Optimization Of Welding Parameters For TIG Welding Of 304 L Stainless Steel Using Taguchi Approach

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***Abstract*— The main aim of this paper is to analyze and experimentally investigate the TIG welding process parameters for purpose of maximizing tensile strength and minimizing distortion with the requirements of maximizing of weld strength of thin walled structures of stainless steel respectively. TIG welding parameters were analyzed to determine their significance on thin plates of 304L stainless steel of 4 mm thicknesses by design of experiments (DOE) with employing Taguchi method designs to have response (tensile strength &distortion). The effects of following two parameters: welding current, Root gap have investigated upon following two performance measures: tensile strength and distortions for 4 mm thickness of 304L stainless steel. The experimental results were analyzed using ANOVA and significance of effects for all the tested parameters upon performance measures was determined. Empirical models for tensile strength and distortion, in terms of significant parameters were developed and numerical optimization was performed according to the desirability for the maximization of tensile strength and minimization of distortion.**

***Index Terms*—TIG welding, Welding strength, Distortion, Taguchi method, ANOVA**

I. INTRODUCTION

The welding technology is applied as major joining technique in hi-tech industries to the welding of steels for manufacturing of different structures like pressure vessels and aerospace applications. The major design and industry constraints are weld strength and cost competitive. Tungsten inert gas welding is one of the widely used techniques for joining ferrous and non ferrous metals.

The optimization of TIG welding process parameters play important role for the final product quality in terms of weld distortions, joint efficiency and mechanical properties. As welding process involves the heating and cooling process in non uniform manner, the distortions are unavoidable. The weld process contributes to the development of several kinds of distortions like longitudinal, transverse or angular distortions [1].

Gas Tungsten Arc Welding (GTAW) or TIG process is mostly applied due to the excellent tensile strength and cost competitiveness. The various process parameters of TIG welding which are optimize by orthogonal array are Material, Weld geometry, Welding Position, Shielding Gas (lit/min), Welding Speed (cm/min), Wire Feed Rate (cm/min), Material Thickness (mm), Welding Current (Amp), Welding Voltage (V).Welding distortion leads to dimensional inaccuracies and misalignment of structural members, which can result in corrective tasks or rework when tolerance limits are exceeded[2].

Angular distortion is a major problem and most pronounced among different types of distortion in the butt welded plates. This angular distortion is mainly due to non-uniform transverse shrinkage along the depth of the plates welded [3]. Taguchi method is efficient method for designing process that operates consistently and optimally over a variety of conditions. To determine the best design it requires the use of a strategically designed experiment [4]. In the present study, an attempt has been made to apply Taguchi approach to optimize process parameters for obtaining maximum tensile strength and minimum distortion.

II. LITERATURE REVIEW

Different following researchers have carried out investigation on different quality characteristics for the different materials weld joints.

- **KUMAR AND S. SUNDARRAJAN**

They have done the improvement of mechanical properties of AA 5456Aluminum alloy welds through pulsed tungsten inert gas (TIG) welding process. They have employed Taguchi method to optimize the pulsed TIG welding process parameters of AA 5456 Aluminium alloy welds for increasing the mechanical properties[5].

- **G. GUIMARAES**

He has done study on the Tungsten Inert Gas (TIG) welding process which takes place in an atmosphere of inert gas and uses a tungsten electrode. In this process heat input identification is a complex task and represents an important role in the optimization of the welding process. The technique is used to estimate the heat flux is based on solution of an inverse three-dimensional transient heat conduction model with moving heat sources[6].

- **MELIH BAYRAMOGLUET**

He has study on investigated the multi-response optimization of tungsten inert gas welding (TIG) welding Process for an optimal parametric combination to yield favorable bead geometry of welded joints using the Grey relational analysis and Taguchi method [7].

- **SUDHAKARAN R.**

He has done study on optimization of process parameters using genetic algorithm to minimize angular distortion in 202 grade stainless steel gas tungsten arc welded plates. Angular distortion is a major problem and most pronounced among different types of distortion in butt welded plates [8].

- **M. G. HARKARE**

He has done study on investigate the effect of process parameters like weld current, gas flow and work Piece thickness on the Bead Geometry (Front width and Back width) of the welded joint [9].

III. EXPERIMENTAL PLAN AND PROCEDURE

A. Welding Machine

TIG welding equipment is used to carry out the experimentation as shown in Figure 1.

Figure 1. TIG Welding Equipment

B. Selection of Material

304L stainless steel is used as workpiece in the present study.304L is a Austenitic type stainless steel which has very good weld ability, good corroision resistence properties, resistance to oxidation, ease of fabrication, excellent formability, ease of cleaning and low weight material.It is general purpose steel used for tanks, tools, food industry machinay and appliances, archietectural trim, filtaration screen and fasteners in corroision resistence environment. Above material is widely used in manufacturing industry because of their different characteristics. The chemical composition of SS 304L is shown in Table 1.

Cr	Ni	Mn	Si	P	S	C	Fe
18-20 %	8-10.5%	$\leq$ 2 %	$\leq$0.75%	$\leq$ 0.045%	$\leq$ 0.03 %	$\leq$ 0.03 %	Balance

Table 1. Chemical composition of SS 304L

Each workpiece is cut in size of 4 mm thickness and size 300 mm × 250 mm. Then after welding has been performed on TIG welding machine.

C. Process Parameters

In present study, there are two parameters: Current and Root gap are taken as input process factors. Each process parameter has three levels of values as mentioned in Table 2.

Level	Process parameters	
	Current (amp.)	Root gap(mm)
1	100	1
2	130	1.5
3	150	2.5

Table 2. Levels of Process Parameters

D. Response parameter

After TIG welding as shown in Figure 2, Angular Distortion is measured by using Dial Indicator as shown in Figure 3. Tensile sample was prepared on Plasma cutting machine as shown in Figure 4. Tensile sample before testing are shown in Figure 5. Weld strength measurement was carried out by using Universal Testing Machine as shown in Figure 6. After performed all the samples on Universal Testing machine, for the measurement of tensile strength as shown in Figure 7.

Figure 2. TIG welding

Figure 3. Measuring Distortion on welded part

Figure 4. Plasma Cutting for Tensile sample

Figure 5. Tensile sample before testing

Figure 6. Tensile sample tested on Universal Testing machine

Figure 7. Tensile sample after testing

E. Experimental deign using Taguchi method

The objective of Design of experiment is to determine the variables in a process that are the critical parameters and their target values. On the basis of selected parameters, experimental design is carried out. Taguchi method is powerful tool for the design of high quality systems. It provides simple, efficient and systematic approach to optimize designs for performance, quality and cost [10]. The Taguchi experimental design is done for L_9 Orthogonal Array for two parameters which are Current and Root gap. Table 3 shows complete design matrix with coded variables as well as actual value of this variables.

Sr no	Actual Variables		Responses			
	Current	Root Gap	Tensile Strength(kN)		Angular Distortion(°)	
			Set 1	Set 2	Set 1	Set 2
1	100A	1mm	33.61	34.02	6.10	6.20
2	100A	1.5mm	30.47	30.25	5.05	5.01
3	100A	2.5mm	33.86	33.35	3.40	3.75
4	130A	1mm	31.45	32.81	5.95	5.88
5	130A	1.5mm	37.73	37.98	4.85	4.91
6	130A	2.5mm	37.22	36.84	3.25	3.18
7	150A	1mm	37.73	37.11	5.80	5.72
8	150A	1.5mm	39.54	40.02	4.70	4.81
9	150A	2.5mm	39.60	38.78	2.95	3.02

Table 3. Experimental Results

IV. RESULTS AND DISCUSSION

ANOVA is carried out to analyze the effect of factors on response with the aid of trial version of MINITAB16 Software.

A. Analysis of variance for Tensile Strength

It can be seen that with increase the parameters, Current and Root gap, weld strength would increase remarkably i.e. current and root gap are directly proportional to Weld Strength. The optimum combination of parameter, current and root gap are 150 amp and 2.5 mm for respectively for higher value of weld strength.

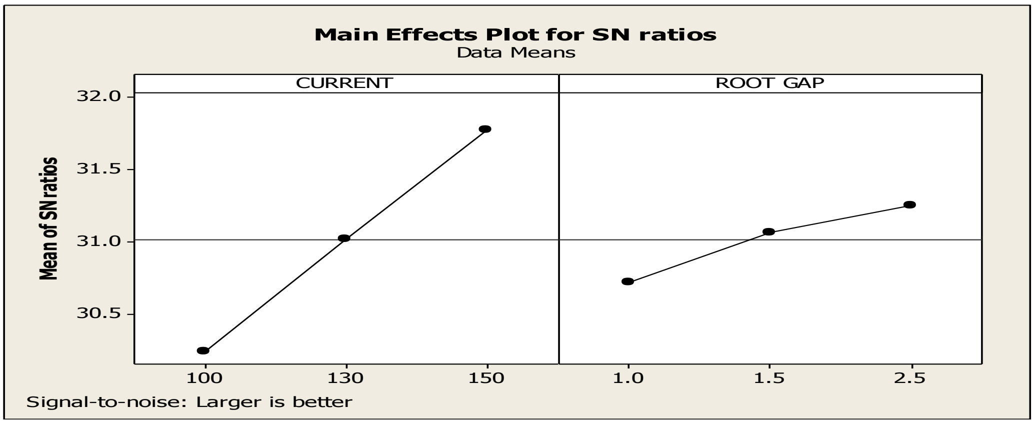

Figure 8. Main effects plot for SN ratio for weld strength

SOURCE	DF	Seq SS	Adj SS	Adj MS	F	P
CURRENT	2	24.64	24.64	12.32	0.38	0.708
ROOT GAP	2	152.46	152.46	76.23	2.33	0.214
Residual Error	4	131.00	131.00	32.75		
Total	8	308.10				

Table 4. Results for Weld Strength

Table 4 shows that analysis of variance for weld strength. It is clear from the table that root gap is the most significant factor for weld strength.

B. Analysis of variance for Distortion

It can be seen that with both the parameters, Current and Root gap, Distortion would optimum for Nominal value of current and root gap. The optimum combination of parameter, current and root gap are 130 amp and 1.5 mm for respectively for minimum distortion.

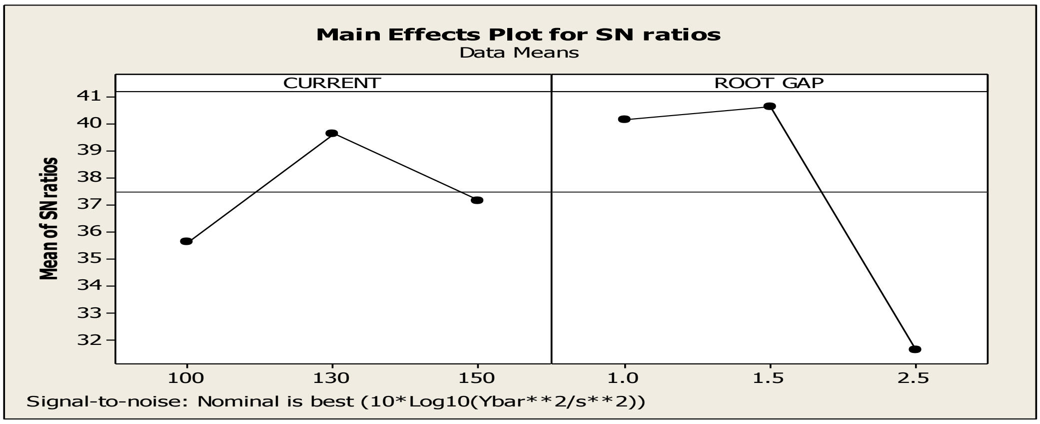

Figure 9. Main effects plot for SN ratio for distortion

SOURCE	DF	Seq SS	Adj SS	Adj MS	P
CURRENT	2	3.4676	3.4676	1.7338	0.089
ROOT GAP	2	0.4307	0.4307	0.2154	0.600
Residual Error	4	1.4797	1.4797	0.3699	
Total	8	5.3780			

Table 5. Results for Distortion

Table 5 shows that analysis of variance for distortion. It is clear from the table that current is the most significant factor for distortion.

V. REGRESSION ANALYSIS

In order to establish the correlation between the parameters (i) Root gap (ii) Current regression model was used. The regression equation for **weld strength**

WELD STERNGTH = 18.0 + 0.122 CURRENT + 1.32 ROOT GAP

The regression equation for **distortion**

DISTORTION = 8.70 - 0.00836 CURRENT - 1.77 ROOT GAP

VI. CONFIRMATION TEST

The confirmation test was performed by selecting the set of parameters as shown in table 6 and 7.

Sr. No	Current (Amp)	Root Gap	Regression Equation For Weld Strength	Exp.	%Error
1	100	1.0	31.52	33.815	2.295
2	130	1.5	35.84	37.855	2.015
3	150	2.5	39.6	39.19	0.410

Table 6. Confirmation wears tests and their comparison with regression model For weld strength

The conformation tests showed that error associated with weld strength of the Stainless Steel 304L varies from 0.410 to 2.295% which is under acceptable range as shown in Table 6.

Sr. No	Current (Amp)	Root Gap	Regression Equation. For Distortion	Exp.	%Error
1	100	1.0	6.094	6.15	0.056
2	130	1.5	4.958	4.88	0.078
3	150	2.5	3.021	2.98	0.063

Table 7. Confirmation wears test and their comparison with regression model For distortion

The conformation tests showed that error associated with distortion of the Stainless Steel 304L varies from 0.056 to 0.078% which is under acceptable range as shown in Table 7.

VII. CONCLUSION

The analysis of Experimental observations highlights that the root gap is the most significant parameter for weld strength and the current is the most significant parameter for distortion. The error associated with weld strength for the Stainless Steel 304L varies from 0.410 to 2.295% which is under acceptable range and the error associated with distortion of the Stainless Steel 304L varies from 0.056 to 0.078% which is under acceptable range.

VIII.REFERENCES

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