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Parametric Optimisation of MIG Welding Process with the Help of Taguchi Method

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Abstract

Gas metal arc welding is a fusion welding process having more importance in industry. This study aims to examine the interaction between process parameters and torsional rigidity. In this process proper selection of input welding parameters is necessary in order to optimize fillet welded structure and subsequently increase the productivity of the process. In order to obtain a good quality weld, it is therefore, necessary to control the input welding parameters For this, not only linear and the curvilinear equations were developed to predict bead geometry, but also interactions between process parameters and bead geometry were analysed through sensitivity analysis. One of the important welding output parameters in this process is torsional rigidity affecting the quality and productivity of weldment. In this research paper using Taguchi's method of design of experiments a mathematical model was developed using parameters such as, wire feed rate (W), welding voltage (V), welding current. After collecting data, signal-to-noise ratio (S/N) were calculated and used in order to obtain the optimum levels for every input parameters.

***Keywords*— Gas Metal Arc Welding (GMAW), Torsional rigidity, Taguchi Method,, Signal-to- noise ratio**

1. INTRODUCTION

The GMAW has got wide applications in industries due to the advantages such as high reliability, all position capability, low cost, high productivity, high deposition rate, ease of use, absence of fluxes, cleanliness and ease of mechanization. This process establishes an electric arc between a continuous filler metal electrode and the weld pool, with shielding from an externally supplied gas, which may be an inert gas, an active gas or a mixture. The most important gases which have been used in order to shield the weld pool are Argon (Ar) Helium (He), CO2 and O2..The heat of the arc melts the surface of the base metal and the end of the electrode. The electrode molten metal is then transferred through the arc the work piece where it combines with the molten metal from the weld puddle and creates the weld bead.In this welding process the quality of the weld joint can be defined by many characteristics. One of these characteristics is torsional rigidity which is the ratio of product of twisting moment and length to the angle of twist. In order to obtain a good quality weld and at the same time consuming lesser amount of consumable such as material, filler wire, gas, time and decreasing costs and subsequently increasing productivity, it is therefore required to control the input welding parameters of the gas metal arc welding process. In this connection using the concept of loss function, signal -to-noise ratios for torsional rigidity was utilized and based on this the optimum levels for input welding parameters were determined.

The method presented in this study is an experimental design process called the Taguchi design method. Taguchi design, developed by Dr. Genichi Taguchi, is a set of methodologies by which the inherent variability of materials and manufacturing processes has been taken into account at the design stage . Although similar to design of experiment (DOE), the Taguchi design only conducts the balanced (orthogonal) experimental combinations, which makes the Taguchi design even more effective than a fractional factorial design. By using the Taguchi techniques, industries are able to greatly reduce product development cycle time for both design and production, therefore reducing costs and increasing profit.

Taguchi proposed that engineering optimization of a process or product should be carried out in a three-step approach: system design, parameter design, and tolerance design. In system design, the engineer applies scientific and engineering knowledge to produce a basic functional prototype design.

The objective of the parameter design is to optimize the settings of the process parameter values for improving performance characteristics and to identify the product parameter values under the optimal process parameter values. The parameter design is the key step in the Taguchi method to achieving high quality without increasing cost. The steps included in the Taguchi parameter design are: selecting the proper orthogonal array (OA) according to the numbers of controllable factors (parameters); running experiments based on the OA; analysing data; identifying the optimum condition; and conducting confirmation runs with the optimal levels of all the parameters.

Taguchi method the experimental procedure included experimental design by Taguchi method, welding materials, welding equipment and welding procedure. Taguchi method can study data with minimum experimental runs. In this paper, the design of experiment work can be decided by this method.

Steps of Taguchi method are as follows:

1. Identification of main function, side effects and failure mode.
2. Identification of noise factor, testing condition and quality characteristics.
3. Identification of the main function to be optimized.
4. Identification the control factor and their levels.
5. Selection of orthogonal array and matrix experiment.
6. Conducting the matrix experiment.
7. Analysing the data, prediction of the optimum level and performance.
8. Performing the verification experiment and planning the future action.

2. DESIGN OF EXPERIMENTS

A. Experimental Procedure

The experiments were conducted using a semi automatic PARS MIG welding machine using direct current electrode positive. Test pieces of size 20 mm diameter were cut from ST-37 rod and their surfaces were ground to remove oxide scale and dirt and moreover, consumable electrode of 0.8 mm diameter was used for depositing the weld beads on the base metal. Chemical composition of base metal and filler wire is given in Table 1 and Table 2 respectively. Shielding of the gas puddle and molten metal droplets from the electrode was carried out by a Gas mixture of 80% argon and 20% CO2.

TABLE 1 THE CHAMICAL COMPOSITION OF FILLER WIRE

Eleme nt	Cr	P	S	Si	Ti	Mn	C	Fe
W%	0.03 1	0.00 7	0.0 1	0.02 4	0.00 2	0.41 7	0.11 3	Bal

TABLE 2 THE CHAMICAL COMPOSITION OF STEEL ST-37

Eleme nt	Cr	P	S	Si	Ti	Mn	C	Fe
W%	0.03 1	0.00 7	0.0 1	0.02 4	0.00 2	0.41 7	0.11 3	Ba l

B. Development of Design Matrix

To select an appropriate orthogonal array for experiments, the total degrees of freedom need to be computed. The degrees of freedom are defined as the number of comparisons between process parameters that need to be made to determine which level is better and specifically how much better it is. For example, a Four-level process parameter counts for four degrees of freedom. The degrees of freedom associated with interaction between two process parameters are given by the product of the degrees of freedom for the two process parameters . In the present study, the interaction between the welding parameters is neglected. Once the degrees of freedom required are known, the next step is to select an appropriate orthogonal array to fit the specific task. Basically, the degrees of freedom for the orthogonal array should be greater than or at least equal to those for the process parameters. In this study, an L09sss orthogonal array was used. The input welding process parameters considered for this research work were wire feed rate (W), welding voltage (V), and welding current. The output quality characteristic was torsional rigidity. All these parameters were investigated on 3 levels. The welding input variables and their limits are given Table 3. For avoiding systematic errors further in carrying out the experiments, 09 experiments were randomized for placing bead-on-rod welds on the ST-37 steel rod. The experimental layout for the welding process parameters using L09 orthogonal array and the experimental results for the torsional rigidity are shown in

TABLE 3 Welding variables and their levels

		Level			
Variable	**Notation**	1	2	3	**Units**
Wire feed rate	**W**	80	100	120	**m/min**
Arc voltage	**V**	350	360	370	**volts**
Welding current	**A**	340	350	360	**ampere**

Table 4 Experimental Results

Run Number	**V**	**A**	**W**	**Torsional Rigidity**	**S/N Ratio**
1	1	1	1	131.66	47.16
2	1	2	2	65.74	41.16
3	1	3	3	95.52	44.37
4	2	3	4	54.14	39.44
5	2	4	1	78.25	42.06
6	2	1	2	70.01	41.67
7	3	1	3	80.02	42.83
8	3	2	4	102.63	44.99
9	3	3	1	58.66	40.13

3. ANALYSIS OF EXPERIMENTAL RESULTS BASED ON TAGUCHI METHOD ANALYSIS OF S/N RATIO

According to Taguchi method, S/N ratio is the ratio of "Signal" representing desirable value, i.e. mean of output characteristics and the "noise" representing the undesirable value i.e., squared deviation of the output characteristics. It is denoted by η and the unit is dB. The S/N ratio is used to measure quality characteristic and it is also used to measure significant welding parameters.

According to quality engineering the characteristics are classified as Higher the best (HB) and lower the best (LB). HB includes Torsional rigidity which desires higher values. Similarly LB includes Heat Affected

Zone (HAZ) for which lower value is preferred . The summary statistics Higher the best performance 52.43 the best performance

$$L_{ij} = \frac{1}{n} \sum \frac{1}{y^2_{ijk}}$$

$$n_j = -10 \log (L_{ij})$$

4. ANALYSIS OF VARIANCE (ANOVA)

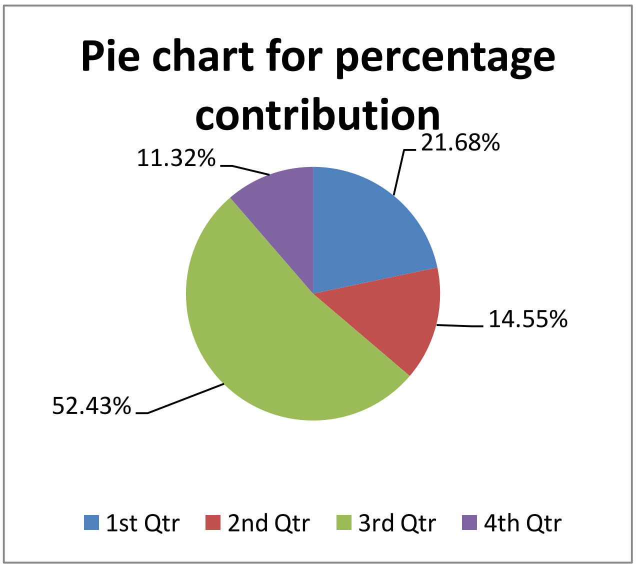
The main aim of ANOVA is to investigate the design parameters and to indicate which parameters are significantly affecting the output parameters. In the analysis, the sum of squares and variance are calculated. F-test value at 95 % confidence level is used to decide the significant factors affecting the process and percentage contribution is calculated. The ANOVA analysis for percentage calibration is shown in Table.

TABLE 5 RESULTS OF THE ANOVA

CF	DOF	SS	MS	%C
V	2	13.79	6.89	21.68
I	2	9.26	4.63	14.55
W	2	33.35	16.67	52.43
Error	2	7.2	3.6	11.32
Total	8	63.6	31.8	

5. RESULTS AND DISCUSSIONS

Basically, the larger the S/N ratio, the better is the quality characteristic for the percentage calibration. As per the S/N ratio analysis from graph the levels of parameters to be set for getting optimum value of percentage calibration. According to ANOVA analysis as shown in Table-5, the most effective parameters with respect to percentage calibration is welding Wire feed rate, welding voltage, welding current,. For a factor with a higher percent contribution, a small variation will have a great influence on the performance. The percent contributions of the welding parameters on the percentage calibration shown in Table-5 According to this, wire feed rate was found to be the major factor affecting the percentage calibration), whereas welding voltage was found to be the second factor (21.68 %). The percent contributions of welding current are much lower, being 14.55 % .



6. CONCLUSIONS

This paper has presented an investigation on the optimization and the effect of welding parameters on the torsional rigidity of MIG welded STEEL ST-37 rod. The level of importance of the welding parameters on the torsional rigidity is determined by using ANOVA. Based on the ANOVA method, the highly effective parameters on torsional rigidity were found as wire feed rate and welding voltage, where as welding voltage was less effective factors. The results show that the welding voltage was about less than half times more important than the first factor wire feed rate for controlling the torsional rigidity. An optimum parameter combination for the maximum torsional rigidity was obtained by using the analysis of S/N ratio.

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