Abstract

Duplex Stainless Steel (DSS) is structural material used in multiple applications in a variety of industries such as construction, desalination plants, defence and military services, nuclear and pharmaceutical industries and marine engineering fields. Tungsten Inert Gas (TIG) welding is widely used for the joining of thin plates of stainless steel, however, it is not useful to join thick plates by a single pass. Activated TIG (A-TIG) welding capable to increases weld penetration up to 300 % as compared to the TIG welding process in a single pass. Due to its attractive penetration ability, A-TIG welding process is become the focus of research.

In the present investigation, to study the effect of weld parameters on 2205 grade of DSS TIG/A-TIG welding fixture has been manufactured. Trial experiments are performed to identify the range of process variables and fluxes. Box-Behnken design matrix is used to design the experiments in A-TIG welding. The systematic experiments are performed by varying welding current, torch speed and fluxes. The effect of these parameters on weld morphology, microstructure and mechanical properties is investigated. Experiments results indicate that oxide fluxes (TiO_2, SiO_2 and Cr_2O_3) not only increases the weld penetration but it also enhances the mechanical strength of weld joint. To improve and enhance the performance of weld joint the identification of optimum welding variables are very essential. For predicting the responses (depth of penetration, bead width, tensile strength and microhardness) mathematical models are generated for a given set of input variables using Response Surface Methodology (RSM). After performing multi-objective optimization, the predicted parameters are welding current of 201 amps, torch speed of 140 mm/min and flux as SiO_2. By maintain these parameters, optimal value of microhardness and bead width are 322 HV and 7.58 mm respectively. Moreover, maximum depth of penetration of 6.23 mm and maximum tensile strength of 775 MPa are observed. Conformity test results are in good agreement with the model predicted values. Hence, the proposed optimized framework can be used in A-TIG welding applications in the industry. A-TIG welding process extensively increases the weld penetration, however due to activated flux large amount of slug gets deposited on the weld surface. This shortcoming can be overcome by new variants of the A-TIG welding process known as the Flux Bounded TIG (FB-TIG) welding process.

The present study on FB-TIG welding explores the nature of flux gap and influence of different single constituent flux on weld bead geometry in 2205 DSS weld. Significant improvement in penetration depth is observed at a 2 mm flux gap with SiO_2 flux. The

constriction of arc and reversal of Marangoni convection is the most predominant mechanisms to improve the penetration depth. Furthermore, the influence of heat input (welding current), on weld bead geometry, metallurgical and mechanical properties (i.e. tensile strength and microhardness) has been investigated. The measured highest value of tensile strength and microhardness of FB-TIG weld is 772 MPa and 354 HV respectively under the different heat input weld conditions. However, compare to A-TIG welding less penetration is reported under the same heat input.

Therefore, a new chronological approach Flux Zone TIG (FZ-TIG) welding is studied based on the arc constriction mechanism. To generalize this welding procedure, it is very important to identify the perfect combination (outer and inner region) of fluxes. Furthermore, this needs to analyze the effect of the flux on weld bead geometry as well as influence on weld appearance. The study includes the effect of eight different combination fluxes (based on arc constriction theory) on weld bead geometry and appearance. After selecting the perfect combination flux for FZ-TIG welding comparison of TIG, A-TIG, FB-TIG and FZ-TIG weld are investigated concerning weld geometry. Moreover, the effect on mechanical properties, electrode geometry and weld bead appearance has been reported in A-TIG, FB-TIG and FZ-TIG 2205DSS weld metal under the same welding conditions. The highest D/W ratio is achieved in the FZ-TIG weld. This attributes to constriction of arc, insulating layer theory and reversal of Marangoni convection. Moreover, FZ-TIG weld joint revealed 2.3 % higher tensile strength when compare to A-TIG weld joint and 8% higher than that of FB-TIG weld joint.

Keywords: Activated Tungsten Inert Gas (A-TIG) Welding, Flux Bounded TIG (FB-TIG) welding, Flux Zone TIG (FZ-TIG) welding, Duplex Stainless Steel, Flux, Bead width, Penetration, Microstructures, Mechanical properties, Optimization.