CHAPTER 7

CONCLUSION AND SCOPE FOR FURTHER RESEARCH

In this research modelling and process parameters optimization of CTIG, PTIG and HPTIG welding processes for super alloy IN 718 have been performed based on the research objectives. To predict the output responses effective prediction models have been developed and all the models are accepted, since those models are predicted the output responses with minimum error. The contribution of process parameters on output responses are found out. The optimum combination of process parameters are identified to obtain optimum output responses. In order to validate the optimum combination of process parameters, confirmation tests are performed. All the confirmation test results are very close to the experimental optimum results. Therefore the identified optimum combinations of process parameters are accepted to achieve optimum output responses.

7.1 FINDINGS ON CTIG WELDING PROCESS

RSM Based modelling and Optimization of CTIG Welding Process for Room Temperature Mechanical Properties

- The super alloy IN 718 sheets are welded successfully using CTIG welding process.

- Based on the experimental results it is understood that, the maximum room temperature the mechanical properties UTS, YS, E and MH are obtained for the weld joints welded using Ar (70%) + He (30%) as a shielding gas (G). Therefore Ar (70%) + He (30%) shielding gas is recommended for obtaining optimum room temperature mechanical properties. It is also found from experimental results that, room temperature mechanical properties increases significantly with current, welding speed and decreases with welding voltage.

- Effective prediction models have been developed to predict room temperature mechanical properties. The percentage of error for experimental and predicted outputs is calculated. The maximum percentage of error is 6.3%. Hence it is proved that the predicted room temperature mechanical properties are almost equal, when compared with experimental results.

- Experimentally optimum room temperature mechanical properties are obtained, when Current (I) = 60 Amp, Voltage (V) = 10 Volts, Speed (S) = 0.8 mm/sec and Shielding Gas (G) = Ar (70%) + He (30%).

214
Based on RSM methodology optimum combination for obtaining optimum room temperature mechanical properties are I 60 Amp, V = 9.6 Volts, S = 1 mm/sec and G = Ar (70%) + He (30%). The obtained room temperature mechanical properties are UTS 1442 MPa, YS 1218 Mpa, E 8.2% and MH 437 VHN.

It is noted that optimum output response obtained from RSM is correlate very close with experimental optimum output responses. This specifies that the optimization methodology proposal by RSM is effective.

RSM Based Modelling and Optimization of CTIG Welding Process for Subzero (-196°C) Tensile Properties

It is found from experimental results that welding parameters I and V have negative effects on subzero tensile properties where S and G has a positive effect on subzero tensile properties.

Regression models are developed to predict UTS, YS, and E within the range of experimental conditions.

The experimental values and prediction values are very close, hence the models are valid one to predict the subzero tensile properties within the range of experimental conditions.

The optimum subzero tensile properties obtained from experimental method is UTS = 1499 MPa, YS = 1275 Mpa and E = 13.7% when I = 60 Amp, B = 10 V, S = 0.8 mm/sec and G = Ar (70%) + He (30%).

The optimum subzero tensile properties obtained from RSM based methodology was UTS = 1490 MPa, YS = 1274 Mpa and E = 13.6%, when I = 60 Amp, V = 12V, S = 0.87 mm/sec and G = Ar (70%) + He (30%).

The experimental optimum and predicted optimum values have good correlation between them; therefore RSM based optimization is accepted one.

RSM Based Modelling and Optimization of CTIG Welding Process for Bead Profile Study

It is clearly understood from experimental results that the joints which have been welded using Ar and Ar (70%) + He (30%) as shield gas have achieved good D/W.

Experimental results reveal that the D/W decreases with I, V and increases with S.

Mathematical models have been developed to predict bead profile dimensions like BD, BW and D/W with 95%confident level.

The optimum D/W obtained from RSM methodology was 0.489 when I, V, S and G was 60 Amp, 8V, 1mm/sec and Ar (70%) + He (30%) respectively.
The experimental optimum D/W is very close to RSM optimum D/W, therefore the optimum combination of welding parameters obtained by RSM methodology is accepted to achieve optimum D/W.

Grey Based Modelling and Optimization of CTIG Welding

- GRA has been performed to convert multi responses like room temperature mechanical properties, sub zero tensile properties and bead profile study in to a single response.

- Effective GRA based prediction models have been developed to predict the grade of the output responses.

- The experimental grade value and predicted grade values are compared to calculate the error. The maximum error value is 4.96%, hence the prediction model is valid to predict the grade value within the range of experimental condition.

- To find the influences of welding parameters on output responses, ANOVA has been performed. The result of ANOVA reveals that the G (66.6%) contributed a significant influence on output responses followed by I (17.4%) S (9%) and V (6%).

- The optimum combination of welding parameters has been identified based on RSM and GRA for obtaining optimum room temperature mechanical properties, subzero tensile properties and bead profile dimensions.

- The optimum combination of welding parameters for obtain optimum output responses is I = 60 Amp, V = 8V, S = 1 m/sec, G = Ar (70%) +He (30%).

- The optimum combination of parameters are validate through conformation test. The result obtained from conformation test was good correlation with predicted and experimental optimum values of output responses. Hence it is concluded that the above combination of parameters are valid to achieve optimum quality IN718 weld joints using CTIG welding process.

7.2 FINDINGS ON PTIG WELDING PROCESS

RSM Based Modelling and Optimization of PTIG Welding Process for Room Temperature Mechanical Properties

- The quality super alloy IN 718 joints have been fabricated successfully using PTIG welding process

- The experimental results clearly shows that, the joints which have been welded by using Ar or Ar (70%)+He (30%) as a shielding gas have obtained good room temperature mechanical properties than He as a shielding gas.
• Room temperature mechanical properties increase with decreasing Peak Current (P), Base Current (B), Pulse on Time (T) and increasing Pulse Frequency (F).

• The mathematically relationships are generated to predict room temperature mechanical properties. All the models can be efficiently utilized to predict the room temperature mechanical properties of PTIG welded joints at 95% confident level.

• The optimum room temperature mechanical properties obtained from experimental method is UTS = 1427 MPa, YS = 1181 MPa and E = 7.9% when P = 55 Amp, B = 25 Amp, T = 50%, F = 4 Hz and G = Ar.

• The optimum room temperature mechanical properties obtained from RSM based methodology is UTS = 1453 MPa, YS = 1192 MPa and E = 8.3%, when P = 55 Amp, B = 25 Amp, T = 40%, F = 6 Hz and G = Ar (70%) + He (30%).

• The optimum room temperature mechanical properties obtained from RSM are compared with experimental optimum results. It is found that the optimum room temperature mechanical properties obtained from RSM are slightly higher than the experimental optimum values. Thus that the proposed RSM optimization methodology is effective one.

RSM Based Modelling and Optimization of PTIG Welding Process for Subzero (-196°C) Tensile Properties

• The super alloy IN 718 sheets have been successfully welded to evaluate the tensile properties at -196°C.

• The shielding gases Ar and Ar (3%) + He (30%) have achieved favourable subzero tensile properties than He.

• It is very clear from experimental results that the subzero tensile properties increases significantly with F and decreases with P, B and T.

• To predict and reduce the experimental cost, simple effective mathematical relations have been developed.

• The maximum obtained error percentage of prediction models are less than 5%, hence the models are suitable to predict the subzero tensile properties.

• The optimum subzero temperature tensile properties obtained from experimental method is UTS = 1501 MPa, YS = 1243 MPa and E = 15.6% when P = 55 Amp, B = 25 Amp, T = 50%, F = 4 Hz and G = Ar.

• The optimum subzero tensile properties obtained from RSM based methodology is UTS = 1502 MPa, YS = 1245 MPa and E = 15.7%, when P = 55 Amp, B = 25 Amp, T = 40%, F = 6 Hz and G = Ar (70%) + He (30%).
• The experimentally obtained optimum and RSM based optimum subzero tensile properties have good association between them. Thus RSM methodology is effective tool to optimize the subzero tensile properties of PTIG welded IN718 alloy.

**RSM Based Modelling and Optimization of PTIG Welding Process for Bead Profile Study**

• It is found from experimental results that the welding parameters B, P, T and F have positive effects on BD.

• The BW increases with P, B, T and decreases with F

• The D/W increases with increasing F and decreases with increasing P, B and T.

• The shielding gases Ar and Ar (3%)+He (30%) have obtained favourable D/W than He.

• Efficient regression model have been developed to predict the bead profile dimensions. All the developed model have been accepts to predict the bead profile dimensions with minimum error value.

• The optimum D/W obtained from experimental method is 0.79, when P = 55Amp, B = 25Amp, T = 50%, F = 4Hz and G = Ar

• The optimum D/W obtained from RSM based methodology is 0.792, when P = 55 Amp, B = 42 Amp, T = 40%, F = 6 Hz and G = Ar (70%) + He (30%).

• The experimental optimum D/W is compared with predicted optimum and found average difference was less than 5% this indicates that optimum combination of parameters identified by RSM is effective.

**Grey Based Modelling and Optimization of PTIG Welding**

• Experimental grade values have been calculated based on the output values of room temperature mechanical properties, subzero tensile properties and bead profile study.

• Efficient prediction model has been developed to predict the grade. Based on the predicted values of grade error percentage is calculated. The maximum obtained error value is 4.76%

• ANOVA has been carried out to find the contribution of PTIG of welding parameters on output responses. The F value of ANOVA noticeable make known that P and F contribute more to output responses followed by T, G and B.

• The unique optimum combination of welding parameters has been identified to obtain optimum output from all the three different types of studies. i.e., P = 55 Amp, B = 25, T = 40%, F =6 Hz and G = Ar (70%) + He (30%).
• Experimental validation has been done to ensure the suitability of optimum combination of parameters. The result obtained from experimental validation is slightly higher than predicted and experimental optimum values of output responses. Hence it is concluded that the above combination of parameters are valid to achieve optimum quality IN 718 weld joints using PTIG welding process.

7.3 FINDINGS ON HPTIG WELDING PROCESS

RSM Based modelling and Optimization of HPTIG Welding Process for Room Temperature Mechanical Properties

• It is understood from experimental results that room temperature mechanical properties increases with decreasing Peak Current (P), Base Current (B), Pulse on Time (T) and increasing Pulse Frequency (F). The welding parameter shielding gas is not make any noticeable effect on room temperature mechanical properties.

• Efficient prediction models have been developed to predict room temperature mechanical properties. The percentages of error for experimental and predicted outputs are calculated. The maximum percentage of error is 3.7%. Hence it is proved that the predicted room temperature mechanical properties are almost equal, when compared with experimental results.

• The optimum room temperature mechanical properties obtained from experimental method is UTS = 1499 MPa, YS = 1247 MPa and E = 9% when P = 55 Amp, B = 25 Amp, T = 50%, f = 1200 Hz and G = Ar

• The optimum room temperature mechanical properties obtained from RSM based methodology is UTS = 1498 MPa, YS = 1245 MPa and E = 9.2%, when P = 55 Amp, B = 25 Amp, T = 40%, F = 2000 Hz and G = Ar (70%) + He (30%).

• The experimental optimum room temperature mechanical properties are very close to RSM optimum output values, therefore the optimum combination of welding parameters obtained by RSM methodology is accepted to attained optimum room temperature mechanical properties.

RSM Based Modelling and Optimization of HPTIG Welding Process for Subzero (-196°C) Tensile Properties

• Experimental results reveals that the subzero tensile properties increases significantly with F and decreases with P, B and T.

• Simple effective prediction models have been developed to predict subzero tensile properties.
• The maximum obtained error percentage of prediction models were 4.97%, hence the models are suitable to predict the subzero temperature tensile properties.

• The optimum subzero temperature tensile properties obtained from experimental method is UTS = 1571 MPa, YS = 1303 MPa and E = 20.8% when P = 55 Amp, B = 25 Amp, T = 50%, f = 1250 Hz and G = Ar.

• The optimum subzero temperature tensile properties obtained from RSM based methodology is UTS = 1569 MPa, YS = 1301 MPa and E = 19.9%, when P = 55 Amp, B = 25 Amp, T = 40%, f = 2000 Hz and G = Ar (70%) + He (30%).

• The experimentally obtained optimum and RSM based optimum subzero tensile properties have good association between them. Thus RSM methodology is effective tool to optimize the subzero tensile properties of HPTIG welded IN 718 alloy.

**RSM Based Modelling and Optimization of HPTIG Welding Process for Bead Profile Study**

• The experimental results clearly reveals that the BD increases with increasing welding parameters P, B, T and f and BW decreases with decreasing P, B, T increasing f.

• The D/W decreases with decreasing F and increases with decreasing P, B and T.

• The welding parameter shielding gas not makes noticeable effect on bead dimensions.

• Efficient regression model have been developed to predict the bead profile dimensions. All the developed models have been accepts to predict the bead profile dimensions with maximum error value of 5.71%.

• The optimum D/W obtained from experimental method is 0.965, when P = 55 Amp, B = 25 Amp, T = 50%, f = 1200 Hz and G = Ar.

• The optimum D/W obtained from RSM based methodology is 0.950, when P = 55 Amp, B = 42 Amp, T = 40%, f = 2000 Hz and G = Ar (70%) + He (30%).

• The experimental optimum D/W is very close to RSM optimum D/W, therefore the optimum combination of welding parameters obtained by RSM methodology is accepted to achieve optimum D/W.

**Grey Based Modelling and Optimization of HPTIG Welding**

• Efficient GRA based prediction models have been developed to predict the grade of the output responses using RSM.

• The experimental grade value and predicted grade values are compared to calculate the error. The maximum error value is 4.76%, hence the prediction model is valid to predict the grade value within the range of experimental condition.
• ANOVA has been performed to find the contribution of HPTIG welding parameters on output responses. The result of ANOVA reveals that the P (38.8%) and f (26.8) contributed a significant influence on output responses followed by T (15.4%) B (9.9%) and G (7.3%).

• The optimum combination of HPTIG welding parameters has been identified based on RSM and GRA for obtaining optimum room temperature mechanical properties, subzero tensile properties and bead profile dimensions.

• The optimum combination of welding parameters to obtain optimum output responses is P = 55 Amp, B = 25 Amp, T = 40%, f = 2000 Hz and G = Ar 70%+He (30).

• The optimum combination of parameters are validate through conformation test. The result obtained from conformation test is good correlation with predicted and experimental optimum values of output responses. Hence it is concluded that the above combination of parameters are valid to achieve optimum quality IN718 weld joints using HPTIG welding process.

7.4 SVM BASED PREDICTION AND CLASSIFICATION OF OPTIMUM PROCESS VARIANT

• Based on the conformation test results optimum processes variant has been identified. It found from conformation test results that HPTIG welding process is identified as a optimum process variant.

• SVM based prediction has been performed for predict the output responses of optimum process variant and found good correlation with experimental output.

• Based on SVM classification optimum group of parameters have been identified. From the optimum group based on the grade value optimum combination of parameters have been identified.

• The optimum welding parameters identified based on SVM classification is P = 55 Amp, B = 25, T = 50%, f = 1200 Hz and G = Ar. The conformation test has been carried out for SVM optimum parameters and found it is very close to experimental optimum and RSM GRA optimum results. Hence SVM is the accepted methodology to optimize the welding parameters for obtain quality weld joint.

7.5 RECOMMENDATIONS FOR FURTHER RESEARCH

• With our encouraging experimental results, this work can be extended to perform metallurgical study on CTIG, PTIG and HPTIG welded IN718 alloy and other materials and alloys.
• In this research room temperature and subzero temperature performance analysis of IN 718 alloy has been performed. This research work can be extended for performance analysis at elevated temperature.

• The experimental study can be performed with higher thickness plates of IN 718 alloy.

• The effect of process parameters such as size of the electrode, gas flow rate and welding position also investigated.