Research Paper

OPTIMIZATION OF MIG WELDING PARAMETERS FOR IMPROVING STRENGTH OF WELDED JOINTS

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ABSTRACT

This paper presents the influence of welding parameters like welding current, welding voltage, welding speed on ultimate tensile strength (UTS) of AISI 1030 mild steel material during welding. A plan of experiments based on Taguchi technique has been used. An Orthogonal array, signal to noise (S/N) ratio and analysis of variance (ANOVA) are employed to study the welding characteristics of material & optimize the welding parameters. The result computed is in form of contribution from each parameter, through which optimal parameters are identified for maximum tensile strength. From this study, it is observed that welding current and welding speed are major parameters which influence on the tensile strength of welded joint.

KEYWORDS: MIG welding, optimization, orthogonal array, S/N ratio ANOVA.

1. INTRODUCTION

The problem that has faced the manufacturer is the control of the process input parameters to obtain a good welded joint with the required weld quality. Traditionally, it has been necessary to study the weld input parameters for welded product to obtain a welded joint with the required quality. To do so, requires a time-consuming trial and error development method. Then welds are examined whether they meet the requirement or not. Finally the weld parameters can be chosen to produce a welded joint that closely meets the joint qualities. Also, what is not achieved or often considered is an optimized welding parameters combination, since welds can often be formed with very different parameters. In other words, there is often a more ideal welding input parameters combination, which can be used.

In order to overcome this problem, various optimization methods can be useful to define the desired output variables through developing mathematical models to specify the relationship between the input parameters and output variables. Design of experiment (DoE) techniques has been applied to carry out such optimization. Taguchi method have been adapted for many applications in different areas.

2. LITERATURE REVIEW

Sukhomay Pal, Santosh K. Malviya, Surjya K. Pal and Arun K. Samantaray[1] studied ptimization of quality characteristics parameters in a pulsed metal inert gas welding process using grey-based Taguchi method. K.Y. Benyounis and A.G. Olabi[2] The optimization methods used in this study are appropriate for modeling, control and optimizing the different welding process. A. Kumar and S. Sundarrajan[3] Taguchi method was applied to optimize the pulsed TIG welding process parameters of AA 5456 Aluminum alloy welds for increasing the mechanical properties. P. Srinivasa Rao, O. P. Gupta, S. S. N. Murty and A. B. Koteswara Rao[4] studied the effect of process parameters and mathematical model for the prediction of bead geometry in pulsed GMA welding. Ching-Been Yang & Chyn-Shu Deng and Hsiu-Lu Chiang[6] proposes a progressive Taguchi neural network model, which combines the Taguchi method with the artificial neural network to construct a prediction model for a CO2 laser cutting experiment. Her-Yueh Huang[8] They presents the effect of each welding parameter on the weld bead geometry, and then sets out to determine the optimal process parameters using the Taguchi method to determine the parameters. S.C. Juang and Y.S. Tarng [12] studied the process parameter selection for optimizing the weld pool geometry in the tungsten inert gas welding of stainless steel.

EXPERIMENTAL PROCEDURE

In the present study, in order to identify the process parameters with the maximum ultimate tensile strength in the GMAW for plan carbon steel, the Taguchi method was used. Three three-level process parameters, i.e. welding current, voltage and welding speed were considered. Based on theoretical and experimental viewpoints, the respective levels are set. The levels of parameters are listed in Table 1. The experimental layout for the parameters, using the L_9 orthogonal array, is shown in Table 2.

Table 1 Levels of process variables

Variables	Unit	Level 1	Level 2	Level 3
Current (I)	Amp	200	220	240
Voltage (V)	Volt	23	25	27
Welding Speed (S)	Mm/min	250	350	450

Table 2 Experimental layout using L_9 orthogonal array

Expt. No.	Current	Voltage	Welding Speed
1	200	23	250
2	200	25	350
3	200	27	450
4	220	23	350
5	220	25	450
6	220	27	250
7	240	23	450
8	240	25	250
9	240	27	350

In the welding experiments, a carbon steel wire ER70S-6 with a 1.2-mm diameter was used. The work-pieces consisted of AISI 1030 carbon steel with a thickness of 10-mm. The chemical composition (wt.%) of both base metal and electrode wire are given in Table 3. The GMAW process was used for the welding of a single V-butt joint with a single pass on 100x50 mm plates. Argon (100%) gas was used as shielding gas at a constant flow rate of 17 L/min.

Table 3 Chemical composition (wt.%) of work material and electrode wire used

	C	Si	Mn	P	S
AISI 1030	0.290	0.137	0.642	0.0566	0.0481
ER70S-6	0.10	1.00	1.70	0.010	0.015

3.1 Taguchi's design method

Taguchi Technique is used to plan the experiments. The Taguchi method has become a influential tool for improving output during research and development, so that better quality products can be produced quickly and at minimum cost. Dr. Taguchi of Nippon Telephones and Telegraph Company, Japan has established a method based on "ORTHOGONAL ARRAY" experiments which gives much reduced "variance" for the experiment with "optimum settings" of control variables. Thus the marriage of Design of Experiments with optimization of control parameters to find best results is attained in the Taguchi Method. "Orthogonal Arrays" (OA) gives a set of well balanced (minimum) experiments and Dr. Taguchi's Signal-to-Noise ratios (S/N), which are log functions of desired output, serve as objective functions in optimization, help in data analysis and estimation of optimum results.

The signal-to-noise (S/N) ratio for each level was based on the S/N ratio analysis. Based on the tensile strength of the weld joint (larger-the-better), a higher S/N ratio produced a better quality. The standard S/N ratio formula for this type of response is:

$$(S/N) = -10 \log (M.S.D.)$$

Where, M.S.D. is the mean square deviation for the output characteristic.

$$n_i = -10 \log \left[\frac{1}{n}\sum_{i=1}^{n}\frac{1}{Y_{ij}^2}\right]$$

Where 'i' is the number of a trial; 'Y_{ij}' is the quality of the i^{th} trial and j^{th} experiment; 'n' is the total number of experiments.

3.2 Analysis of Variance (ANOVA)

The purpose of the analysis of variance (ANOVA) is to examine which design parameters significantly affect the quality characteristic. This is to accomplished by separating the total variability of the S/N ratios, which is measured by the sum of the squared deviations from the total mean S/N ratio, into contributions by each of the parameters and the error. First, the total sum of squared deviations SS_T from the total mean S/N ratio n_m can be calculated as,

$$SS_T = \sum (n_i - n_m)^2$$

3. RESULTS AND DISCUSSION

In this research work effect of main input welding parameters on the tensile strength of welded joint in gas metal arc welding process were investigated.

Table 4 Experimental result for UTS and S/N ratio

Expt. no.	(I)	(V)	(S)	UTS (MPa)	S/N Ratio
1	200	23	250	383	51.6640
2	200	25	350	404	52.1276
3	200	27	450	450	53.0643
4	220	23	350	394	51.9099
5	220	25	450	439	52.8493
6	220	27	250	370	51.3640
7	240	23	450	427	52.6086
8	240	25	250	366	51.2696
9	240	27	350	374	51.4574

Results show that among main input welding parameters the effect of the welding speed is significant. Increasing the welding speed and decreasing the current increases the ultimate tensile strength of welded joint. In this research work it was observed that the voltage did not contribute as such to weld strength. Regardless of the set of the quality characteristic, a greater S/N ratio relates to better quality characteristics. Therefore, the optimal level of the process variables is the level with the greatest S/N ratio. The S/N response table for ultimate tensile strength is shown in Table No.5 as below.

Table 5 S/N Response table for UTS

Symbol	Parameters	Mean S/N Ratios		
		Level 1	Level 2	Level 3
A	Current	52.29	52.04	51.78
B	Voltage	52.06	52.08	51.96
C	Welding speed	51.43	51.83	52.84

Table 6 Results of analysis of variance for UTS

Symb	Para.	DOF	Sum of Sq.	Mean	F	(%)
A	(I)	2	0.38536	0.19268	30.97	10.76
B	(V)	2	0.02471	0.01235	1.99	0.69
C	(S)	2	3.16035	1.58018	254	88.20
Error		2	0.01244	0.00622		0.35
Total		8	3.58286			100

From table 5, the optimum levels are A3B3C3 which is based on larger-the-better criterion. The ANOVA is a statistical tool used to determine the level of contribution of each process parameter to the overall improvement of the tensile strength of the welded joint. From the table 6, the welding speed has maximum contribution. This has been found to have the most influence on tensile strength. Thus, a little variation in the welding speed is expected to greatly affect the tensile strength of the weld. Hence, the more the welding speeds, higher the strength.

4. CONCLUSIONS

In this research study, the mild steel failure problems encountered by loads were successfully addressed by applying the Taguchi Method. A Taguchi orthogonal array, the signal-to-noise (S/N) ratio and analysis of variance (AVOVA) were used for the optimization of welding parameters. The optimum levels obtained are A3B3C3. It is found that welding speed has major influence on tensile strength of welded joints.

REFERENCES

1. Sukhomay Pal, Santosh K. Malviya, Surjya K. Pal & Arun K. Samantaray, "Optimization of quality characteristics parameters in a pulsed metal inert gas welding process using grey-based Taguchi method," Int J Adv Manuf Technol (2009)44:1250–1260, DOI 10.1007/s00170-009-1931-0.
2. K.Y. Benyounis and A.G. Olabi, "Optimization of different welding processes using statistical and numerical approaches – A reference guide," Advances in Engineering Software 39 (2008) 483–496.
3. A. Kumar and S. Sundarrajan, "Optimization of pulsed TIG welding process parameters on mechanical properties of AA 5456 Aluminum alloy weldments," Materials and Design 30 (2009) 1288–1297.
4. P. Srinivasa Rao, O. P. Gupta, S. S. N. Murty and A. B. Koteswara Rao, "Effect of process parameters and mathematical model for the prediction of bead geometry in pulsed GMA welding," Int J Adv Manuf Technol (2009) 45:496–505, DOI 10.1007/s00170-009-1991-1.
5. Saurav Datta, Asish Bandyopadhyay and Pradip Kumar Pal, "Modeling and optimization of features of bead geometry including percentage dilution in submerged arc welding using mixture of fresh flux and fused slag," Int J Adv Manuf Technol (2008) 36:1080–1090, DOI 10.1007/s00170-006-0917-4.
6. Ching-Been Yang, Chyn-Shu Deng and Hsiu-Lu Chiang, "Combining the Taguchi method with artificial neural network to construct a prediction model of a CO2 laser cutting experiment," Int J Adv Manuf Technol (2012) 59:1103–1111, DOI 10.1007/s00170-011-3557-2.

7. Ni Xiansheng, Zhou Zhenggan, Wen Xiongwei and Li Luming, "The use of Taguchi method to optimize the laser welding of sealing neuro-stimulator," Optics and Lasers in Engineering, 49(2011)297–304.
8. Her-Yueh Huang, "Effects of activating flux on the welded joint characteristics in gas metal arc welding," Materials and Design 31 (2010) 2488–2495.
9. Sandip Bhattacharya, Kamal Pal and Surjya K. Pal, "Multi-sensor based prediction of metal deposition in pulsed gas metal arc welding using various soft computing models," Applied Soft Computing 12 (2012) 498–505.
10. E.M. Anawa and A.G. Olabi, "Using Taguchi method to optimize welding pool of dissimilar laser-welded components," Optics & Laser Technology 40(2008)379–388.
11. Catarina Vidal, Virginia Infante and Pedro Vilaca, "Assessment of Improvement Techniques Effect on Fatigue Behaviour of Friction Stir Welded Aerospace Aluminium Alloys," Procedia Engineering 2 (2010) 1605–1616.
12. S.C. Juang and Y.S. Tarng, "Process parameter selection for optimizing the weld pool geometry in the tungsten inert gas welding of stainless steel," Journal of Materials Processing Technology 122 (2002) 33–37.