Abstract

Friction stir welding (FSW) is a solid state joining process and is efficient in welding aluminum alloys. Study on material flow mechanism, forces and defect formation are important as it could help in proper selection of process parameter and pin design. Their experimental study is exhaustive due to lots of post weld analyses. Numerical modeling could be an efficient method to study the material flow and defect formation. This will reduce the cost associated for material and development of infrastructure. Literature suggest that Lagrangian method could be used to model all the three phases of FSW.

In the current research work, two different three-dimensional thermo-mechanical models are developed to simulate FSW. First model is developed based on the Lagrangian method. The developed model is used to model FSW for AA2024 and AA6061 aluminum alloys. For AA2024 material, the model is validated with the forces and spindle torque data obtained from the literature. Two different pin shapes viz. conical and threaded conical are compared in terms of forces, material flow, material velocity, effective strain and strain rate. Threaded conical pin produced higher deformation and vertical flow of the material among the two. For AA6061 material, in-house experiments are performed to validate the model with temperature, force and spindle torque. Three different pin shapes, namely, cylindrical, triflat and square are compared. For flat pin surfaces bulk material flow is prominent, while shearing or layer by layer material flow is more prominent for cylindrical pin. Distribution of the material is uniform across the stirred region for the triflat pin while it is stretched towards the advancing side for the square pin.

Second model is developed using coupled Eulerian Lagrangian method to predict the defect formation based on volume of fluid principle. Effect of tilt angle on defect formation is studied and simulation predicted defect is compared with the experiments. Lastly, the Lagrangian model is used to compare twin tool and single tool FSW. Twin tool produces uniform distribution of temperature and strain as compared with single tool FSW. Higher material velocity and lower thermal gradient is also observed for twin tool FSW.

Keywords: Friction stir welding; Finite element modeling; Lagrangian method; Coupled Eulerian Lagrangian; Twin tool; Defects; Material flow