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OPTIMIZATION OF PROCESS PARAMETERS FOR GAS METAL ARC WELDING OF DISSIMILAR AA7075 AND AA6063 ALUMINIUM ALLOYS USING ARTIFICIAL NEURAL NETWORKS (ANN)

G. Swaminathan[1], A. Mathivanan[2], S.D. Kumar[1], C. Uthirapathy[1]

[1]Assistant Professor, Department of Mechanical Engineering, SRM University, Ramapuram Campus, Chennai-89, India. [2]Professor, Department of Mechanical Engineering, SRM University, Ramapuram Campus, Chennai-89, India. ssnathan79@gmail.com, mathivanana@gmail.com

ABSTRACT

The present investigations deal with the effect and optimization of gas metal arc welding parameters on the mechanical properties in welding of dissimilar AA7075 and AA6063 Aluminum alloys. The process parameters used are current, voltage and gas flow rate and Taguchi experimental design method were followed. Tensile strength and Impact strength have been found for the optimum welding parameters. Further an *Artificial Neural Network* model was developed for the analysis and simulation of the correlation between process parameters and mechanical properties. The input for the model is current, voltage and gas flow rate and the output for the model is Tensile and Impact strength. The combined influence of current, voltage and gas flow rate on the mechanical properties of the joint was simulated. The model can calculate tensile strength and impact strength as functions of process parameters. Lastly a comparison was made between the measured and calculated value and it was found that the calculated results were in agreement with the measured data.

Key Words Welding current, Welding Voltage, Gas flow rate, ANOVA, S/N ratio, *Aritificial Neural Network.*

INTRODUCTION

Aluminium alloys are mainly being used in Ship building industry because of its light weight compared to steel. Aluminum alloys are supportive in reducing weight, excellent corrosion resistance and very good strength to weight ratio. It is most difficult to weld the Aluminium alloy because of aluminium oxide form over the surface. The principle of MIG welding shows Figure-1.

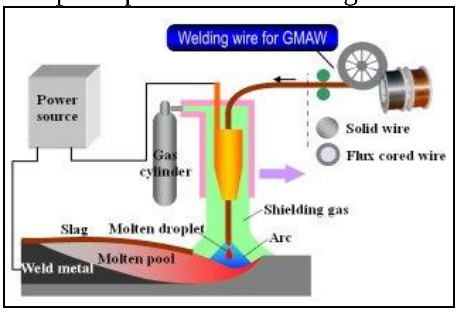

Figure 1: Principle of GMAW

The effects and properties of AA6061 for which parameters welding current, voltage and gas flow rate exhibit large micro structural changes, as high welding current will result in high heat generated and weakening of weld formation, so a balance is needing to be struck between welding parameters and mechanical properties. They concluded that with increase in welding current and voltage there is slight decrease in tensile strength (Chandan Kaushal, et al., 2015). The GMAW process parameters of aluminium alloy by using L9 Orthogonal Array to find out UTS and also perform confirmatory experiment to find out optimal run set of current, voltage and gas flow rate. Gas flow rate significantly affects the tensile strength, yield strength and elongation at 18l/min, 180A and 24-28V (Venkadeshwaran, et al., 2015). The MIG and MAG and found that the low ionization potential of argon helps create an excellent current path and superior arc stability. The tensile strength and hardness value was found to have maximum under medium current and low voltage conditions. The optimum welding configuration was found as 105A welding current, 18V arc voltage and 2.00 mm/s weld speed (Rakesh Ranjan, et al., 2016). The effects of welding current and arc voltage of GMAW. While increasing of the arc voltage and welding current simultaneously increases the welding heat input, so the chance of defects formation such as burn through in weld metal also increases. They concluded that aluminium alloys are susceptible to large microstructural changes after welding (Chandan Kaushal et al., 2014). The influences of shielding gas on GMAW process of precipitation hard enable Al alloys (AA6082 and AA7022). Pure Ar of different gas flow 0-35 l/min, different Ar+He mixtures, up to 70 % He, active Ar+CO_2 gases were used He content in Ar+He shielding gas mixtures is changing heat input and therefore weld shape. Increase of He content improves heat transfer efficiency, weld penetration, weld width etc. Optimum Ar shielding gas flow was found to be 15 l/min for used welding parameters. The experiments with varying He ratio in Ar gas has proved that increase of He content increases heat transfer into the weld, increases heat input. The increased heat input is caused by properties of He, higher ionization potential (i.e. arc voltage) and by thermal conductivity. Overall the He use can improve welding efficiency and speed. He gas is advantageous also for improved weld shape and decrease of porosity (Ladislav Kolarik, et al., 2015). The effect of process parameters on Mechanical and Metallurgical Properties of Aluminium Weld Joints using GMAW. Argon is used as shielding gas. The process parameters used are Current, Voltage and Welding Speed. The results showed that due to the affinity of aluminium for oxygen, it cannot successfully be arc welded in an air environment. If fusion welded in a normal atmosphere oxidization readily occurs and this results in both slag inclusion and porosity in the weld, greatly reducing its strength (Hemant Chauhan, et al., 2014). The process parameters by using Argon as shielding gas for AA6063 and the parameters selected are current, voltage and gas flow rate. The Tensile and hardness tests were conducted on the welded joint. For tensile strength the percentage of current contribution is higher and for hardness voltage percentage is higher (Brahmanandam, et al.,2016). GMAW method and the effect of the process parameters on the joints has been studied, however there is a necessity to study the effect of the same on producing joints of AA7075 and AA6063 due to their heavy usage in boat truck, tower building, ships, electric car, furniture, machine parts, automobile frames and aero plane industrial applications. With this reason the research has been conceded out to study the effect of process parameters on creating high strength aluminium alloy joints.

MATERIALS AND METHODS

In this investigation, aluminum alloy of AA7075 and AA6063 plate with thicknesses of 6 mm were used. The plate was cut to required (100x50x6 mm) size by power hacksaw cutting and followed by grinding to remove the burr. These plates were cut into coupons with a 30° bevel of each plate to provide 60° groove angle for a single-V-groove butt joint configuration was used to fabricate the joint. The joint was initially obtained by locking the plates in position using mechanical clamps to avoid the bend during welding process. Edges were cleaned in order to remove dirt, oil and grease. The plates are then kept on welding table and maintained the root gap and alignment. The selection of the welding electrode wire based on the matching the mechanical properties and physical characteristics of the base metal, weld size and existing electrode inventory (Nirmala, et al., 2013). The joints were fabricated using GMAW machine by single pass method. The process parameters combination showed in Table 1. After V groove made on the materials the AA7075 and AA6063 placed on the table by keeping 2mm root gap for better weld joining. The AA7075 was placed on the left side and AA6063 was placed on right side. Initially the ends of the materials were tackling for parallel weld passage on the root gap. Welding current and voltage were set through the knob situated at the machine. And for Gas flow rate the settings were made on the Cylinder head. For every specimen we need to set parameters accordingly to the process levels. The device used for MIG welding materials was TOSHON 400 with IGBT technology adopting inverter, easy arc-start; Reliable and stable performance. Feedback circuit, constant voltage suitable for wide voltage range (± 15%). Controlled by electronic ballast, spark, deep welding pond, beautiful weld seam.

TESTING

Tensile test: Tensile testing is some way of evaluating welds strength and to find the ability of the welded material up to which it can resist two opposite forces acting on it. Specimen were prepared using Milling machine as per ASTM E8 standard. Tensile test was made using Universal Testing Machine (UTM). The results for 27 samples welded at different combinations of current, voltage and gas flow rate were shown in table 1 Impact test is the purpose of determine the amount of energy observed by a material that ability of material to resist at high rate loading during fracture. Weld properties behave differently if a pre-existing fracture in the weld is exposed to a sudden impact. Specimen was prepared for Charpy impact test as ASTM standard.

Table 1: Process Parameters combinations and Test Results

Trail no	Current, A	Voltage, V	Gas flow rate, L/min	Yield strength Mpa	% of Elongation	Impact strength Joules
1	100	20	13	154.66	12.76	5
2	100	20	14	152.24	9.67	6
3	100	20	15	153.89	10.75	7
4	100	22	13	154.56	12.98	6
5	100	22	14	152.78	10.34	6

6	100	22	15	154.32	12.67	7
7	100	24	13	155.74	12.34	4
8	100	24	14	151.56	8.87	4
9	100	24	15	153	10.23	4
10	110	20	13	154.34	12.67	6
11	110	20	14	152.89	9.98	6
12	110	20	15	155.65	13.96	7
13	110	22	13	156.42	14.43	6
14	110	22	14	154.92	13.02	6
15	110	22	15	156.78	14.86	7
16	110	24	13	155.67	13.75	5
17	110	24	14	154.92	12.67	5
18	110	24	15	153.42	11.56	5
19	120	20	13	158.76	15.23	4
20	120	20	14	161.23	16.43	4
21	120	20	15	160.78	17.88	4
22	120	22	13	161.65	17.45	3
23	120	22	14	160.23	16.97	4
24	120	22	15	163.25	18.98	4
25	120	24	13	161.78	17.67	3
26	120	24	14	160.78	17.02	4
27	120	24	15	161.89	17.98	3

OPTIMIZATION: Optimization work was carried out by using neural network and regression model. Neural network was performed using MATLAB 2010 in order to predict the output with the experimental results and finding the Root Mean Square Error. The Root Mean Square Error is the square root of the variance of the residuals. If the RMSE value close to zero indicates the model fits to response variable observed from the experiment and it is absolute measure of fit. Regression model analysis was developed using MINITAB 17 which was also used to predict the response variable and therefore finding the significance level of the process parameters. Coefficient of determination (R-sq) shows the profit of difference in the response. Higher the R-sq shows the analysis fits the data. Here R-sq 95% indicates that how much the analysis predicted the output with high precision. By use of Minitab software the regression analysis clarifies that if the probability values are less than 0.05, then the inputs are most important to the outputs. From Analysis of Variance it was noted that the current, voltage and gas flow rate were significant. Therefore current, voltage and gas flow rate were influencing parameter for tensile strength, % of elongation and impact strength.

$$UTS = 587-6.145C+12.71V-36.6G+0.02393C^2-0.2308V^2+1.303G^2+0.0174C*V+0.0623C*G-0.310V*G$$

$$\% EL = 376-3.922C+14.73V-46.66G+0.01246C^2-0.3053V^2+1.567G^2+0.0203C*V+0.0743C*G-0.247V*GIS = -247.1+2.711C+6.92V+4.92G-0.0133C^2-0.166V^2+0G^2 0.01667C*V-0.0167C*G-0.1250V*G$$

Table 2: Significant description used in ANN modeling

Sl.No	Parameter	Technique used/ Type of Parameter Used
1	Nos. of input neuron	3 (current, Voltage, Gas flow rate
2	Nos. of output neuron	1 at a time (Ultimate tensile strength, % of elongation and Impact strength)
3	Total nos. of data set	27 nos.
4	Data normalization	Between (0 – 1)
5	Transfer function of hidden layer	Tansig
6	Transfer function of output layer	Purelin
7	Error function	Mean squared error function
8	Learning rule	Back propagation

RESULTS AND DISCUSSION

Tensile strength prediction: From table 3 show the comparisons of actual experimental value with ANN predicted value and regression value and also show the percentage of error. In which can see that ANN value closer to experimental value. It can be seen from table 3 that regression model value not much close as ANN prediction model. So, ANN best prediction model which gives close value to Response. Maximum tensile strength of 163.25 Mpa were observed experimentally at welding current of 120amp, voltage of 22 volts and gas flow rate of 15 lts/min. According to ANN model at same process parameters the tensile strength was observed 163.21 Mpa. Hence, the error percentage between experimental and ANN values was 0.022.

Table 3: Comparison of Actual, ANN predicted and Regression Model Tensile strength

S.NO	UTS	Ann predicted	% Error in ann prediction	Regression model predicted	% Error in regression model prediction	Rmse Of ann	Rmse Of regression
24	163.25	163.2131	-0.0226	161.0558	-1.3624	0.2233	3.69

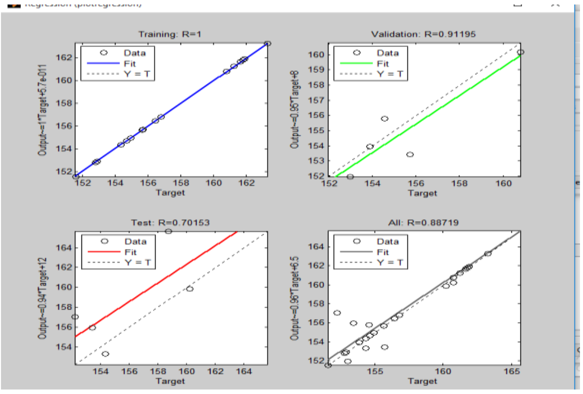

Figure 2: Plot Regression for tensile strength

% 0f elongation prediction: From table 4 show the comparisons of actual experimental value with ANN predicted value and regression value and also show the percentage of error. In which can see that ANN value closer to experimental value. It can be seen from table 4 that regression model value not much close as ANN prediction model. So, ANN best prediction model which gives close value to Response. Maximum % of elongation 18.98 were observed experimentally at welding current of 120 A, voltage of 22 V and gas flow rate of 15 lts/min. According to ANN model at same process parameters the % of elongation were observed 18.24. Hence, the percentage of error between experimental and ANN values was 4.02.

Table 4. Comparison of Actual, ANN predicted and Regression Model % of Elongation

S.No	% of Elon	Ann predicted	% Error in ann prediction	Regression model predicted	% Error in regression model prediction	Rmse Of ann	Rmse Of regression
24	18.98	18.24	-4.05702	19.5758	3.04355	1.0011	0.5767

Impact strength prediction: Comparisons of actual experimental value with ANN predicted value and regression value and also show the percentage of error. In which can see that ANN value closer to experimental value. It can be seen from table 5 that regression model value not much close as ANN prediction model. So, ANN best prediction model which gives close value to Response. Maximum tensile strength of 7 joules were observed experimentally at welding current of 100 amp, voltage of 20 volts and gas flow rate of 15 lts/min. According to ANN model at same process parameters the tensile strength was observed 7.012 joules. Hence, the error percentage between experimental and ANN values was 0.17.

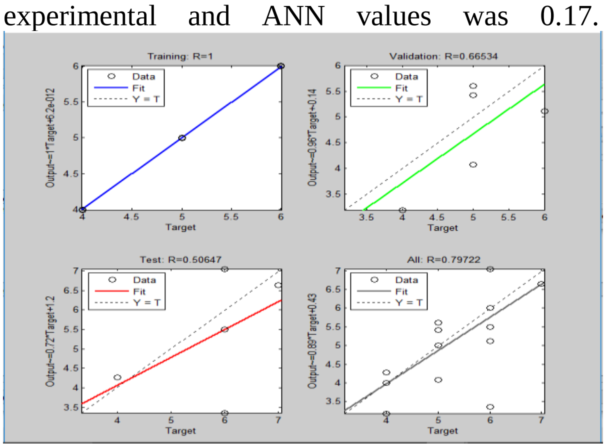

Figure 3: Plot Regression for impact strength

Table 5: Comparison of Actual, ANN predicted and Regression Model impact strength

S.No	Impact strength	Ann predicted	% Error in ann prediction	Regression model predicted	% Error in regression model prediction	Rmse Of ann	Rmse Of regression
3	7	7.12	0.17142	7.01	0.14286	1.6260	0.6046

CONCLUSION

GMAW was done to find the parameter of AA70-75 and AA6063 with Mechanical properties has been reported. When voltage increases ultimate tensile strength increases while impact energy decreases. The maximum tensile strength and yield strength was observed at high constant welding current and rising welding voltage. The maximum tensile strength was found as 163.25 Mpa at 120A, 22V and 15lit/min. Based on the experiments, results of selected input parameters on the Mechanical properties were studied. ANN and regression model was developed for modeling the relationship between the response and control variables in this work. Suitable process parameter of AA7075 and AA6063 dissimilar aluminum alloy joint made by GMAW process based on Mechanical properties has been evaluated. The maximum tensile strength was observed as 163.25 MPa with optimum run set 120A, 22V and 15 lit/min. The maximum elongation was observed as 18.98% with optimum run set 120A, 22V and 15 lit/min. The maximum impact strength was observed as 7 J with optimum run set 100A, 24V and 15 lit/min. Both the ANN model and regression model analysis predicts the response variables with less error (less than 2). It concluded that from the less error of prediction may be used as a good alternative for the analysis of the effects of Input parameters of GMAW on the weld mechanical properties.

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