INDIAN INSTITUTE OF TECHNOLOGY GUWAHATI
SHORT ABSTRACT OF THESIS

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Thesis Title: Evaluation of Surface and Sub-Surface Defects in Friction Stir Welding through Experiments and Coupled Eulerian and Lagrangian Based Finite Element Model

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SHORT ABSTRACT

In the present work, a 3D thermo-mechanical model is developed following the Coupled Eulerian-Lagrangian (CEL) approach to evaluate the varying surface morphology, material flow, and defect formation in FSW process. The similar and dissimilar combinations of AA6061 and AZ31B materials are extensively investigated by solid-state FSW process. The tool wear is also estimated to account its influence on the defect formation viz. weld quality. Proper selection of mass scaling factor eliminates the high computational time associated with the CEL approach. The influence of mass scaling technique on the total computational time, weld quality, thermo-mechanical responses, and defect prediction are extensively investigated. Any adverse effect of the artificial mass scaling is kept under check by maintaining the kinetic energy (KE) to internal energy (IE) ratio below 10%. The KE to IE ratio varies as the tool moves from a sound weld region to a defective weld region, but it remains constant if the weld quality is sound or defective for the complete weld length. Therefore, the KE to IE ratio variation cannot be conclusively used to determine the weld quality and can only be used to check any adverse effect of mass scaling. The developed numerical model is validated by comparing the experimentally measured temperature evolution, volumetric defects, and residual stress data. The model can accurately predict the different surface and sub-surface defects, viz., the tunnel defect, flash formation, failed joints, exit hole, and other surface defects, while considering the tool rotation speed, traverse speed, pin height, plunge depth, pin geometry, tool condition and plate position as the process variables. Further, the developed model can estimate the material mixing and weld interface location specifically for dissimilar welding. The residual stress is more generous during dissimilar FSW due to the non-uniformity of the heat flow and material properties. This makes the residual stress estimation more complicated in dissimilar FSW. Hence, the CEL based mechanistic model is coupled with the machine learning (ML) algorithms to predict the temperature distribution and residual stress in dissimilar AA6061-AZ31B FSW. Different ML algorithms are compared to estimate their prediction accuracy. The extra tree regressor, XGBoost, and random forest regressor models predict the temperature evolution and residual stress with a maximum deviation of less than 8% for temperature and 10.3% for residual stress, respectively. Essentially, the physics-informed ML algorithm is a reliable process model for predicting the transient state of thermal and mechanical responses during the FSW process, which is more appealing to apply for any other industrial problem of interest.