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Optimizations of MIG Welding Process Parameter for Improving Strength

Kundan kumar sharma
Department of Production Engineering, BIT sindri

Prof. Prakash Kumar
HOD, Production Engineering, BIT Sindri, Dhanbad
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ABSTRACT
The research of hardness and toughness with regard to various input parameters is the focus of the project optimization of MIG welding settings for enhancing welded joint strength. Gas Metal Arc Welding is a procedure in which heat is generated by an arc between a consumable metal electrode and the work piece, with an argon gas shield supplied externally. This experimental work intends to reduce the number of level analyses of welded area of a mild steel specimen by employing a factorial design technique to optimise various Gas Metal Arc welding parameters such as wire feed rate, welding current, and inert gas supply rate. The link between various process parameters and weld deposit area was investigated using a factororial design technique.

I. INTRODUCTION

1.METAL INERT GAS WELDING

Background

The principle of MIG Welding History began to developed around the 19thcentury, with Humphry's discovery of the electric arc in 1801. At first, carbon electrodes were used, but by the late 1800s, metal electrodes had been invented by Slavian and C. L. Coffin. In 1920 predecessor of GMAW was invented by Nobel. It used a electrode wire and direct current, and used arc voltage to regulate the feed. It did not use a shielding gas to protect the weld, as development in welding atmosphere did not take place until later that decade.

In 1936 another forerunners of GMAW was released, but it was not suitable for practical use. It was not until 1948 that GMAW was finally developed by the Batelle collage. It used a smaller diameter electrode and a constant voltage power source, which had been developed by H Kennedy. It offered a Increased deposition rate but the high cost of inert gases limited its use to nonferrous material.

Definition

MIG welding is a method in which a source of heat is used to create an arc between a consumable electrode and the work piece, and the arc and molten puddle are protected from contamination by the environment (oxygen and nitrogen). Because only inert gases are employed to shield the molten puddle, GMAW was formerly known as MIG welding. This method could only be used on aluminium, deoxidized copper, and silicon bronze. It was later used to weld ferrite and austenitic steels.

3 OBJECTIVE

- This project presents the influence of welding parameters like welding current, Gas flow rate and Wire feed rate on Hardness and toughness of AISI 1015 mild steel material during welding.
- Analysis of 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 Hardness

Input parameters
Gas Flow rate
Welding Current
Wire Feed Rate
Optimized
1.hardness
2.toughness

II. METHODOLOGY

TAGUCHI'S DESIGN METHOD

To plan the tests, the Taguchi Technique is employed. The Taguchi technique is a powerful instrument for increasing research productivity so that higher-quality products may be generated rapidly and at a low cost. Dr. Taguchi of the Nippon Telephone and Telegraph Company in Japan has developed a method based on "ORTHOGONAL ARRAY" tests that results in a considerably lower "variance" for the experiment when the control variables are "optimised."

Level of parameters

In this project gas flow rate, welding current and wire feed rate are selected as design factors while other parameters have been assumed to be constant over the experimental domain

Taguchi's L9 orthogonal design has been used with three levels to carry out the experiments since it only allows for 9 numbers of tests, which accurately portrays the entire process while being cost-effective and time-saving.

1.1 three levels of welding parameters

Variables	**Unit**	**Level1**	**Level2**	**Level3**
Gas flow rate	l/min	1.0	1.5	2.0
Current	Amp	60	70	80
Wire feed rate	m/min	5	6	7

Taguchi's Orthogonal Array

Taguchi orthogonal design creates a plan of experiment using a special set of preconfigured arrays called orthogonal arrays. These standard arrays compute the full information of all the factors that influence the process's performance. The orthogonal arrays that will be utilised in the experiment are chosen from a set of predefined number of factors and their levels.

Table 1.2 L9 Orthogonal array

S. No.	**Gas flow rate**	**Current**	**Wire feed rate**
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

EXPERIMENTAL PROCEDURE

WELDING OF SPECIMENS

The MIG welding of well-prepared specimens is done and the parameter of welding of each specimen is taken according to Taguchi‟s L_9 orthogonal arrays.

Table 1.3 Experimental layout for welding

S. No.	Gas flow rete (I/min)	Current (Amp)	Wire feed rate (m/min)
1	1.0	60	5
2	1.0	70	6
3	1.0	80	7
4	1.5	60	6
5	1.5	70	7
6	1.5	80	5
7	2.0	60	7

8	2.0	70	5
9	2.0	80	6

HARDNESS TESTING

Hardness may be defined as the ability of a substance to resist indentation of localized displacement. A hardness test is used to determine the hardness of weld metal. For hardness testing, the welded specimens are grinded first then performing Brinell hardness test on welds joint of each specimen.
The results of Brinell hardness tests are as:

$$BHN = \frac{F}{\frac{\pi}{2} D * \left(D - \sqrt{D^2 - Di^2}\right)}$$

Where: F is force used in KgF

D is the diameter of the indenter in mm

Di is the diameter of the indentation in mm

Formulae for BHN

Table 1.4 Results of hardness tests

S.No.	Gas flow rate (I/min)	Current (Amp)	Wire feed rate (m/min)	Hardness (BHN)
1	1.0	60	5	163
2	1.0	70	6	155
3	1.0	80	7	152
4	1.5	60	6	175
5	1.5	70	7	162
6	1.5	80	5	160
7	2.0	60	7	184
8	2.0	70	5	174
9	2.0	80	6	171

Figure 6.5 Penetration of indentor on weld joint

IMPACT TESTING

For impact testing, preparation of V-notch on weld joints of each specimen are done first then performing Charpy impact test on prepared (welded) specimens. The Charpy piece is supported horizontally between two anvils and the pendulum strikes opposite the notch ACharpy test measures the welds ability to withstand an Impact force. Low Charpy test readings indicate brittle weld metal Higher Charpy readings indicate the samples toughness. ` The impact test results are as:

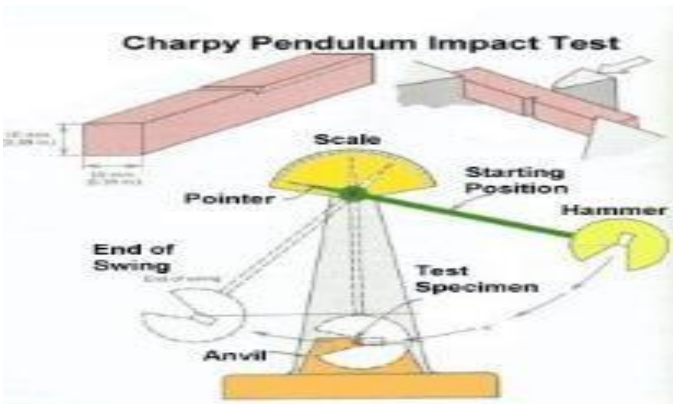

Figure 6.6 Charpy testing

Table 1.5 Results of impact tests

S. No.	Gas flow rate (I/min)	Current (Amp)	Wire feed rate (m/min)	Toughness (Joule)
1	1.0	60	5	70
2	1.0	70	6	94
3	1.0	80	7	142
4	1.5	60	6	98
5	1.5	70	7	124
6	1.5	80	5	74
7	2.0	60	7	106
8	2.0	70	5	56
9	2.0	80	6	68

The toughness values of the weld pieces are tabulated above. Weld pieces are placed at the impact testing machine as simply supported. The hammer of the heavy weight is then released and corresponding values of weight provides the toughness values for weld pieces.

Analysis Of S/N Ratio For Hardness

In this project effect of main input welding parameters on the hardness of welded joint in MIG welding process were investigated.

For S.No 1-S/N Ratio = $-10 \text{ Log}10(1/163^2)=44.24$

Table 1.6 S/N ratio for hardness results

S.No.	**Gasflowrate (l/min)**	**Current (Amp)**	**Wire feed rate (m/min)**	**Hardness (BHN)**	**S/N Ratio (db)**
1	1.0	60	5	163	44.24
2	1.0	70	6	155	43.80
3	1.0	80	7	152	43.63
4	1.5	60	6	175	44.86
5	1.5	70	7	162	44.19
6	1.5	80	5	160	44.08
7	2.0	60	7	184	45.29
8	2.0	70	5	174	44.81
9	2.0	80	6	171	44.65

Regardless of the category of the quality characteristic, a greater S/N ratio corresponds to better quality characteristics. Therefore, the optimal level of the process parameters is the level with the greatest S/N ratio.

Table 1.7 The S/N response table for hardness:

Symbol	Parameters	Level 1	Level 2	Level 3	Delta	Rank
A	Gas flow rate	43.89	44.37	44.91	1.03	1
B	Current	44.80	44.26	44.12	0.67	2
C	Wire feed rate	44.37	44.43	44.39	0.07	3

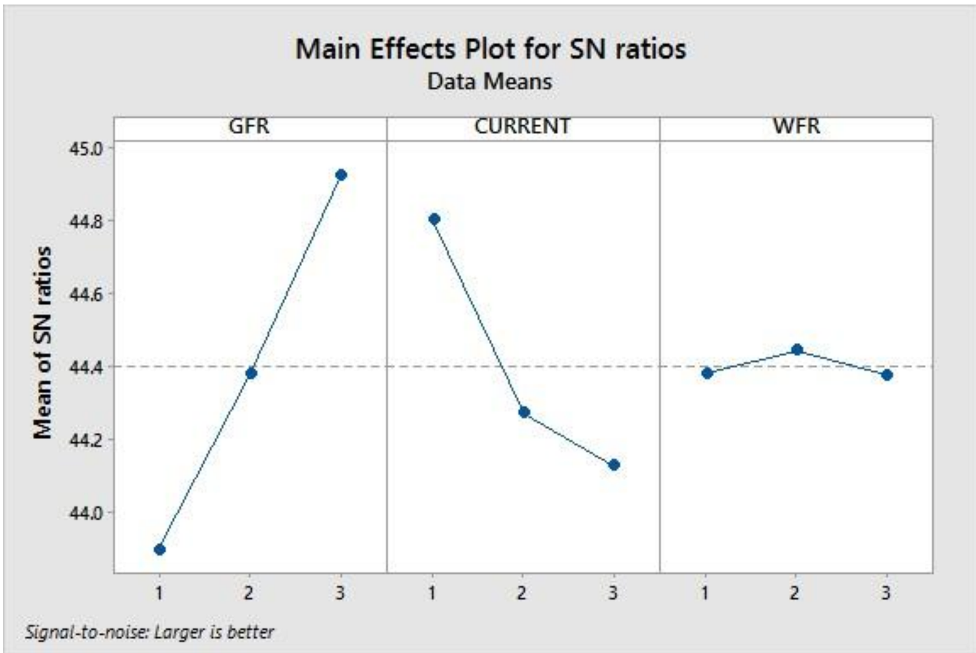

Figure Graph between mean s/n ratio and levels of parameters

Analysis Of S/N Ratio For Toughness

For S.No 1-S/N Ratio = -10 Log10(1/70^2)=36.90

Table 1.8 S/N ratio for toughness results

S.No.	**Gasflowrate(l/min)**	**Current (Amp)**	**Wire feed rate (m/min)**	**Toughness (joule)**	**S/N Ratio**
1	1.0	60	5	70	36.90
2	1.0	70	6	94	39.46
3	1.0	80	7	142	43.04
4	1.5	60	6	98	39.82
5	1.5	70	7	124	41.86
6	1.5	80	5	74	37.38
7	2.0	60	7	106	40.50
8	2.0	70	5	56	34.96
9	2.0	80	6	68	36.65

Table 1.9 The S/N ratio response table for toughness:

Symbols	Parameters	Level 1	Level 2	Level 3	Delta	Rank
A	Gag Flow rate	39.80	39.68	37.38	2.43	2
B	Current	39.07	38.76	39.02	0.31	3
C	Wire feed rate rate	36.41	38.64	41.80	5.39	1

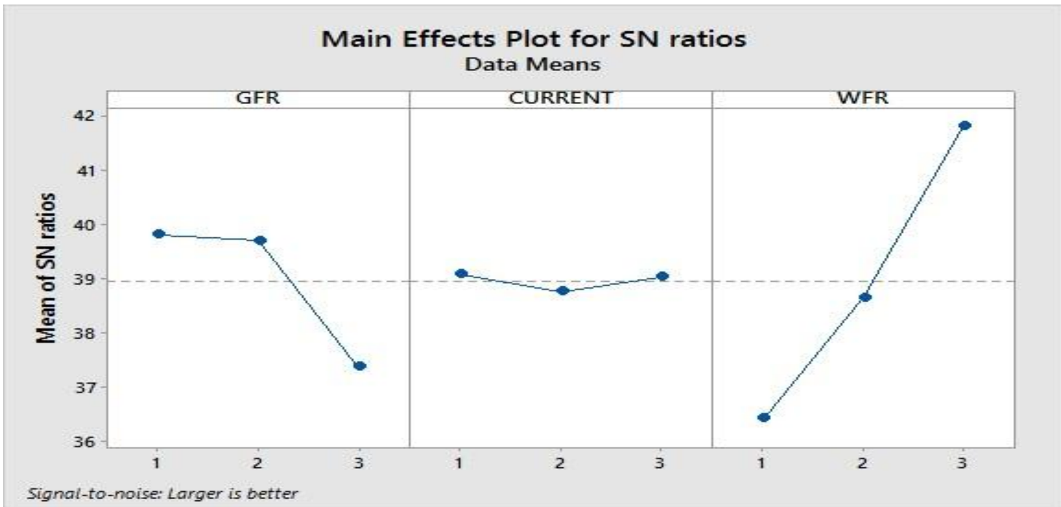

Figure : Graph between mean s/n ratios and levels of parameters for toughness ANALYSIS OF VARIANCE

The purpose of the analysis of variance (ANOVA) is to investigate 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 design parameters and the error.

ANOVA for Hardness

For Gas Flow rate:-[3]

Seq.Square of Sum=$(43.89-44.37)^2+(43.89-44.91)^2+(44.37-44.91)^2$=1.58303

Adj MS= Seq.SS/DF=1.58303/2=0.791714

F-value= Adj MS/ Adj MS_E=0.791514/0.003867=204.66

Table 1.10: ANOVA for Hardness

Parameters	DF	Seq.SS	Adj MS	F	P
V Gas Flow Rate	2	1.58303	0.791514	204.66	0.005
Welding Current	2	0.75650	0.378248	97.80	0.010
Wire Feed Rate	2	0.00865	0.004327	1.12	0.472
Error	2	0.00773	0.003867		
Total	8	2.35591			
DF - degrees of freedom, SS - sum of squares, MS – mean squares(Variance), F-ratio of variance of a source to variance of error, P < 0.05 - determines significance of a factor at 95% confidence level.					

Calculation of SS' and Percentage Contribution of Hardness

The formula used for finding the Pure Sum of Square (SS) and Percentage contribution(P) are[2]-

SS= Seq SS – DF * (Adj MS Error)

P = (SS / Total Seq. SS) * 100%

- **Pure sum of square (SS)**:

For GFR: SS= 1.58303 – (2*0.003867)= 1.5752

For WC: SS= 0.75650– (2*0.003867)=0.7487 For WFR: SS= 0.00865 – (2*0.003867) =0.000916

- **Percentage contribution**:

For GER : P= (1.5752/2.35591)* 100 = 66.8%

For WC : P= (0.7487/2.35591)* 100= 31.7%

For WER : P= (0.000916/2.35591)* 100 =0.03%
Above results describe the percentage contribution of individual process input parameters of MIG on Mild steel for Hardness. The percentage contribution of Gas flow rate is 66.86,Welding Current is 31.77,Wire feed rate is 0.03%, and error is about 2%. This error is due to machine vibration.

ANOVA For Toughness

The optimum parameter for hardness is decided from ANOVA analysis:[3]

Table 1.11 ANOVA analysis for Toughness

Parameter	DF	Seq.SS	Adj MS	F	P
Gas flow rate	2	0.38741	0.193371	5.26	0.160
Current	2	0.12438	0.06219	1.69	0.372
Wire feed rate	2	1.79824	0.89912	24.43	0.039
Error	2	0.07361	0.03681		
Total	8	2.38365			

- **Percentage contribution**:

For GER : P= (0.31379/2.38365)* 100 = 13.16%
For WC : P= (0.05076/2.38365)* 100= 2.12%
For WER : P= (1.72462/2.38365)* 100 =72.35%
Above results describe the percentage contribution of individual process input parameters of MIG on Mild steel for Toughness. The percentage contribution of Gas flow rate is 13.16,Welding Current is 2.12,Wire feed rate is 72.35%, and error is about 16%. This error is due to machine vibration.

7.3 CONFIRMATION TEST

Table 1.12 Confirmation Experimental Test Results for Hardness

Responses	**Initial process parameter**	**Optimal process parameters prediction**	**Improvement in S/N ratio**	**%Error**
Flux Composition	A1B3C1	A3B1C2		
Hardness(BHN)	152	184		
S/N(db)	43.64	45.38	1.74	3.98

The improvement in S/N ratio is 1.74 dB from the initial welding parameters to the optimal welding parameter and the Hardness increased by 1.21 times. Therefore, the Hardness is significantly improved by using the Taguchi Method.

Table 1.13 Confirmation Experimental Test Results for Toughness

Responses	**Initial process parameter**	**Optimal process parameters prediction**	**Improvement in S/N ratio**	**%Error**
Flux Composition	A3B2C1	A1B1C3		
Toughness (joule)	56	142		
S/N(db)	34.65	42.77	8.12	23.37

The improvement in S/N ratio is 8.12 dB from the initial welding parameters to the optimal welding parameter and the Toughness increased by 2.53 times. Therefore the Toughness is significantly improved by using the Taguchi Method.

III. RESULTS AND DISCUSSION

• The experimental confirmation test is the final step in validating the conclusions drawn using Taguchi's design approach, and it is highly advocated by Taguchi.

A confirmation experiment was carried out in this project using the levels of the ideal process parameters A3B1C2 for improved 184 BHN hardness and A1B1C3 for better 152 Joule toughness in the weld zone.

IV. CONCLUSION

For the optimization of MIG welding parameters, a Taguchi orthogonal array, the signal-to-noise (S/N) ratio, and analysis of variance (AVOVA) were utilised in this research. Based on the experimental results of this project's work, the following conclusions can be drawn:
1. Taguchi's orthogonal array design method is appropriate for analysing the challenge in this project.
2. It was seen that the Taguchi method's parameter design provides a straightforward, systematic, and efficient way for optimising MIG welding settings.
3. Based on the ANOVA, the gas flow rate and welding current are the most important parameters for weld joint hardness. With an increase in gas flow rate, the value of hardness rises, while welding current hardness falls.
4. The effect of the gas flow rate on the major input welding parameters is significant, according to the results. Increasing the gas flow rate and reducing the gas flow rate

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