CHAPTER 7

CONCLUSION

7.1 INTRODUCTION

The following conclusions have been arrived after analyzing the various aspects of gas metal arc welding of SS409M ferritic grade stainless steel. The conclusions are development of mathematical models and optimization of weld bead geometry, development of neural network model, evaluation of mechanical properties like tensile test, impact test and bend test, and metallurgical properties like % of ferrite, micro hardness and microstructure stated chapter-wise.

7.2 DEVELOPMENT OF MATHEMATICAL MODELS AND OPTIMIZATION OF WELD BEAD GEOMETRY (CHAPTER 3)

- The working range was established for GMAW of 4 mm thick SS409M ferritic grade stainless steel sheets based on bead appearance and lack of visible defects.
- Three factors, five levels factorial design matrix could be effectively used for the development of mathematical models both in natural form and coded form.
The models developed for the GMAW process for welding SS409M plates were simple quadratic equations of first and second order, correlating the welding parameters with bead dimensions of weld bead width, penetration, reinforcement and weld bead area. These models can be readily used for predicting the bead dimensions for any given set of process variables.

The accuracy of the developed models was tested by conformity tests for the two sets of experiments and the results reveal that the precision of all the models was around 97%.

In the experiments, it was found that the reduced models (with significant coefficients only) are better than the actual full models because of higher adjusted R²-values with lesser standard error of estimates.

In the GMAW process when the welding speed is increased, the responses viz. weld bead width, penetration and weld bead area was decreased.

When the welding torch as at vertical position 90° better penetration was achieved.

When the wire feed rate increased results in increase in weld bead width, reinforcement and weld bead area.

In general medium scale industries are using analog GMA welding machines due to the cost factor. In analog machines setting of accurate current is not possible because of fluctuations. Hence wire feed rate can be accurately used to control the welding parameters, because welding current and wire feed rate are directly related to each other.

It is found that there is strong interactive between welding speed and wire feed rate for the responses mainly weld bead width, penetration and weld bead area.
The three dimensional surface graphs clearly show the interactive influences of diverse input parameters used on the bead geometry.

The developed reduced models can be utilized for optimizing the process parameters. Design expert software can be effectively employed for the optimization of bead parameters and for finding the corresponding optimum process variables.

The conformity tests show that the optimum parameters settings are accurate and the error is less than 3%.

7.3 DEVELOPMENT OF NEURAL NETWORK MODEL (CHAPTER 4)

Neural networks can be best adopted to model the input-output relationship of nonlinear and interconnected systems like welding applications.

Training of the network was done based on the back propagation algorithm.

The back propagation neural network model was developed to predict the bead dimensions of for weld bead width, penetration and weld bead area in SS409M ferritic grade stainless steel as a function of wire feed, welding speed and torch angle.

While comparing the experimental data and the predicted data from the trained network, the maximum percentage error was found to be around 1.90%.

The prediction results of the model are close to the experimental results.

Training the network gives best results when the training data are normalized, and the range of data is between 0 and 1.
7.4 EVALUATION OF MECHANICAL PROPERTIES 
(CHAPTER 5)

- Tensile test samples and impact test samples were selected based on the heat input. The wire feed rate and welding speed was a major source to control the heat input.
- Tensile test results of the GMAW process parameter on SS409M ferritic grade stainless steel showed that failure had taken place in the base material.
- From the tensile test results it was found that the tensile strength of 529.58 N/mm\(^2\) occurred at low heat input of 54.79 kJ/mm.
- It was observed that in specimen no.11 fracture occurred at the weldment because of the maximum heat applied.
- Impact test gave the maximum impact value of 304 joules for the heat input of 92.71 kJ/mm.
- The bend test results showed no cracks or open discontinuity as a result of high ductility.

7.5 EVALUATION OF METALLURGICAL PROPERTIES 
(CHAPTER 6)

- The wire feed rate and welding speed was a major source to control the heat input. It was observed that the ferrite content decreased with the increasing heat input.
- Three factors, five levels, central composite design matrix is effectively used for developing mathematical model to predict FN.
- At the vertical position of the welding torch, maximum heat is propagated on the weld metal, which resulted in reduced (57 %) ferrite levels.
At the high heat input condition the cooling rate is slow, resulting in more transformation of ferrite to austenite resulting in reduced % of ferrite.

If the welding speed increases to certain level, % of ferrite increases significantly. The reason is due to the high cooling rate at a higher welding speed which holds back solid state transformation of ferrite.

The microhardness profiles of the GMAW welded specimens showed no significant difference between hardness of the base material and that of the weld metal.

Hardness of the base metal was slightly higher than that of the base metal regardless of heat input.

For the various heat inputs used in the study, the microhardness values along the fusion line were around 275.4 VHN to 325.7 VHN and it was observed to be around 145.3 VHN to 171.6 VHN for the base material.

It is observed that if the heat input increases, the size of the bead also increases. Since the heat input is high, the volume of base metal melted is also high.

It was noticed that the higher the welding speed, the liner cellular dendritic grains are obtained. This is ascribed to the intensity of both solidification as well as cooling rates caused by minimal heat input resulting from elevated welding speed (Hongxiao et al., 2009).

Coarse ferritic grains were observed near the fusion boundary line in the high heat input samples.

Very fine dendritic growth was observed starting from the fusion line extending towards the center line. The absence of distinct heat affected zone was noticed.

At low heat input, the solidification results in very fine dendritic arms. Dendritic arm spacing will be inversely proportional to the cooling rates.
7.6 SCOPE OR FUTURE WORK

- Varying nitrogen and argon content in shielding gas, bead geometry and corrosion studies on weldment can be studied.
- Comparison between single pass and multi pass welding can be studied on various properties of weld metals.
- Simulated Annealing, Ant colony optimization, Genetic Algorithm, Fuzzy Logic and Artificial Intelligence can be used for the optimization of GMAW process parameters.
- The studies performed can be attempted by varying the plate thickness as a parameter.
- Dissimilar metals can be weld with SS409M can be studied.
- Hybrid welding can be done with the same parameters and compare with the GMAW to optimize the welding process.
- Auger Electron Spectroscopy can be employed to study the passive film formation in the GMAW weld metal when it is exposed to the corrosive environment.
- Wear tests can be conducted for the weld metal and the effects of process parameters on the wear property can be studied.
- Finite element analysis to predict the residual stresses in the weldment can be studied. Residual stresses and distortion could be obtained by finite element simulation.
- Studies on effect of GMAW on micro serration of chromium, molybdenum, phosphorous & sulphur elements in the ASS (316l) can be carried out.