OPTIMIZATION AND MODELLING ON TIG WELDING OF AISI 309 STAINLESS STEEL UNDER VARIOUS WELDING PARAMETER USING TAGUCHI METHOD

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Abstract: The material stainless steel (AISI 309) is widely used in almost all types of thermal power plant, petroleum industries, waste treatment industries etc. The material AISI 309 stainless steel is used as sample which is prepared by wire cut EDM process. The sampledetail is tested according to the ASTM standard. Tungsten inert gas (TIG) welding is used to improve mechanical properties and to reduce the manufacturing costs, by the taguchi`s experimental design method which is used for optimization. The three different welding process parameters such as gas flow rate, welding speed and welding current have opted to perform the tests using L9 orthogonal array. The bending strength and impact strength output of best result on the 7th experiment, best result get by the input parameter 170 welding current 2 welding speed 15gas flow rate.

Key: TIG welding, EDM cutting, bending test, impact test, taguchi method

1. Introduction

1.1 material AISI 309 stainless steel

Stainless steel (AISI 309) are mostly used almost all types of thermal power plant,petroleum industries, waste treatment industries etc. This type of AISI 309 has high strength, weldability,toughness, ductility, excellent oxidization resistance and excellent formability.AISI 309 stainless steel applications includes jet engine parts, evaporators, heat exchangers, furnace parts, automotive exhaust part, chemical processing equipment, tanks, fire box sheet and other high temperature containers. The chemical composition of AISI309 is show in table1:

Table 1. The chemical composition of AISI309

Grade	C%	Si%	Mn%	P%	S%	N%	Cr%	Ni%
309	0.067	0.26	1.73	0.036	0.003	-	22.15	12.19

1.2 TIG welding of AISI 309 stainless steel

Tungsten inert gas (TIG) welding process is applied to increase mechanical properties in stainless steel. TIG welding provides better quality, accurate weld and absence of slag, low heat affected zone and less defects other than welding processes so it can be used widely.TIG welding is abbreviatedGTAW (gas tungsten arc welding) which is non consumable tungsten electrode.
The preparation of a good quality weld is considered to be a complex task. So welding quality can be controlled by input parameters such as welding current, welding speed, gas flow rate, gas pressure, etc. TIG welding process generates an electric arc between a tungsten electrode and base metal. In TIG welding process, inert gas (argon-helium)shieldis used instead of a slag to protect the weldpool. TIGwelding setup show in fig.3.

3. Experimental Set-up

The material is AISI309 stainless steel use as sample prepared by wire cut EDM process. EDM machine able to create complex model and design by electric discharge between the wire and the conductive material produces some sparks, which are exactly guided to cut through the material

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to achieve the desired cuts.EDM cutting process show in figure. Testing sample dimension according to the ASTM standard as show in fig.2 (a) and fig.2 (b).Then implementation of taguchi optimisation, l9 taguchi's orthogonal array in design of experimental method utilise 3 levels of current, 3 level of welding speed and 3 level of gas flow rate as show in table no.2.The experimental procedure of l_9(OA) have been developed by MINITAB 19 software, l9 array show in table 3.

Figure 1: EDM Cutting

Figure 2 (a): Before EDM Cut

Figure 2 (b): After EDM Cut

Table 2. Process parameters

Factor (process parameters)	Levels		
	1	2	3
Welding current (amps)	150	160	170
Welding speed (mm/sec)	2	3.5	5
Gas flow rate(lit/min)	10	12	15

After prepared by the EDM processsample applying TIG welding on the selected parameters (welding current, welding speed, gas flow rate) show in table 3 and using boistig200 machinefor weldingas show in fig.3. TIG welding according to the table 3 parameter and testing specimen show in figure 4.

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Figure 3: TIG Welding setup **Figure 4**: Welded Sample for Testing

After that performing the test, impact test on izod impact (a) and bending test on UTM(b). The outcomes achieved from all the three tests performed are mentioned below in table no. 3.

(a) (b)

Figure 5: Performing test on Sample Testing

Table 3. Experimental results using l_9 (OA)

Exp. No.	Input parameters			Output parameters	
	Welding current (amp)	Welding speed (mm/sec)	Gas flow rate (lit/min)	Impact strength (joule)	Bending strength (MPa)
1	150	2	10	92	437.52
2	150	3.5	12	96	440.22
3	150	5	15	97	515.33
4	160	2	12	117	450.23
5	160	3.5	15	142	428.32
6	160	5	10	105	443.95
7	170	2	15	159	580.22
8	170	3.5	10	148	475.51
9	170	5	12	142	530.34

3.1Result

The impact test and bending test samples according toASTM standard were prepared corresponding to L9 taguchi orthogonal array tests, have been conducted and the samples were tested and the results were achieved are given in table 3. From the table 3 the best outcome is achieved from test no.7 the value of impact strength is 159j and bending strength 580.22 and the smallest outcome is achieved from test no. 1 the value of impact strength is 92j and bending strength 437.52MPa.

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3.2 taguchi optimization

The optimum TIG welding parameters values have been achieved by the taguchi method. In this analysis the TIGwelding characteristics parameters like welding current, welding speed and gas flow rate were set as objective function.

Table 4 and fig. 6. Show that for welding current maximum mean s/n ratio value is achieved at level 3. And welding speed maximum mean s/n ratio value is achieved at level 3.Also gas flow rate maximum mean s/n ratio value is achieved at level 3. Hence the optimum value is welding current 170 amp (level 3), welding speed 2mm/sec (level 1)and gas flow rate 15 lit/min (level 3). Larger is better.

Table 4. Response for signal to noise ratios

Symbol	Factors	Mean of multiple s/n ratio (db)		
		Level 1	Level 2	Level 3
A	Welding current (amp)	42.38	44.30	46.16*
B	Welding speed (mm/sec)	44.30*	44.69	43.85
C	Gas flow rate (lit/min)	43.77	44.10	44.91*

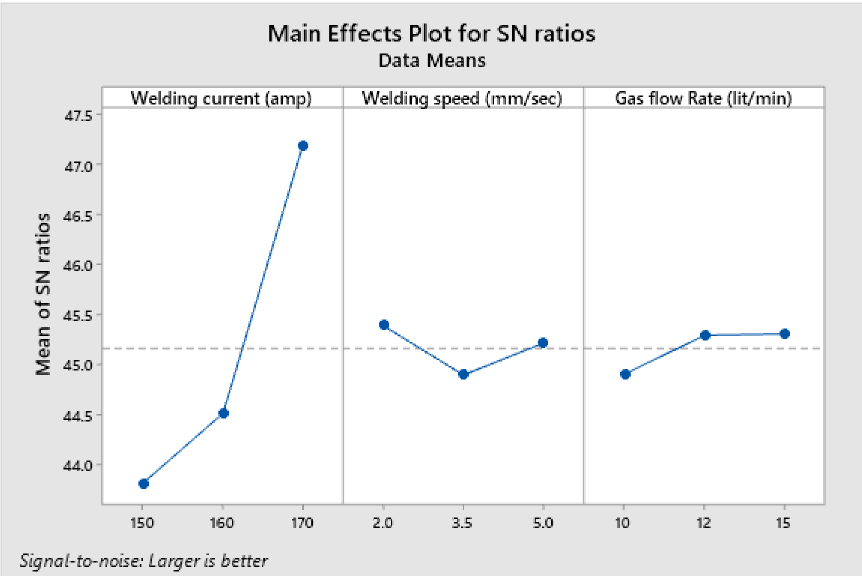

Figure 6: Main effects plot for S/N ratio

3.3 ANOVA

The analysis of variance (ANOVA) has been applied.

Correlative factor (c.f.) = $\frac{(GT)^2}{n}$

Where,

GT = grand total of response

n = no. Of observations

Sum of square = variance of response

Total sum of square =∑sum of square- cf

Mean square =$\frac{\text{sum of square}}{DOF}$

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Percentage contribution (pc) = $\frac{\text{sum of square}}{\text{total sum of square}}$ x 100

F-value = $\frac{MS}{MS_{error}}$

The ANOVA analysis and their results are listed in table 5.

Table 5. Analysis of variance for sn ratios

Source	DF	SS	Pc (%)	MS	F
Welding current (amp)	2	21.4582	85.66	10.7291	104.49
Welding speed (mm/sec)	2	1.0637	4.25	0.5319	5.18
Gas flow rate (lit/min)	2	2.3220	9.27	1.1610	11.31
Residual error	2	0.2054	0.82	0.1027	
Total	8	25.0493			

The percentage contribution (pc) of each parameters on responses are as welding current=85.66%, welding speed=4.25% and gas flow rate=9.27% positively.

4. Experimental validation

The higher value of mean MSNR (table 5) represents the exceptional value. The confirmation tests have been performed by conducting a test at central value of the factor and the levels that were calculated previously. The purpose is to verify the optimum level suggested by taguchi technique. The experimental results and the predicted values at initial setting of parameters are listed in table 6.

Table 6. Confirmation test using tm technique

Response	Initial setting	Optimum values Test	% improvement
Level	A_1-b_1	A_3-b_3	
Impact strength	90.00	159.00	43.40%
Bending strength	436.52	580.22	24.77%

Table 7 shows that with the experimental values of welding current (170 amp), welding speed (2 mm/sec) and gas flow rate (15ltr/min), the improvement of 43.40%, 24.77% in impact strength and bending strength is found respectively on comparing it with the initial values of welding current (150 amp), welding speed (2 mm/sec) and gas flow rate (10 ltr/min).

5. Conclusion

1. The best result have been achieved for the test no.7 and the lowest value of output parameters from the bending testing has been achieved for the sample no.1
2. The best result have been achieved for the test no.7 and the lowest value of output parameters from the impact testing has been achieved for the sample no.1

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