INDIAN INSTITUTE OF TECHNOLOGY GUWAHATI
SHORT ABSTRACT OF THESIS

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Programme of Study : Ph.D.

Thesis Title:
Thermo-Mechanical Analysis and Experimental Investigation on Weld Induced Residual Stress, Distortion and its Mitigation for Submerged Arc Welded Butt Joints of P91 Steel Plate

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SHORT ABSTRACT

P91 steel is the modified form of Cr-Mo low alloy steel with enhanced creep strength at elevated temperature. P91 steel is preferred to manufacture the components like pipelines, pressure vessels and power plant elements such as boilers, steam generators and breeders in nuclear power plant, subjected to high operating temperature at and above 600 oC. Fabrication of most of these power unit components involves fusion welding process such as SMAW, GMAW, GTAW, SAW etc. Fusion welding offers good mechanical properties and joint efficiency with flexibility in design and weight reduction. Nonetheless, the rapid heating and cooling cycles of welding process lead to welding induced residual stresses and distortion. Residual stresses in weld components provoke failures below the design load whereas, distortions wreak havoc on the dimensional accuracy of the fabricated structures. Therefore, the current study explores submerged arc square butt welding of P91 steel plate to investigate the welding induced residual stresses and distortions. The submerged arc welding experiment is performed on 10 mm thick P91 steel plate to make square butt single and double side single pass welded joints. Welding induced distortions are estimated in terms of angular distortion and edge deflection using coordinate measuring machine. Deep hole drilling and contour surface residual stress measurement techniques, are employed to determine the residual stress across the thickness and spatial distribution across the weld, respectively. Single side single pass welding resulted in the formation of compressive residual stress distribution throughout the thickness in the fusion zone. However, double-sided single-x pass welded joint developed the tensile residual stress in the mid thickness region of fusion zone. FE analysis is also carried out for SAW square butt single and double side single pass welded joints of P91 steel plate. The uncoupled thermal-structural FE analysis is performed in ANSYS Mechanical APDL solver. Temperature-dependent material properties, phase changes, solid-state phase transformation, heat source model and element death & birth technique are considered for precise modelling of P91 steel weldments. Solid-state phase transformation exhibited a significant role in accurate prediction and validation of distortion and residual stress results. Pre-process, in-process, and post-process mitigation heat treatments are proposed to control welding induced residual stresses and distortion. At last, microstructure, mechanical properties, chemical compositions and phases are ornately inspected to check the impact of submerged arc welding and mitigation heat treatments on P91 steel welds.