ABSTRACT

Cladding is the method of depositing a layer of filler metal on a base metal by a welding process for the purpose of providing a corrosion resistant surface. It is used during the fabrication of engineering components to protect them from the effects of corrosion as well as to enhance their service life. Among the several welding processes used for stainless steel cladding Plasma Transferred Arc Welding (PTAW) process has been widely employed due to several advantages such as higher volume of metal deposition rates, achieving lower dilution levels, etc. However, there are some practical difficulties to control dilution which is influenced by applied heat input. Heat input can be controlled by proper selection of PTAW process parameters with the help of mathematical models correlating PTAW process parameters to clad bead geometry. Also, dilution influences the mechanical, corrosion and wear properties of the claddings. To address these problems, a systematic investigation is carried out to develop a mathematical model to establish an optimum PTAW welding procedure to improve mechanical, corrosion and wear properties of claddings.

In the present work, AISI 316 L stainless steel was deposited on to the structural steel plates by the PTAW process. It was observed through the literatures that the PTAW process parameters such as welding current, torch travel speed, powder feed rate, oscillation frequency and torch standoff distance had greater influence on the properties of clad bead. In order to predict appropriate PTAW process parameters for the desired clad bead quality experiments were conducted based on a five factor, five level, central composite rotatable design matrix by depositing a single bead on the surface of structural steel plate by the PTAW process. The clad bead parameters the penetration, reinforcement and bead width were measured by cross sectioning
the plates at their mid section and subsequently adopting standard metallographic procedures and also the dilution is calculated.

From the measured clad bead parameters mathematical models were developed using the Response Surface Methodology (RSM) to predict the effect of the process parameters on clad bead geometry and dilution. Minitab software is used for developing the models and the adequacy of the developed models were tested by using the Analysis of variance (ANOVA) method. The final models were arrived at using the significant coefficients determined using student t test. The desired values of the bead geometry variables could be predicted with the help of direct and interaction effects, in order to suit the requirements for a specific application. The response surfaces were drawn at the end of regression analysis for understanding the two way interactive effects of welding variables. Subsequently the PTAW process parameters were optimised using the Microsoft Excel software to achieve lower dilution.

Stainless steel claddings are produced at different heat input conditions namely low, medium, high and also at optimum heat input conditions. The XRD method was used to measure the surface residual stresses that have been developed in the stainless steel claddings. A surface hardening method called liquid nitriding was developed in order to enhance the surface hardness of the claddings. The weld claddings after liquid nitriding showed an excellent improvement in their surface hardness. The nitriding bath was formulated in such a way that the effluents contain only cyanate based compounds and not of cyanide based substantiating that the developed process is of eco friendly in nature.

The soundness of the claddings is tested by the side and face bend tests. Also, the wear rate of the claddings deposited at different heat input and optimum dilution conditions as well as in the as cladded and nitride conditions were estimated using a pin on disc wear testing machine. It was
found that the nitrided claddings produced at optimum heat input conditions possessed higher wear resistance. The Weight loss and the Electrochemical Potentiokinetic Reactivation (EPR) tests were also conducted as per ASTM procedures to predict the susceptibility of the claddings towards Pitting and Intergranular corrosion (IGC), in the as cladded and nitrided condition. The nitrided cladding produced at optimum heat input condition showed better resistance to the Pitting and IGC.

The microhardness distributions along various zones such as base metal, heat affected zone, fusion boundary zone and the cladded layer of the weld claddings deposited at low, medium, high and optimum heat input conditions are obtained using a microhardness tester. It is found that the variations in the microhardness of the cladding deposited at high heat input conditions are highly significant. Also, the hardness-depth profiles of the claddings in the as cladded and nitrided conditions are presented and the case depth of the cladding deposited at optimum heat input condition is found to be significant. The ferrite content of the claddings is measured using a ferritescope and it is found that ferrite number of the claddings deposited at low heat input condition is higher than that of other claddings.

Finally, microstructural analysis of the claddings deposited at different heat input and optimised conditions were carried out after colour etching as well as oxalic acid etching the specimens prepared as per standard metallographic procedure. It is found that claddings deposited at low heat input conditions have very fine grains of austenite. Vermicular and lathy ferrites are present in microstructure of claddings produced at optimum and low heat input conditions.