# ABSTRACT

Friction stir welding (FSW) is a solid state welding process capable of joining high strength aluminium alloys that are difficult to be joined by fusion welding processes. In FSW process, heat is generated by friction between a rotating tool and the work piece. Although FSW is a solid state process, a significant magnitude of residual stress is present in the weld due to the complex fixturing system used during welding. These residual stresses affect the properties of the welded components during their service. Hence, it becomes important to evaluate the nature of stresses developed during the FSW process. For estimating the magnitude and distribution of welding residual stresses along with thermal cycles, a three dimensional non-linear thermo-mechanical finite element (NLTMFE) model using ANSYS package was developed for butt welded aluminium alloy AA2014–T6. The variations in thermal and mechanical properties of the material with temperature were included in the model. In the thermal modeling, boundary conditions play a vital role in predicting the temperature profile. In order to simulate the thermal fields during the FSW process, the adaptive boundary conditions were used.

Simultaneously experimental study was carried out for the measurement of temperature and residual stresses to validate the accuracy of the thermo-mechanical model. Residual stress measurement was carried out using X-ray diffraction technique to assess the longitudinal stress in the

transverse direction. The NLTMFE model was validated based on close agreement of temperature distribution and residual stress patterns with that of the experimental values. Statistical analysis of simulated and experimental data shows that the simulated temperature and stress data are in agreement with experimental data with 95% confidence level.

Further the effect of process parameters such as tool rotation (TR) and welding speed (WS) on temperature distribution and residual stress of aluminium alloy AA2014 joined by friction stir welding was investigated. To systematically study the influence of input parameters, nine experiments based on full factorial design were performed. The temperature and stress data were studied to relate the input parameters such as tool rotation and welding speed with temperature and residual stress. The analysis of variance (ANOVA) was employed to investigate the effect of input parameters on temperature distribution. Temperature measurements and analysis of variance (ANOVA) indicate that the temperature under the tool shoulder was strongly dependent on the tool rotation. It was observed that the magnitude of longitudinal residual stresses in welded specimen is proportional to the tool rotation.

The effect of process parameters such as tool rotation and welding speed of FSW on mechanical properties and microstructure of aluminium alloy AA2014 was investigated. Samples were prepared and welded by varying the input parameters tool rotation and welding speed. Tensile test, hardness survey and microstructure examination were carried out to study the effect of tool rotation and welding speed. The analysis of variance (ANOVA) was employed to investigate the effect of input parameters on tensile strength of weld. The ANOVA results indicate that the welding speed is the main input parameter that has the highest statistical influence on tensile strength.

The combined effect of tool rotation and welding speed on tensile properties, was studied by the parameter revolutionary pitch (ratio of WS to TR) proposed by Lie et al (2003). Tensile strength increases with increase of revolutionary pitch upto 0.11 mm/rev and then it decreases gradually. The study was conducted up to a revolutionary pitch of 0.33 mm/rev. Under the condition of optimum revolutionary pitch of 0.11 mm/rev, the tensile strength of the joint was maximum at 78% of the base metal.

It was observed from the microstructural analysis, that the welding parameters, tool rotation and welding speed influence the grain size in the nugget region of the weld. At a fixed welding speed, an increase in tool rotation increases the grain size due to the higher heat input. At fixed tool rotation there is little change in grain size when changing the welding speed.

The 3D non-linear finite elemental model developed, will be useful to predict thermal cycles and residual stresses. Findings of this investigation will provide prior knowledge about residual stress contours along with thermal history, in order to design stress relief techniques, while designing FSW based aluminium alloy structures. In addition to the above, the thermal history finds application in designing of welding tools.