Prediction of Residual Stresses and Property Distributions in Friction Stir Welds of Aluminum Alloy 6061-T6

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Friction stir welding (FSW) is an innovative solid-state joining process that offers significant advantages over fusion welding processes for joining aluminum alloys. Because of the unique mechanisms of material bonding in FSW, the residual stresses in the friction stir weld could be different from these of fusion welds. In addition, the thermal cycle in FSW introduces microstructural changes in the weld region of heat-treatable aluminum alloys. The resultant property field and residual stress field in a friction stir weld joint have shown to have significant influence on the performance of frictions stir welded structures.

In this study, an integrated thermal-mechanical-metallurgical model was used to study the formation of the residual stress field and the HAZ softening of Al6061-T6 friction stir welds. The simulations were conducted using a three-dimensional model, accounting for the frictional heating, aging and dissolution processes of the precipitates, and the mechanical contact effects of the moving tool. Temperature-dependent material properties were also considered in the finite element model. In addition, the residual stress fields of two friction stir welds made under different welding speeds were measured using the neutron diffraction mapping technique, compared with the 3-D model predictions.

For the friction stir welds investigated, it was found that the residual stress distribution is strongly dependent on the welding process parameters and the degree of material softening during welding. The recovery of material strength from natural aging does not increase the residual stress in the weld. The failure of a friction stir weld under tensile load is controlled by the combination of the material softening and the high residual stresses in the HAZ.

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