CHAPTER 7

CONCLUSIONS

7.1 INTRODUCTION

In PTAW claddings, a foremost problem required to be tackled is dilution. Otherwise, it could significantly affect the corrosion, wear and mechanical properties of the claddings. The present study deals with the effect of PTAW process parameters such as welding current, travel speed, powder feed rate, torch oscillation frequency, and torch stand off distance on the clad bead parameters. The microhardness of the claddings were also investigated along with the corrosion and wear properties.

7.2 THESIS CONTRIBUTION

The operational rang for PTA clad valve seat a ring of size 92 x 76 x 15 mm was established for the production of PTA cladding. A five level five factor fractional factorial design matrix based on the central composite rotatable design (Box-Wilson) was evolved for the development of mathematical models. All the models developed are simple quadratic equations of first and second order relating process variables with the weld bead parameters and therefore can be easily utilized for predicting bead parameters for any given set of process variables. It was found that the reduced models are better than the actual full models because of achieving higher $R^2$ (adjusted) values with lower standard error of estimates. The precision of the mathematical models developed were tested by
conformity tests and the test results confirm that the accuracy of all the models is about 97%. Out of the five process variables considered, welding current had a significant positive effect but welding speed had an considerable negative effect on most of the important bead parameter. Total weld bead area increases when the welding current increases but the total weld bead area decreases when the welding speed increases. The value of dilution increases when welding current is increased. The penetration increases marginally when the welding current increases but the total area of weld bead increases predominantly. The clad bead width increased with the torch stand off value. The welding current and welding speed had a significant effect on most of the clad bead parameters. Response surface methodology was found to be a powerful tool for developing mathematical models and to predict accurately the direct and interaction effects.

The process parameters were optimized through excel solver for minimising the dilution percentage. The predicted response in minimizing the dilution is found to be 0.005%. The dilution obtained in the optimum condition is 1.76%.

The optimization module available in the MATLAB software package is found to be an easy and effective tool for optimizing the clad bead parameters. The complete information about the interdependences of the bead parameters was given by sensitivity analysis. The developed artificial neural network model was found to be more accurate to predict clad bead geometry than the regression model. The estimated error for dilution was 1.49%. The study exposed that the weld bead geometry can be predicted more accurately using the artificial neural networks. The average error on Comparison of experimental and predicted output of wear, was found to be 1.148%.
A three-level factorial technique can be employed easily for developing mathematical models for predicting wear behavior with in the optimal region of control process parameters for 410 L stainless steel cladding. The QA Six Sigma DOE IV PC software package can be effectively employed for the predictions of wear behavior and finding the corresponding optimum process variables. The average error for most of the models was 1.148\%.

The microhardness survey of different zones of the weldment was carried out to assess the nature of its microstructural constituents. Clad at an optimum HI of 10.89 kJ/mm and for a dilution of 6.8\%, the maximum hardness for the optimum HI specimen was found to be 59.4 HRC.

The specimens obtained from the cladded valve seat rings deposited at low, medium, high and optimum heat input conditions were used for corrosion studies. The resistance to pitting corrosion was tested using the polarization curves to assess the pitting behavior of clad 410 L stainless steel layer. For a dilution of 6.8\%, the average corrosion rate for the optimum HI specimen was found to be $16.63 \times 10^9$ mm/yr.

### 7.3 Scope for Future Research Work

Further research work may be carried out on the following aspects of 410 L stainless steel clad valve seat rings. The present research work may be extended to other martensitic stainless steel alloys along with necessary modeling and optimization. The effects of process parameters on modes of solidification of the clad layer may be studied. Optimization techniques like Genetic algorithm may be applied for the PTA process parameters. Metallurgical characterization could be done more thoroughly.
Based on the results of the studies, an exclusive and meticulous study could be carried out on all weld clad samples produced at different heat input conditions. A thorough study can be focused upon the claddings deposited at optimum heat input condition and its corrosion behavior can be analyzed. Finite element models can be developed to obtain bead parameters and microstructures.