OPTIMIZATION CHARACTERISTICS OF GAS TUNGSTEIN ARC WELDED ALUMINIUM ALLOY - AA5083 USING ORTHOGONAL ARRAY METHOD

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Abstract

In this study, joining of AA5083 plates, an Al-Mg based alloy are carried by using Gas Tungsten Arc Welding (GTAW). The Conventional welding procedures were found inadequate for welding aluminium alloys due to their higher conductivity resulting in hot cracking and high frequency of porosity. The optimization of GTAW process parameter enhances the quality of the welding joints. Here, an attempt is made to maximize the tensile strength of the weld joints by using Taguchi L9 orthogonal experimental design. The process potential considered for optimization are the Peak current in Amps, Base current in Amps and the Pulse frequency in Hz. The responses are the tensile strength of GTAW welded joints were obtained and optimum results were found. Confirmation run was carried out in order to authorize the optimum predicted levels of the parameter.

Keywords: Gas tungsten arc welding, hot cracking, higher conductivity, high incidence of porosity, Pulse frequency

I. INTRODUCTION

GTAW is a welding process that produces coalescence of metals by heating them with an arc between a non-consumable electrode and base metal in the presence of inert gases like argon or helium or a mixture of two to prevent electrode degradation, [1]. The GTAW process can be performed with or without filler material (autogenously). It produces strong and high quality welds and is used for welding both ferrous and non-ferrous materials. The welds formed using GTAW processes are highly resistant to corrosion and cracking over long time periods. The pulse current was optimized for improving corrosion resistance of AA5083 aluminium welds. Based on his study he has found that percentage of pulse-on time (50.48%), pulse frequency (28.62%) has major influence on pitting corrosion rate of AA5083 aluminium alloy. The mechanical properties of AA 5456 Aluminium alloy welds can be improved through pulsed tungsten inert gas (TIG) welding process.

The optimized Taguchi method was employed for welding C-276 aluminium alloy and better depth of penetration was obtaining [2]. The optimum conditions were found to be 165 A pulses current, 77 A background current, 60 % on time and 5 Hz pulse frequency [3].From the literature survey reviewed it is found that no systematic study has reported in GTAW on AA5083.The present investigation is aimed to discover the influence of significant factor and proportion contribution of every factor on tensile strength of friction stir welded RDE-40 aluminium joints with Taguchi orthogonal array [4].

II. EXPERIMENTAL PROCEDURE

The single pass butt welds were shaped in 5 mm thick plates of aluminium alloy 5083 with indigenously designed Gas Tungsten Arc welding machine. Rolled plates of 3 mm thickness were cut into necessary size (150 mm ×50 mm) by power hacksaw machines. The mechanical clamps were utilized to hold the plate on the work table of the machine, [5].

The experiments were conducted using the obtained values of the parameters from the designed orthogonal array matrix. Aluminium alloy 5083 plates and one surface were cleaned to take away the dirt before welding and to remove oxide scale deposits, [6]. The chemical composition of plate and mechanical properties are as shown in Table 1 and Table 2 Several parameters were kept

constant and some are varied to frame the orthogonal array. The Values of the factors that are kept constant are listed in Table 3.The wire cut EDM is used to cut the smooth profile tensile specimens. The dimensions equipped with tensile specimen are shown in the Figure 2.1.

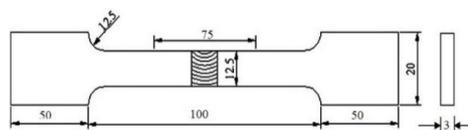## 2.1   Base metal properties and composition

Figure. 2.1. Tensile specimen dimensions

The American Society for Testing of Materials (ASTME 8-0M) were followed and dimensions are in mm. The specimens were subjected to tensile test at Scientific and industrial testing and Research Centre, Coimbatore (Recognized by DSIR/Ministry of Science and Technology, Government of India).

Table 2.1: Chemical Composition Of The Plate AA 5083, Wt %

Material	Mg	Mn	Fe	Si	Cu	Cr	Ti	Al
AA 5083	4.15	0.73	0.31	0.13	<0.025	<0.01	<0.01	Remaining

Table 2.2: Mechanical Properties Of The Base Plate Aa 5083

Base material	Yield Strength (MPa)	Ultimate Tensile strength (MPa)	% of Elongation
5083	260.67	291.67	26.42

Table2.3: process Parameters And Their Values

Parameters	Shielding gas flow rate, l/min	Filler rod diameter, mm	Electrode material	Electrode diameter, mm	Pulse on time, %
Constant Values	10	1.6	98% W + 2% Zr	3.15	50

2.1.1 Selection of orthogonal array (OA)

As three levels and three factors are taken into consideration, L9 OA is used in this investigation. Only the factors having major effects are taken into consideration and not its interactions, [7]. The degrees of freedom (DoF) for each factor is 2 (No. of levels -1, i.e. 3-1=2) and therefore the total degrees of freedom will be 3×2=6. Generally the DoF of the OA should be greater than the total DoF of the factors. As the DoF of L9 is 8, it can be suitable for the study, [8].

2.1.2 Levels of process parameters

It has been clearly shown in the literature that GTAW process parameters such as Peak current, Base current and Pulse frequency play a major role in deciding the quality of the weld. The considered parameters, their values and levels are listed in Table 2.4.

Table 2.4: Varying Process Parameters Values

Level	Peak current(Amps)	Base current(Amps)	Pulse frequency(HZ)
1	170	85	2
2	180	90	4
3	190	95	6

The experiments and tensile testing of the specimens were carried out. The experiments were conducted according to the designed L9 Orthogonal Array and the values are listed in Table2. 5.

Table 2.5: Experimental Layout Using L9 Orthogonal Array

Sl.No	Peakcurrent (Amps)	Base current (Amps)	Pulse frequency (Hz)	Tensile strength (MPa)	S/N Ratio
1	1	1	1	145	43.224
2	1	2	2	152	43.639
3	1	3	3	147	43.343
4	2	1	2	158	43.971
5	2	2	3	155	43.806
6	2	3	1	154	43.754
7	3	1	3	150	43.528
8	3	2	1	146	43.281
9	3	3	2	143	43.106

The welding is done based on L9 Orthogonal array combination and the Tensile strength of the welded joint is obtained, [9].

Table 2.6: Mean Value And S/N Ratio For Tensile Strength

Sl.No	Input Parameters			Response	
	Peak current (RS)	Base current (TS)	Pulse Frequency (AL)	Tensile strength (TL)	S/N Ratio
1	170	85	2	145	43.227
2	170	90	4	152	43.636
3	170	95	6	147	43.346
4	180	85	4	158	43.973
5	180	90	6	155	43.806
6	180	95	2	154	43.754
7	190	85	6	150	43.52
8	190	90	2	146	43.28
9	190	95	4	143	43.10

The various input parameters were used to found the tensile strength and S/N ratio. The factors of peak current, base current and pulse frequencies were utilized to carried the response of tensile strength and appropriate ratio of S/N values as shown in Table 6.

III. RESULTS AND DISCUSSION

3.1 Signal to noise ratio

The S/N Ratio is measured based on the excellence of the characteristics intended. The main function described in this investigation is maximization of the tensile strength, so the larger the best S/N ratio is to be calculated. The formula used for calculating the S/N ratio is given below

$$S/N \ ratio(\eta) = -10 \ log_{10} \frac{1}{n} \sum_{i=1}^{n} 1/y_i^2$$

Where   n - number of replications

         Yi - observerd response value

The experimental data was enhanced into mean and S/N ratio. The measured mean and S/N ratio values are tabulated in Table 1.6. The main effects, average mean and S/N ratio values of all levels are calculated and listed in Tables 1.7 to 1.8. Based on both mean and S/N ratio values the optimal level setting is RS2TS2AL2 i.e., the Peak current is to set at 180 Amps, the Base current has to be set at 90 Amps and the Pulse frequency is to be 4 Hz.It must be calculated that the above combination of factor levels A2 B2 C2 are not among the nine combinations experienced for the research. This is expected owing to the multifactor nature of the experimental design employed (9 from 33=27 possible combinations). The optimum significance of tensile strength is expected at the selected altitudes of important parameters. The approximate mean of the response description (tensile strength) can be calculated as Tensile strength = RS2 + TS2 + AL2 -2T.

3.2 Analysis of variance (ANOVA)

The ANOVA table for both mean and S/N ratios are calculated and listed in Tables 1.9 and 1.10. The main effects for mean and S/N ratio are plotted in Figures 2 and 3. The F test is being carried out to study the significances of the process parameter.

The high F value indicates that the factor is highly significant in affecting the response of the process. In our investigation, the Peak current is a highly significant factor and plays a major role in affecting the tensile strength of the weld and the effect of Pulse frequency makes very little impact in the responses.

Table 3.1: Response table for tensile strength- signal to noise ratio

Level	RS	TS	AL
1	43.40	43.57	43.42
2	43.84	43.58	43.57
3	43.31	43.40	43.56
Delta	0.54	0.18	0.15
Rank	1	2	3

For Table 3.1 & 3.2, The optimal setting is $RS_2TS_2AL_2$ based on S/N ratio

Table 3.2: Response table for tensile Strength- mean

Level	RS	TS	AL
1	148.0	150.8	148.3
2	155.7	151.0	151.0
3	146.3	148.0	150.7
Delta	9.3	3.0	2.7
Rank	1	2	3

Table 3.3: Analysis of variance for tensile strength means

Source	DoF	Seq SS	Adj SS	Adj MS	F	%Contribution
RS	2	148.67	148.67	74.33	5.19	67
TS	2	18.00	18.00	9.000	0.63	28.3
AL	2	12.67	12.67	6.333	0.44	1.4
Residual Error	2	28.67	28.67	14.333	-	3.3
Total	8	208.00	-	-	-	100

Table 3.4: Analysis of variance for tensile strength S/N ratio

Source	DoF	Seq SS	Adj SS	Adj MS	F	%Contribution
RS	2	0.49281	0.49281	0.24640	4.93	67
TS	2	0.06079	0.06079	0.03039	0.61	28.3
AL	2	0.04156	0.04156	0.02078	0.42	1.4
Residual Error	2	0.09989	0.09989	0.04994	-	3.3

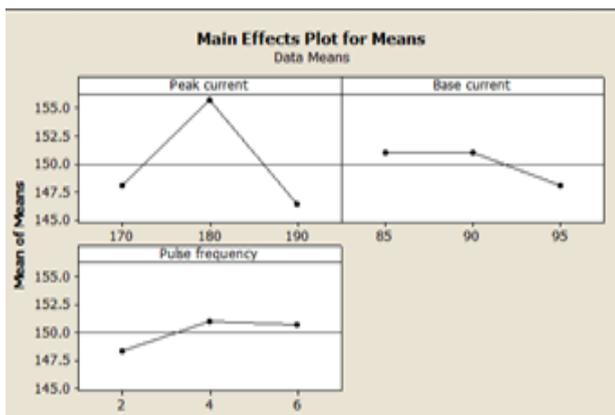| Total	8	0.69504	-	-	-	100

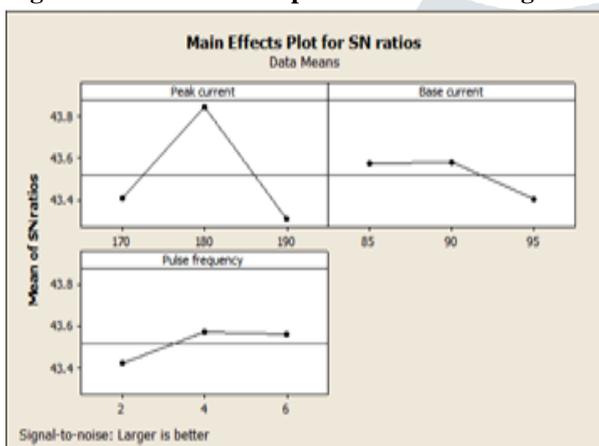**Figure. 3.1. Main effects plot for tensile strength mean**

Figure. 3.2. Main effects plot for tensile strength S/N ratio

The different values parameter such as DoF - Degrees of freedom, Seq SS- Sequential sum of squares, Adj SS- Adjusted sum of square, Adj MS- Adjusted mean square, F- Fisher ratio.

3.3 Predicted value of Tensile strength

Based on the experiments, the optimum level setting is RS2 TS2 AL2. The additive model to assess the predicted tensile strength is taken from the literature. The average values of the factors at their stages analysed and the predicted value of the response is given below

Tensile strength = RS2 + TS2 + AL2 -2T =155.7+151.0+151.0-2(150)(Table 5)= 157.7 MPa

IV CONCLUSION

The major process parameters were identified as well as the optimum levels of the process parameters were found out. The optimum levels of the parameter of predicted values are 180 Amps peak current, 95 Amps base current, 4Hz pulse frequency and the predicted value of tensile strength is 157.7 MPa, the experimental value of ultimate tensile strength is found to be 164 MPa and it is found to be good conformity with the predicted tensile strength. To review the optimum parameters of GTAW joint of AA 5083 using AA 5356 filler material.

• The optimum parameter for peak current is 180 Amps. The tensile strength of the GTAW not achieved   properly when the peak current increases beyond that obtained parametric limit and continuous weld is   not achieved beyond the known parametric limits.
• The tensile strength mainly depends on the amount of current used.
• The optimum parameter for pulse frequency is 4 Hz, this parameter does not have much impact on the   strength of the weldment.
• The Peak current and Base current and their interactions considerably affect the tensile strength of the   GTAW joint.

• The confirmation experiment run was conducted by setting the optimum parameter as RS2TS2AL2. The   tensile strength of the GTAW joint at optimum condition is 164 MPa, and at this condition no defects   were seen.

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