ABSTRACT

Stainless steels have been extensively used in various industries such as power, petrochemical, nuclear, automotive and other sectors owing to their good corrosive and anti-rust properties. However, certain critical issues like increased distortion, residual stresses and reduced corrosion resistance, still remain an open concern, when these materials are joined with high heat input process like submerged arc welding (SAW). The submerged arc welding process is widely used in fabrication of thick materials due to its ability to achieve greater consistency, higher productivity, deeper penetration, and high deposition rates. The primary process variables in a submerged arc welding (SAW) process that affect the weld quality are welding current (polarity and magnitude), voltage, speed, electrode diameter, length of stickout, composition of flux and width and depth of flux layer. Among these current, voltage and speed are very important process variables. It is important to understand the effect of these process variables in order to achieve good weld quality. Consequently in this thesis experimental and numerical studies were conducted to understand the effect of process variables on weld qualities and to understand the thermo-mechanical behavior of the submerged arc welded joints. The main objective of the present investigation is to study the thermo-mechanical behavior and characterization of submerged arc welded joints and also to develop a suitable technique to minimize distortion.

In this research work, numerical models were developed based on actual experimental bead geometry to study the thermo-mechanical behavior of the weldments. The transient thermal analysis was conducted by incorporation of a moving volumetric heat source with temperature dependent material properties. The heat loss due to convection was considered all over the surface of the plate except at the weld zone. Also the effect of heat loss through fixture was neglected in this study. Subsequently, nonlinear elasto-plastic thermo-mechanical analysis was conducted to determine the residual stresses and distortion. The 3D nonlinear transient elasto-plastic thermo-mechanical model can be effectively used to predict the weld induced distortion in thick stainless steel plates fabricated using submerged arc welding. The results of thermal history and distortion obtained from numerical analysis were compared with the experimental outputs. The deviation of peak temperature between numerical analysis and experiments was found to be 4.75%, while the deviation between maximum predicted distortion and measured distortion was 9.82%.

The prediction of weld induced distortions of large structures using equivalent loading technique was performed by considering average plastic strains. Here the actual transient phenomena of the weld was simulated by considering the application of separate average loads at start, middle and end regions along the weld line. The results obtained from numerical model were validated with experimental results. This numerical model was further extended to a large welded structure for prediction of weld induced distortion using the proposed equivalent load based technique. For large welding structure, the proposed method was computationally more efficient than thermo-mechanical elastic plastic method. The numerical analysis in this work was performed using the finite element method based software package ANSYS^{TM}.

In the present experimental investigation square butt joints were fabricated with top and bottom reinforcements and without any edge preparation in order to reduce the time and cost involved with edge preparation. Single response and multi response optimization was carried out in order determine the most influential parameters. The mechanical properties of the weldment were studied according to ASTM E8 standard. From the single response optimization technique, it was found that welding current exhibits more to the tensile strength of the weld joint, while for multi response optimization it was welding voltage that contributes highest, followed by welding speed, welding current and length of stickout. It was understood from optimization techniques that the length of stickout shows least influence on weld qualities for a square butt joint. In order to minimize the angular distortion in butt welds a heat sink method was employed. To carry the experiment using heat sink method a complete heat sink setup was designed and developed. The conventional welds were compared with that of heat sink to study the effects of heat sink on angular distortion and mechanical properties. It was found that a maximum reduction in angular distortion of about 10.66% was obtained for welds fabricated with heat sink to that of conventional welds. Enhancement in ultimate tensile strength of 25.82% and yield strength of about 15% were observed for heat sink assisted welds in comparison with conventional welding. Heat sink was effective in removing heat from the welded region and thereby enhanced weld qualities and reduced the angular distortion for square butt joints.

Also in this investigation double side weld joints were fabricated and overall bead profile as well as mechanical properties was investigated. The maximum tensile strength of double sided welded joints reached up to 93.70% of the base material, while a marked enhancement in percentage of elongation of 50.2% to that of base material was observed. These prominent effects on mechanical properties may be due to second weld pass. Finally, the effect of surface active flux on weld bead geometry was studied. The surface active flux TiO_2 enhanced the bead width, while Cr_2O_3 increased the penetration. Also mixture of all fluxes gives better penetration as compared with individual flux. The surface active fluxes were beneficial in improving the bead geometry, without the increase of heat input.

Key words:

Transient thermal analysis, Non-linear, Elasto-plastic, Thermo-mechanical analysis, Equivalent loading technique, Distortion, Optimization, Weldment characterization, Heat sink, Double-sided-weld, Bead profile, Surface active element.