CHAPTER 9

CONCLUSIONS

9.1 INTRODUCTION

In PTAW cladding, the dilution is a major problem to be addressed, which could otherwise seriously affect the corrosion, wear and mechanical properties of the claddings. In the present study the effect of PTAW process parameters such as welding current, travel speed, powder feed rate, torch oscillation frequency and torch standoff distance on the bead parameters, corrosion and wear properties of the claddings, were investigated.

9.2 THESIS CONTRIBUTIONS

The working zones have been established for production of PTAW cladding based on minimum dilution, better bead appearance and with minimum defects. The most significant process variables have been identified for conducting the experiments. Out of the five process variables considered the welding current and the torch standoff distance has a significant effect on deciding the bead parameters, mainly dilution. Mathematical models were developed for the prediction of clad bead geometry of the stainless steel claddings using multiple regression analysis and they were tested using the ANOVA method. From the models the direct and interaction effects, desired values of penetration and dilution can be predicted in order to suit the requirements of the specific application. The process parameters were optimized through excel solver for minimising the dilution percentage. The accuracy of the models was determined by conducting conformity test runs using the same welding machine and the results showed the models are accurate.
From the present investigation, the value of the maximum compressive residual stress is more for the low heat input specimen when compared to the other specimens cladded at different heat inputs. Also, for the specimen cladded at higher heat input, higher tensile residual stresses were present on its surface thereby indicating the usage low heat input would reduce the surface tensile residual stresses. Liquid nitriding of stainless steels produced a compound or epsilon layer and a diffusion layer which has resulted in hardness improvement on the surface of stainless steels. Compared with the surface hardness of a virgin stainless steel, a tremendous increase in the surface hardness was obtained for the liquid nitrided cladding.

From the bend tests, it was observed that the cladding produced at optimum heat input condition possessed good ductility compared to the other conditions. The liquid nitrided cladding produced at optimum heat input condition showed excellent reduction in wear rate during the dry sliding wear conditions. Hence, it could be concluded that cladding of AISI 316L stainless steel with optimised PTAW process parameters combined with optimised liquid nitriding have greatly improved the surface properties of the cladding. This improvement in the tribological properties of the liquid nitrided claddings justifies their applicability in high sliding and rotary environments.

The cladding produced at optimum heat input and liquid nitrided was found to possess excellent pitting corrosion resistance. Also, in the potentiodynamic polarisation test carried out for investigating the susceptibility of pitting corrosion attack as per ASTM G-5, an increase in the rest potential and the pitting potential were noticed in the cladding produced at optimum heat input condition. This proclaims that the cladding is nobler and possesses increased pitting corrosion resistance. In the investigation for detecting the susceptibility of intergranular corrosion attack with the Huey’s test, though the average corrosion rates of all the claddings were within the
ASTM acceptance limits it could be concluded that an increased intergranular corrosion resistance was possessed by the cladding produced with low and optimum heat input. In the double loop EPR test, the ratio of the degree of sensitisation (Ir/Ia) was found to be very lower for the cladding produced with optimum heat input and nitrided condition, which revealed the cladding, is less prone to intergranular corrosion.

From the metallurgical analysis, it was found that dilution of stainless steel claddings produced by PTAW with different heat inputs has significant effect on their hardness and microstructure. The stainless steel claddings were characterised to evaluate the properties influencing their corrosion and wear resistance. A significant increase in the hardness is found in the cladding deposited at high heat input condition. This could be due to the formation of an Intermediate Mixed Zone (IMZ) comprising of a hard layer of martensite. The increase in the ferrite content in the cladding deposited at low heat input condition revealed that it is highly prone to hot cracking. The microstructure of the cladding produced at optimum heat input condition revealed the presence of vermicular morphology of ferrite in the austenite matrix which showed its improved quality than the claddings that are deposited at different heat inputs.

9.3  SCOPE FOR FUTURE RESEARCH WORK

The present research can be extended to other austenitic stainless steel alloys along with the necessary modelling of the process parameters and their optimisation. The random search optimization techniques like the genetic algorithm and the artificial neural network can be applied for the optimization of the process parameters. The Finite Element Method (FEM) can be used to analyse the influence of the process parameters and their effect on the clad bead geometry. It can also be used for the prediction of
microstructure and for the estimation of the residual stresses present in the cladding.

The liquid nitriding process can be performed by varying the salt concentrations and the improvement in the surface hardness without damaging the corrosion resistance of the claddings. Further investigations can be done on crevice and stress corrosion cracking that might also occur in the stainless steel cladding and their influence on the corrosion resistance properties of the cladding can be investigated. Galling wear tests can be conducted for the claddings and the effects of process parameters on the wear behaviour can be modelled and investigated. Metallurgical characterisation can be more thoroughly done with XRD analysis and SEM-EDAX examinations of the claddings to enable a more detailed metallurgical analysis.

Based on the results of studies carried out on all the weld cladded samples produced with different heat inputs, an exclusive thorough study and focus can further be made with the optimised heat input samples and the various mechanisms like wear, corrosion and other relevant properties can be analysed with different PTAW process parameters.