User Facility Program.

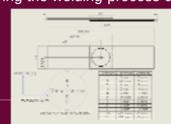
Abstract

This work presents the stress measurements for resistance spot welding joints of 2 mm aluminum sheets by neutron diffraction technique. Residual strains were measured in three different directions denoted as in-plane longitudinal, in-plane transversal and normal . The welding process parameters were established to meet or exceed MIL-W-6858D specifications: approximately 5.7 mm weld nugget and 3.8 kN failure load by performing quasi-static tensile testing. The measurements were taken at a series of points on weld centerline, along lines either 1 mm below the plate top and 1 mm above its bottom. Stresses were captured on fusion zone, heat affected zone and base metal of the resistance spot welded joint. Neutron diffraction results show residual stresses in the weld are approximately 40% lower than yield strength of the parent material. The maximum variation in residual stresses is in the vertical position because of the electrode clamping forces and the high heat input which gave a non-uniform solidification pattern to the weld nugget

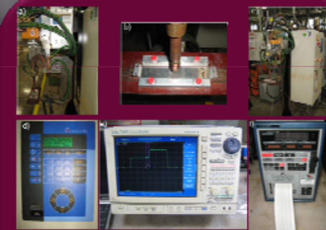
Materials/Welding Equipment

RSW showing (a) electrodes with work pieces, (b) overview of phenomena involved and (c) "witness peeling" samples tested during the welding process development

Fusion zone , heat affected zone and base metal are shown on Electron Back Scatter Diffraction (EBSD) grain size mapping plot in these regions. Only half of welding nugget was scanned via EBSD because of extended time usage. For optical microscopy (OM) the specimen was cold mounted, polished and etched. Entire longitudinal cross section was observed .



Geometry of Al 6061-T6 resistance spot weld lap-shear coupon.

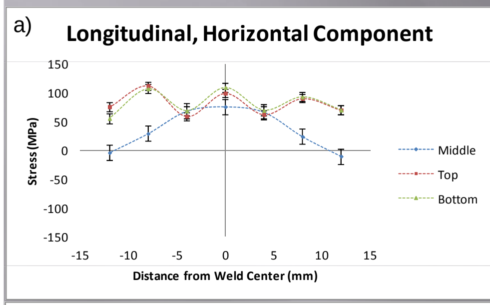


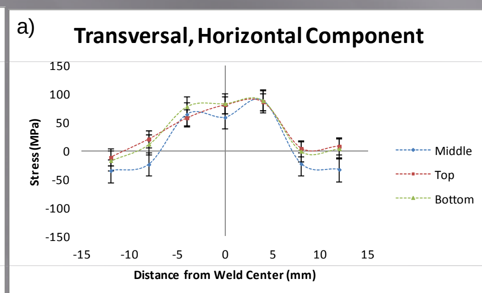
Welding set-up showing a, c) ARO equipment with servo-gun, b) locating fixture used to assure the specimen geometrical consistency, d) weld control, e) Yokogawa DC 750 scope-corder, and f) Miyachi weld monitor. These welds were produced at Edison Welding Institute

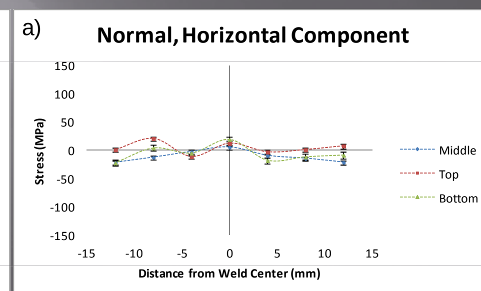
Neutron Diffractometer

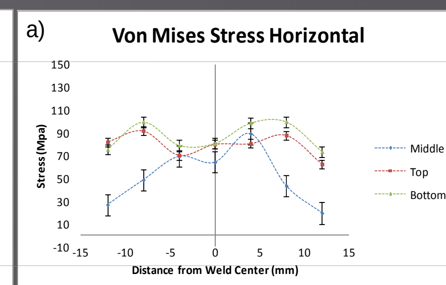
Neutron diffraction equipment at ORNL used to measure residual stresses showing: (a) fixturing to define gauge volume at 1x1x1 mm and to hold specimens, (b) detail view with welded coupon and free-stress cylinder samples and (c, d) optical alignment devices.

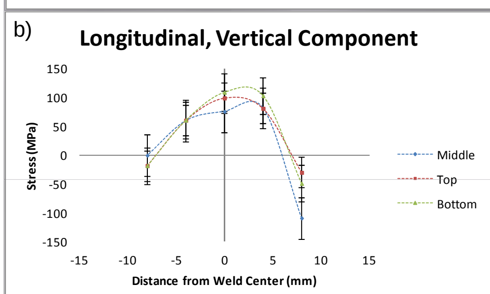
Residual Stresses in Different Directions

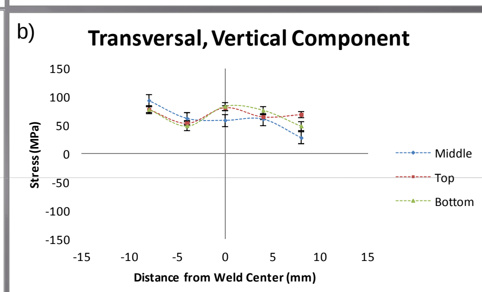


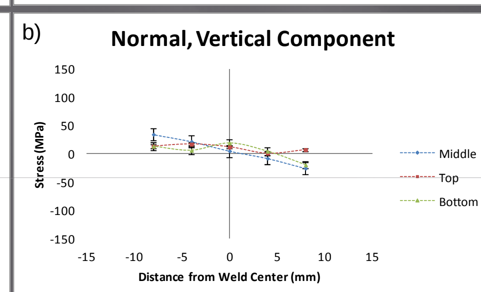


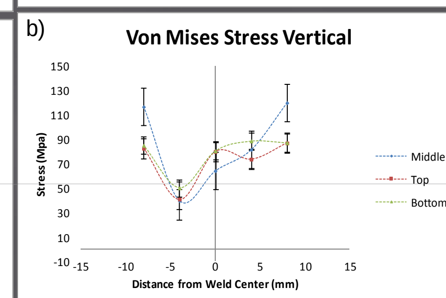












In-Plane longitudinal, transversal, normal and Von Misses stress results in (a) horizontal direction of the welded plate and (b) vertical direction, respectively . This figure illustrates residual stresses for 3 set of depths which were measured as follow: in the center section of the welded joint, 1 mm up and 1 mm down w. r. t. the mid-plane. We denoted them as middle, top and bottom, respectively. Total thickness of the specimen is 4 mm and the origin of the coordinate system is in the center of the weld.

Conclusions and Future Work

Experiments revealed that the welding process parameters have a great influence upon the strength of the RSW of aluminum 6061-T6 alloy. The electron back scatter diffraction and optical microscopy scans for welds show the grain size and orientation for fusion zone, heat affected zone and base metal. The above results were used to create a strong foundation for residual stresses measurements of an acceptable resistance spot welded joint which complies with mentioned specifications. The neutron diffraction residual stress (NDRS) measurements were successfully accomplished. The values of stresses do not exceed 120 MPa which is less than half of 6061-T6 aluminum yield stress. A very interesting conclusion is NO residual stresses in normal component due to the post-heating process which proves to be a critical step in welding process. The RSW stresses are approximately equal through thickness and the normal stresses are close to zero. The in-plane stress components were found to be a significant fraction of the yield stress. XRD-RS measurements are underway and will be compared with ND-RS. This work is part of a program whose objective is to correlate residual stress and hardness gradients with the process parameters and with fatigue performance.

HTML is sponsored by DOE-EERE-Vehicle Technologies and HFIR by DOE-OS Facilities Division.