ABSTRACT

Process industries are associated with handling, storing and processing various types of chemicals such as alkalis hydrocarbons, inorganic chemicals and water with divergent qualities. In some of the process industries such as refineries and petrochemicals both extremes in terms of temperature and pressure are likely to coexist, for example cryogenic and fired heaters, and vacuum to high pressure as high as 200 bar. As a result the equipment handling these chemicals demand construction materials with good corrosion resistance and mechanical properties.

The structural steel plate IS:2062, which was widely used for such construction purpose, is generally cladded with austenitic stainless steel 316L. Because, by cladding the whole equipment or component need not be fabricated with costly anticorrosive material, hence economy is achieved.

In cladding by welding, the most important aspect is the dilution of the base metal, which has to be controlled effectively with in the optimum range for higher economy and to ensure the desired mechanical and corrosion resistance properties of the cladding.

For executing the above cladding process an automatic, two axes, digital, linear manipulator was designed and fabricated. FCAW process was used to deposit the clad metal as it offers low dilution with many other advantages. The influencing primary process variables such as voltage, wire feed rate, welding speed, nozzle to plate distance, and inclination of the electrode, which affect the bead parameters were identified. Using the FCAW power source and manipulator trial runs were conducted to find the upper and lower limits of the process variables. A five level five factor design matrix based on central composite rotatable design was evolved. Experiments were conducted as per the design matrix to clad with low carbon austenitic stainless steel- 316L.

The cladded structures were cross-sectioned at the center. The sectioned surface was polished and etched as per the standard metallurgical procedure to make the bead profile visible. The bead dimensions were measured for all the specimens, using profile projector and digital planimeter. The ferrite content of all the claddings was measured using ferritescope. Using the measured values mathematical models were developed with assistance of SYSTAT software to correlate the FCAW process variables with clad dimensions. The adequacy of these models was tested using F- test and R- test. Conformity test were conducted to find the validity of the developed models and it was found that the developed models were accurate. The direct effects of the process variables on each response were studied and represented in graphical forms. The interaction effects of the process variables on the bead parameters were studied by surface response methodology.

Using those mathematical models and MATLAB software the optimum dilution was found by keeping penetration, reinforcement, bead width, heat input and ferrite content as constraints and the corresponding process variables were estimated. Using these optimum process variables, the structural steel plates were again cladded. Second layer was also deposited to satisfy clad chemistry.
The sensitivity analysis was carried out to analyze the effects of relaxing the limits of the constraint function independently and collectively on the value of the objective function and results are presented in graphical forms and tables.

The validation of those models was further tested by scatter diagrams. Those models help to control the bead parameters, dilution, heat input and ferrite content. Also those mathematical models were very useful to the end users without wasting much time in carrying out the trial runs for optimizing the welding parameters.

The low, medium and high heat input, optimized single and double layers specimens were analyzed for their variation in chemical composition due to the variation in dilution and heat input.

The microhardness distribution at various zones of the cladding were obtained using Mitutoyo high resolution microhardness tester to ascertain the phases present. The maximum value of microhardness of claddings deposited at various heat input conditions were measured to analyze the microstructure.

Schaeffler, Delong, Hammer and Svensson, Espy and WRC-1992 Diagram were used to find out the amount of ferrite content of the clad. Modes of solidification were predicted from Schaeffler, Hammer, Svensson, and Espy equivalences. The low, medium and high heat input, optimized single and double layers specimens were selected and colour etched to find the primary and secondary microstructure of the overlay that resulted by different modes of solidification.

The susceptibility of cladding for corrosion were tested with the help of ACM Gill corrosion testing machine which has provision to acquire corrosion test data at very fast rate. This instrument was interfaced with the computer to acquire the corrosion test data and present it in the graphical or tabular form.

The double loop electrochemical potentiokinetic reactivation method was employed on as welded stainless steel overlays to test the susceptibility of the claddings to sensitization. The pitting corrosion test was also conducted for the above specimens to find the pitting corrosion resistance. The influence of heat input and process parameters on corrosion resistance were analyzed using acquired data from the corrosion test. It is found that all the specimens, except the high heat input were fully resistant to intergranular and pitting corrosion. The ductility of the stainless steel cladding was very important for the fabrication of the components. Hence it was checked by 180° side bend test. It was found that the clad specimens passed bend test showing good soundness of clad.

Similarly the bond strength was tested by shear test in a universal testing machine as per ASTM standards. It was found that the actual shear strength of the cladding tested was well above the standard minimum shear strength, which was an indication of good bond strength. The shear test was performed as per ASTM standards.

All the above analysis and results on stainless steel cladding are useful for the process and manufacturing industries for optimizing bead dimensions. These results are also useful to clad structural steel plates without weld defects such as microfissuring, hot cracking etc, but with good corrosion resistance.