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RESEARCH ARTICLE OPEN ACCESS

Determination of Significant Process Parameter in Metal Inert Gas Welding of Mild Steel by using Analysis of Variance (ANOVA)

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ABSTRACT
The aim of present study is to determine the most significant input parameter such as welding current, arc voltage and root gap during the Metal Inert Gas Welding (MIG) of Mild Steel 1018 grade by Analysis of Variance (ANOVA). The hardness and tensile strength of weld specimen are investigated in this study. The selected three input parameters were varied at three levels. On the analogy, nine experiments were performed based on L9 orthogonal array of Taguchi's methodology, which consist three input parameters. Root gap has greatest effect on tensile strength followed by welding current and arc voltage. Arc voltage has greatest effect on hardness followed by root gap and welding current. Weld metal consists of fine grains of ferrite and pearlite.
Keywords: GMAW, MIG, Mild Steel, Welding, Taguchi, ANOVA.

I. INTRODUCTION

Metal Inert Gas Welding which is also known as Gas Metal Arc Welding (GMAW) uses a consumable metal electrode and an inert gas or an active gas. It is the process in which source of heat is an arc formed between a consumable metal electrode and the work piece. The arc and molten puddle are protected from contamination by the atmosphere with an externally supplied gaseous shield of inert gas or active gas [1-2]. In this process carbon is used as shielding gas and plate of 12 mm is welded using MIG welding. Hardness testing of metals, ceramics, and composite is useful for a variety of applications for which hardness measurements are unsuitable. Hardness testing gives an allowable range of loads for testing with diamond indenter. The resulting indentation is measured and converted to a hardness value. Taguchi method [3-4] is a systematic application of design and analysis of experiment for designing purpose and product quality improvements. In this research work tensile strength, hardness and microstructure of specimen 1018 mild steel welded by MIG welding are evaluated. In this paper, analysis of variance (ANOVA) is used to determine most significant welding parameter.

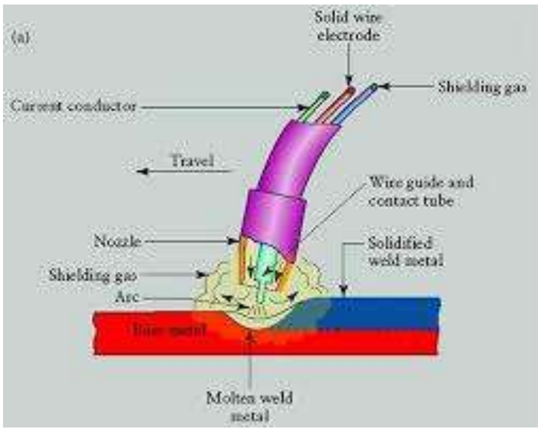

Figure 1 MIG welding of Mild Steel

Suresh Kumar (2002) discuss microstructural development during MIG welding of copper with iron filler. During the experimental work they consider voltage, current and travel speed as welding parameter. They investigate needle shaped morphology of iron matrix typical of martensite and at copper iron interface bended microstructure was observed which varied with travel speed [6].

Haragopal (2011) investigate the mechanical properties of Al-65032 alloy using Taguchi technique and result shows that current is the most influencing parameter for ultimate tensile strength and pressure is most significant parameter for proof stress [7].

Sapakal (2012) investigate the influence of welding parameter like welding current, welding voltage, welding speed on penetration depth of mild steel during welding by using Taguchi design method. Result shows the welding voltage has large effect on penetration [8].

A consumable electrode of mild steel with 2mm diameter shielded by carbon dioxide (CO2) gas is used to produce an electric arc with the base metal as shown in figure 1. The heat generated by electric arc is used to melt the filler electrode and base metal. As discussed earlier, Taguchi Approach is applied in this process for the analysis. It help to determine the best level of parameter used to analyzed the best performance of the result.

II. METHODOLOGY

In this experimental work, the specimen is welded at three different levels of welding parameter i.e. current, voltage and root gap as shown in Table I.

Table 1 Welding parameter and their levels

Parameters	Welding Current (A)	Arc Voltage (B)	Root Gap (C)
Unit	Amp	Volt	mm
Level 1	140	35	2
Level 2	160	40	3
Level 3	180	45	4

Table 2 Chemical Composition of Base Metal Mild Steel 1018

Element	Weight%
C	0.06
Si	0.09
Mn	0.37
P	0.063
S	0.065
Fe	99.05

Samples of size 200×100×90mm were cut with the help of Power Hacksaw. A groove of 600 was also made on each sample with the help of Power Grinder. The chemical composition of mild steel sheet using for present study is shown in Table 2.

Figure 2 Cutting of Sample from Strip

Figure 3 Final Cutting Sample for Welding

Figure 2 shows the cutting of the sample from the big strip with help of power hacksaw. All eighteen samples are cut in same size and their pictorial view is shown in figure 3. The working range of welding parameter were fined by conducting trial run and satisfactory values obtained are used to conduct the experimental work. L9 orthogonal array is used for analysis purpose and standard table of three variables with three different levels of input parameters is shown in table 3 and actual value of selected input parameter arc shown in table 4.

Table 3 L9 Orthogonal Array Design Matrix

Experiment Number	Welding Current	Arc Voltage	Root Gap
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

Table 4 L9 Matrix with Actual Value of Parameters

Experiment Number	Welding Current	Arc Voltage	Root Gap
1	140	35	2
2	140	40	3
3	140	45	4
4	160	35	3
5	160	40	4
6	160	45	2
7	180	35	4
8	180	40	2
9	180	45	3

The nine experiments were performed based on the L9 array. The effect of different parameters such as welding current, arc voltage and root gap of mild steel 1018 is analyzed. The tensile strength and hardness of all nine weld specimen were checked carefully and the observed value of tensile strength and hardness with their S/N ratios are shown in table 5 and in table 6. Figure 4 shows photograph of welded sample.

Figure 4 Welded Sample of Mild Steel

The samples used for measuring micro-hardness are rubbed first using emery paper of size no. 400, 600, 1000 & 2000 and then clean with acetone solution. The diagonals of the indents formed by pyramid- shaped diamond indenter on the samples gives the value of micro-hardness in Vickers.

Table 5 Result for Tensile Strength

Experiment Number	Welding Current	Arc Voltage	Root Gap	Tensile Strength	S/N Ratio
1	140	35	2	347.9	50.8291
2	140	40	3	335.4	50.5113
3	140	45	4	429.0	52.6491
4	160	35	3	341.8	50.6754
5	160	40	4	328.0	50.3175
6	160	45	2	339.4	50.6142
7	180	35	4	482.2	50.6645
8	180	40	2	375.6	50.4945
9	180	45	3	351.1	50.9086

Table 6 Result for Hardness

Experiment Number	Hardness WZ (Hv 10)	Hardness PM (Hv 10)	Hardness HAZ (Hv 10)	S/N Ratio
1	159.5	135.5	169.5	18.9495
2	159.5	138.5	148.5	23.0269
3	146.5	137.5	157.5	23.3417
4	237.5	173.5	248	14.7239
5	205.5	176.5	190	22.3713
6	177.5	162.5	167.5	26.9071
7	186	179.5	220	19.0587
8	155.5	163.5	154.5	30.1020
9	160.5	155.5	180.5	21.9456

III. RESULTS AND DISCUSSIONS

Figure 5 shows the steps involved in the Taguchi analysis. Analysis of variance (ANOVA) is a statistical tool used to analyze the S/N ratios. In ANOVA setting, the observed variance in a particular variable is partitioned into components attributable to different sources of variation. Analysis of variance technique is used in order to check the adequacy of the model. The term "signal" represents the desirable mean value, and the "noise" represents the undesirable value. Hence, the S/N ratio represents the amount of variation, which presents in the performance characteristics.

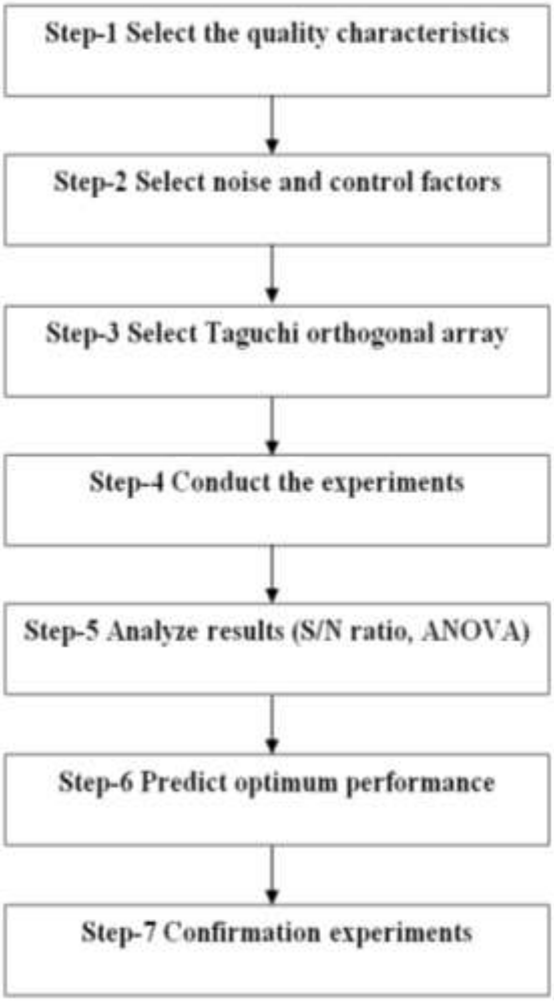

Figure 5 Steps for Taguchi's analysis

In the present study tensile strength and Hardness of the weld specimens were identified as the responses, therefore, "higher the better" characteristic chosen for analysis purpose.

$$HB : S / N\ ratio = -10 \log_{10}\left[\frac{1}{n}\sum_{i=1}^{n} yi^{-2}\right]$$

Where yi represents the experimentally observed value of the with experiment, n is the repeated number of each experiment, is the mean of samples and s is the sample standard deviation of n observations in each run.

Tensile Strength

Tensile strength is calculated experimentally and Taguchi method is applied for analysis with the help of ANOVA. On basis of data analyzed, plots for signal-to-noise (S/N) ratio are shown in Figure 6. The calculated S/N ratio has been tabulated in Table 5.

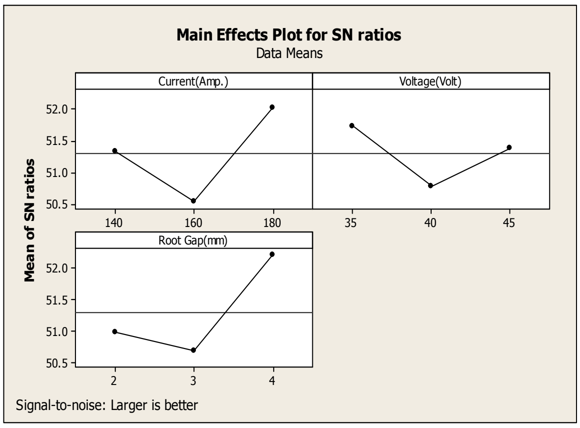

Figure 6 Effects of process parameters on tensile strength S/N ratio

Analysis of variance for S/N ratio is summarized in Table 7 and it is observed that root gap is the most prominent factor which effects tensile strength maximum with percent contribution of 38% followed by welding current with percent contribution 32% then arc voltage with percent contribution 14%.

Table 7 Analysis of Variance for Signal to Noise Ratio

Source	DF	Seq SS	Adj SS	Adj MS	F	P	PC (%)
Arc Current	2	3.321	3.321	1.6606	1.98	0.0336	32
Arc Voltage	2	1.390	1.390	0.6950	0.83	0.0547	14
Root gap	2	3.880	3.880	1.9402	2.31	0.0302	38
Residual Error	2	1.680	1.680	0.8400			16
Total	8	10.272					

The response values for S/N ratio for each level of identified factors have been listed in Table 8 which, shows the factor level values of each factor and their ranking.

Table 8 Response Table for Signal to Noise Ratio of Tensile Strength

Level	Arc Current	Arc Voltage	Root Gap
1	51.33	51.72	50.98
2	50.54	50.77	50.70
3	52.02	51.39	52.21
Delta	1.49	0.95	1.51
Rank	2	3	1

Hardness

The samples used for measuring Hardness are first rubbed with emery paper of size no. 400, 600, 1000 & 2000 and then cleaned with acetone solution. The diagonals of the indents formed by pyramid-shaped diamond indenter on the samples.

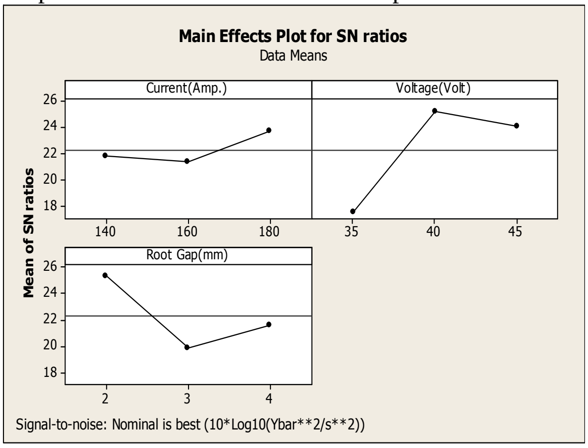

Figure 7 Effects of process parameters on Hardness S/N ratio

Analysis of variance for S/N ratio is summarized in Table 9 and it is observed that arc voltage is the most prominent factor which effects Hardness maximum with percent contribution of 62% followed by root gap with percent contribution 28% then welding current with percent contribution 6%.

Table 9 Analysis of Variance for Signal to Noise Ratio of Hardness

Source	**DF**	**Seq SS**	**Adj SS**	**Adj MS**	**F**	**P**	**PC (%)**
Arc Current	2	9.522	9.522	4.761	1.49	.0402	6
Arc Voltage	2	100.899	100.899	50.450	15.79	.0060	62
Root Gap	2	46.152	46.152	23.076	7.22	.0122	28
Residual Error	2	6.388	6.388	3.194			4
Total	8	162.962					

The response values for S/N ratio for each level of identified factors have been listed in Table 10 which shows the factor level values of each factor and their ranking.

Table 10 Response Table for Signal to Noise Ratio for Hardness

LEVEL	**CURRENT (Amp.)**	**VOLTAGE (Volt)**	**ROOT GAP (mm)**
1	21.77	17.58	**25.32**
2	21.33	**25.17**	19.90
3	**23.70**	24.06	21.59
DELTA	2.37	7.59	5.42
RANK	3	1	2

IV. CONCLUSION

The mild steel 1018 was used for the present study to explore the different input process parameters on the tensile strength and hardness of the weld samples. The L9 orthogonal has been used to assign the identified parameters. ANOVA analysis was performed for the analysis purpose which shows that current is the most significant parameters that influenced the tensile strength and hardness of the weld. The highest tensile strength obtained in the research is 482.2 at current (180 amp), voltage (35 volt) and root gap (4 mm) at a welding current of 210 amp, The maximum hardness is obtained at a welding current (180 amp), arc voltage (40 volt) and root gap (3 mm).

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