International Journal of Advance Engineering and Research Development (IJAERD)
Volume 1,Issue 5,May 2014, e-ISSN: 2348 - 4470 , print-ISSN:2348-6406

Optimization of MIG welding Process Parameter using Taguchi Techniques

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ABSTRACT - The MIG welding parameters are the most important factors affecting the quality, productivity and cost of welding. This paper presents the influence of welding parameters like welding current, welding voltage, welding speed etc. on mechanical properties like tensile strength, hardness etc. on austenitic stainless steel AISI 316. By using DOE method, the parameters can be optimize and having the best parameters combination for target quality. The analysis from DOE method can give the significance of the parameters as it give effect to change of the quality and strength of product or does not. A plan of experiments based on Taguchi technique has been used to acquire the data. An Orthogonal array and analysis of variance (ANOVA) are employed to investigate the welding characteristics of austenitic stainless steel AISI 316 material and optimize the welding parameters. The techniques used for obtaining optimal process parameters with the use of experimental data have been reviewed. The success of MIG welding process in terms of providing weld joints of good quality and high strength depends on the process conditions used in the setup. This research aims to identifying the main factors that have significant effect on weld joint strength.

KEYWORDS - MIG welding, Austenitic stainless steel AISI 316, Process Parameter optimization, DOE method, Taguchi L9 Orthogonal arrays

I. INTRODUCTION

Metal Inert Gas welding as the name suggests, is a process in which the source of heat is an arc formed between a consumable metal electrode and the work piece. The arc and the molten puddle are protected from contamination by the atmosphere (i.e. oxygen and nitrogen) with an externally supplied gaseous shield of inert gas such as argon, helium or an argon-helium mixture. No external filler metal is necessary, because the metallic electrode provides the arc as well as the filler metal. It is often referred to in abbreviated form as MIG welding. MIG is an arc welding process where in coalescence is obtained by heating the job with an electric arc produced between work piece and metal electrode feed continuously. A metal inert gas (MIG) welding process consists of heating, melting and solidification of parent metals and a filler material in localized fusion zone by a transient heat source to form a joint between the parent metals. Gas metal arc welding is a gas shielded process that can be effectively used in all positions.

A. Definition of welding:

The American Welding Society (AWS) defines weld as “A localized coalescence of metals or non-metals produced either by heating the materials to suitable temperature, with or without application of pressure, or by pressure alone, and with or without the use of filler material.”

Indian Standard IS: 812-1957 defines the weld as “a union between two pieces of a metal at faces rendered plastic or liquid by heat or by pressure, or both. Filler metal may be used to affect the union”

B. WORKING PRINCIPLE OF MIG WELDING:

As shown in *Figure 1 & 2* the electrode in this process is in the form of coil and continuously fed towards the work during the process. At the same time inert gas (e.g. argon, helium, or CO_2) is passed around electrode from the same torch. Inert gas usually argon, helium, or a suitable mixture of these is used to prevent the atmosphere from contacting the molten metal and HAZ. When gas is supplied, it gets ionized and an arc is initiated in between electrode and work piece. Heat is therefore produced. Electrode melts due to the heat and molten filler metal falls on the heated joint.

The arc may be produced between a continuously fed wire and the work. Continuous welding with coiled wire helps high metal depositions rate and high welding speed. The filler wire is generally connected to the positive polarity of DC source forming one of the electrodes. The workpiece is connected to the negative polarity. The power source could be constant voltage DC power source, with electrode positive and it yields a stable arc and smooth metal transfer with least spatter for the entire current range.

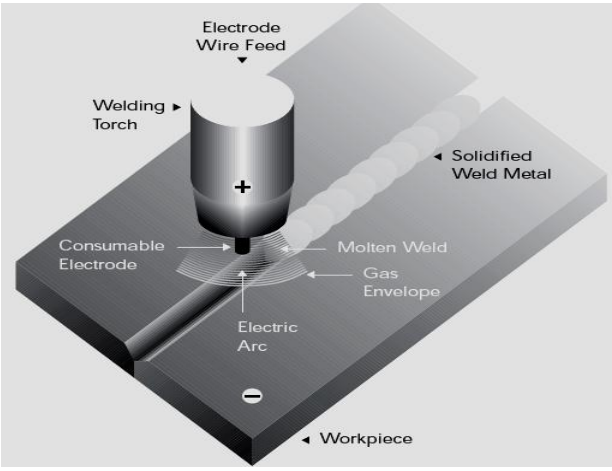

Figure 1. Working condition of Work piece

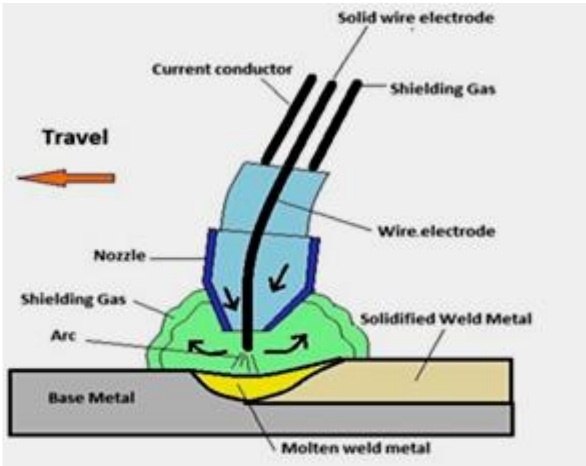

Figure 2. Working principles of GMAW

The gas shield around it does not ionized, which prevents weld against atmospheric co contamination and surface oxidation. Some torch has water cooling systems. MIG welding is also called Gas Metal Arc Welding. The filler metal is transmitted from electrode to joint by different methods. It is dependent on the current passing through the electrode and voltage.

C. MIG welding effecting parameters:

Weld quality and weld deposition rate both are influenced very much by the various welding parameters and joint geometry. Essentially a welded joint can be produced by various combinations of welding parameters as well as joint geometries. These parameters are the process variables which control the weld deposition rate and weld quality. The weld bead geometry, depth of penetration and overall weld quality depends on the following operating variables.

- Welding current, Arc voltage, Arc travel speed, Welding position, Electrode size, Gas Flow rate, Shielding Gas composition, Electrode extension (length of stick out)

II. EXPERIMENTAL PROCEDURE

A. Taguchi's design method

Optimization of process parameters is the key step in the Taguchi method for achieving high quality without increasing cost. This is because optimization of process parameters can improve quality characteristics and the optimal process parameters obtained from the Taguchi method are insensitive to the variation of environmental conditions and other noise factors. Basically, classical process parameter design is complex and not easy to use. A large number of experiments have to be carried out when the number of process parameters increases. To solve this task, the Taguchi method uses a special design of orthogonal arrays to study the entire process parameter space with a small number of experiments only. A loss function is then defined to calculate the deviation between the experimental value and the desired value. Taguchi recommends the use of the loss function to measure the deviation of the quality characteristic from the desired value. The value of the loss function is further transformed into signal-to-noise (S/N) ratio.

Signal - to-Noise Ratio

There are 3 Signal-to-Noise ratios of common interest for optimization

(I) Smaller-The-Better:

n = -10 Log10 [mean of sum of squares of measured data]

(II) Larger-The-Better:

n = -10 Log10 [mean of sum squares of reciprocal of measured data]

(III) Nominal-The-Best:

n = 10 Log10 (square of mean)/ Variance

B. Work Material

The work material used for present work is austenitic stainless steel AISI 316, the dimensions of the work piece length 200 mm, width 75 mm, thickness 6 mm. $Argon_2$ is used as a shielding gas .

Table 1: Chemical composition

Grade	C	Mn	Si	P	S	Cr	Mo	Ni
316	0.08	2.00	0.75	0.045	0.03	16.00-18.00	2.00-3.00	10.00-14.00

C. Orthogonal array Experiment

In the present study, three 3-level process parameters i.e. welding current, welding voltage and welding speed are considered. The values of the welding process parameters are listed in Table 2. The ranges and levels are fixed based on the screening experiments and AWS handbook. The interaction effect between the parameters is not considered.

Table 2: Welding Parameters and Level for MIG

Symbol	Welding Parameters	Unit	Level 1	Level 2	Level 3
A	Welding Voltage	Volt	28	30	32
B	Welding Current	Amp	140	160	180
C	Welding Speed	mm/min	300	350	400

Table 3: L9-3 Level Taguchi Orthogonal Array

Exp. No.	Process Parameters		
	Welding Voltage	Welding Current	Welding Speed
1.	1	1	1
2.	1	2	2
3.	1	3	3
4.	2	1	2
5.	2	2	3
6.	2	3	1
7.	3	1	3
8.	3	2	1
9.	3	3	2

The total degrees of freedom of all process parameters are 8. The degrees of freedom of the orthogonal array should be greater than or at least equal to the degrees of freedom of all the process parameters. Hence, L9 (3^3) Orthogonal array was chosen which has 8 degrees of freedom. This is shown in Table 4.

D. Analysis of S/N Ratio

In the Taguchi Method the term 'signal' represents the desirable value (mean) for the output characteristic and the term 'noise' represents the undesirable value (standard Deviation) for the output characteristic. Therefore, the S/N ratio to the mean to the S. D. S/N ratio used to measure the quality characteristic deviating from the desired value. The S/N ratio S is defined as

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

Where, M.S.D. is the mean square deviation for the output characteristic. To obtain optimal welding performance, higher-the better quality characteristic for Tensile strength must be taken. The M.S.D. for higher-the –better quality characteristic can be expressed

$$MSD = \frac{1}{R} + \sum_{j=1}^{R} (y_j - y_o)^2$$

Where R = Number of repetitions

E. 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 SST from the total mean S/N ratio nm can be calculated as,

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

III. RESULT AND DISCUSSION

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

Table 4: Result for UTS and S/N ratio

Exp. No.	Process Parameters			Tensile strength MPa	S/N Ratio
	Welding Voltage	Welding Current	Welding Speed		
1.	28	140	300	530	54.4855
2.	28	160	350	538	54.6156
3.	28	180	400	546	54.7439
4.	30	140	350	539	54.6318
5.	30	160	400	544	54.7120
6.	30	180	300	562	54.9947
7.	32	140	400	546	54.7439
8.	32	160	300	558	54.9327
9.	32	180	350	563	55.0102

Table 5: Response Table for Means

Level	Welding Voltage (Volt)	Welding Current (Amp)	Welding Speed (mm/min)
1	538.0	538.3	550.0
2	548.3	546.7	546.7
3	555.7	557.0	545.3
Delta	17.7	18.7	4.7
Rank	2	1	3

The set of the quality characteristics, a greater S/N ratio relates to better quality characteristics. Therefore, the optimum level of the quality process variables is the level with the greatest S/N response table for ultimate tensile strength is shown in Table No. 5 as below.

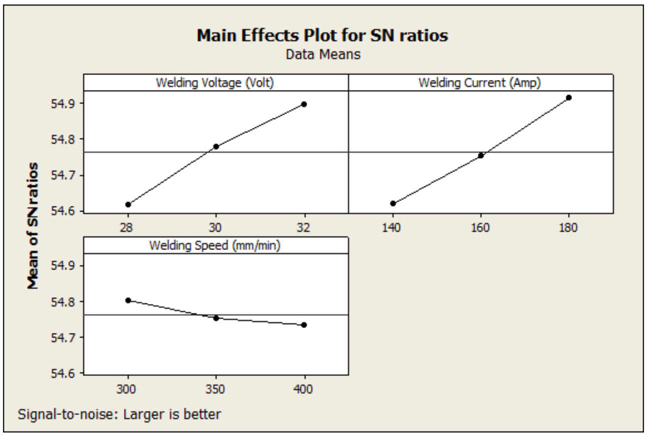

Figure: 2. Main effect plot for SN ratio

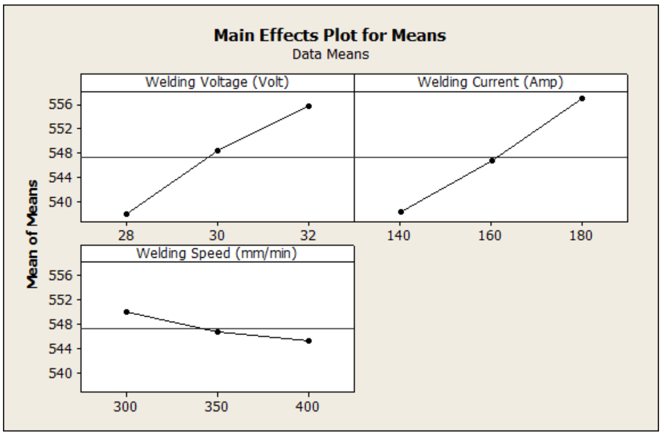

Figure: 3. Main effect plot for Means

From table No. 5 and Fig 3 & 4, the optimum levels are A3B3C1 means 32 V 180 I 300 S 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 table No. 6

Regression for Tensile strength in MIG welding

Table 6: Regression Analysis

Predictor	Coef	SE Coef	T	P
Constant	356.50	15.94	22.37	0.000
Welding Voltage (Volt)	4.4167	0.4330	10.20	0.000
Welding Current (Amp)	0.46667	0.04330	10.78	0.000
Welding Speed (mm/min)	-0.04667	0.01732	-2.69	0.043

The regression equation is
Tensile strength (Mpa) = 357 + 4.42 Welding Voltage (Volt)
+ 0.467 Welding Current (Amp)
- 0.0467 Welding Speed (mm/min)

S = 2.12132   R-Sq = 97.8%   R-Sq (adj) = 96.6%

Analysis of Variance

Analysis of variance (ANOVA) was introduced by Sir Ronald Fisher. The purpose of the analysis of variance (ANOVA) is to investigate which design parameters significantly affect the quality characteristic.

Table 7: Analysis of Variance

Source	DF	SS	MS	F	P
Regression	3	1023.50	341.17	75.81	0.000
Residual Error	5	22.50	4.50		

Table 8: % contribution of welding parameter

Total	8	1046.00			

Source	**DF**	**Seq SS**	**% contribution**
Welding Voltage	1	468.17	45.19
Welding Current	1	522.67	50.16
Welding Speed	1	32.67	3.31
Error	5	22.50	1.34

IV. CONCLUSION

In this paper, the optimization of the process parameters for GMA welding of stainless steel and with greater weld strength has been reported. The Higher-the-better quality characteristic is considered in the Tensile strength prediction. The Taguchi method is adopted to solve this problem. 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 A3B3C1. Result show that among main input welding parameters the effect of the welding voltage and welding current is significant on tensile strength of welded joints. With the help of (ANOVA) the most significant factor also found in this case welding current is having maximum percentage contribution. So it is most significant factor in this result.

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