



Investigating the Effect of Metal Inert Gas Welding Parameters on AA10119 Mild Steel Quality by Taguchi Method

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Authors' contributions

This work was carried out in collaboration among all authors. Author JAI designed the study, performed the statistical analysis, wrote the protocol, and wrote the first draft of the manuscript. Authors AAM and ET managed the analyses of the study. Author ET managed the literature searches. All authors read and approved the final manuscript.

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ABSTRACT

In welding, the quality of welded joints is greatly influenced by the welding process parameters. Thus, in order to achieve a good weld quality, there is exigency to select the right welding process parameters. The focus of this study is to investigate the effect of Metal Inert Gas (MIG) welding process parameters; welding current, welding voltage and welding speed on the tensile strength of mild steel AA10119 welded plates. The experiment was designed using Taguchi's L9 orthogonal array with three levels. Kaiierda MIG MAG Inverter CO₂ Welder Model E-180 welding machine was used to conduct the experiments with three repetitions. From the analysis carried out by applying Taguchi's method, the result shows that the welding speed and welding current have the most significant influence on tensile strength of the weld and an optimum parameter setting of A₃B₂C₂ was suggested; welding current 240 A, welding voltage 25 V and welding speed 0.010 m/s. The mean tensile strength at this optimal setting A₃B₂C₂ was predicted to be 442 N/mm².

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1. INTRODUCTION

Metal inert gas welding (MIG) method is one of the most popular industrial welding processes for mild steel, because of its speed, versatility and high quality of welds. It is widely used in manufacturing and sheet metal industry. 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, such as welding current, arc voltage, welding speed, gas flow rate and electrode extension. These parameters are the process variables that influence the quality of weld [1]. Many researchers have investigated application of metal inert gas welding method on low carbon steel plates. Correia et al. [2] studied optimization of metal inert gas welding parameter using Genetic algorithm (GA) to predict the next experiment based on the earlier and without information of the modelling equations between the inputs and outputs of the metal inert gas welding process. However, the GA was able to obtain near-optimal conditions with a relatively small number of experiments. Nagesh et al. [3] applied artificial neural network (ANN) to predict the penetration and weld bead geometry by selecting welding parameters, such as arc current, arc voltage, electrode feed rate and arc length for optimization of output parameters like bead width, bead height and penetration depth. It was concluded from the study, that use of either low arc travel rate or high arc power will yield better fusion. The bead width and height were found to decrease with increase in arc travel rate. While depth of penetration and HAZ increased with increase in electrode feed rate, at constant arc length. Kumar et al. [4] studied optimization of metal inert gas welding parameters by applying artificial neural network (ANN) and genetic algorithm (GA). In the study, they developed a mathematical model by using artificial neural network to predict the influence of welding parameters, such as welding speed, arc voltage and welding current, on ultimate tensile stress of dissimilar materials of stainless steel (grade 316 and grade 304). The value of output parameter was optimized using genetic algorithm. They concluded that the maximum ultimate tensile strength is achieved at 110 A welding current, 18 V welding voltage and 43.362 cm/min travel speed. Patel et al. [5] investigated the influence of welding current, wire feed rate

and wire diameter on weld bead hardness for tungsten inert gas (TIG) and metal inert gas (MIG) welding using Taguchi's method and Grey Relational Analysis (GRA). They concluded that welding current was the most influencing parameter for both metal inert gas and tungsten inert gas welding. Using GRA optimization method, the optimal parameter combination was found to be welding current, 100 A, wire diameter, 1.2 mm and wire feed rate, 3 m/min for MIG welding. Achebo [6] carried out a study to improve the quality of weld using the Taguchi method. The selected GMAW welding parameters were welding current, welding voltage, welding speed and welding time. The experiments were designed using L18 orthogonal array. It was concluded from the study, that ultimate tensile strength is optimized with welding current of 240 A, welding time of 2.0 mins, welding speed of 0.0062 m/s, and welding voltage of 33 V. Sapakal and Telsang [7] investigated the influence of welding current, welding voltage and welding speed on depth of penetration of mild steel by applying the Taguchi method. They concluded that voltage was the most significant parameter with percentage contribution of 84.42 %, followed by welding speed with 6.83 % and current with 3.55 %. Chomsamutr and Jongprasith [8] used the Response Surface Methodology and the Taguchi method to design process parameters of metal inert gas welding that optimize tool life of mild steel welded joints. The process parameters selected were cutting speed, feed rate and depth of cut. Taguchi's L9 orthogonal array was used for designing the experiments. It was concluded from the study that the longest tool life found by Taguchi's method and RSM were 670.170 min and 670.230 min respectively. The optimum parameters suggested were depth of cut of 0.5 mm, cutting speed of 150m/min and feed rate of 0.10 mm/rev. Kumar et al. [9] studied optimization of GMAW process parameters of mild steel 1018 joints by Taguchi's experimental design method. The L9 orthogonal array was selected to design the experiments. The input welding parameters considered in the study were welding voltage, welding current and gas flow rate. The optimal settings suggested were: welding current of 220 A, welding voltage of 40V and gas flow rate of 17 lit/min. Chavda et al. [10] studied the influence of welding parameters: welding current, welding voltage, gas flow rate and wire feed rate on weld quality and weld pool geometry of medium carbon steel material during

the welding by the Taguchi method. Aghakhani et al. [11] used Taguchi's method to design process parameters of gas metal arc welding to optimize weld dilution for mild steel welded joints. The process parameters considered were feed rate, arc gap, welding voltage, gas flow rate and welding speed. The experiments were designed using L25 orthogonal array. They concluded from the study that the wire feed rate was the most significant parameter while the gas flow rate was the least significant parameter for weld dilution. In this study, an attempt is made to investigate the effect of metal inert gas welding process parameters on tensile strength of mild steel (AA10119) welded joints. The considered process parameters are welding current, welding voltage and welding speed. The experiment is designed using Taguchi's L9 orthogonal array with three levels.

2. MATERIALS AND METHODS

2.1 Materials

The material used for welding is AA10119 mild steel round bars of 6mm diameter that was locally sourced from a state in Nigeria. The spectrometric analysis of the specimens was done using spectromax. The base metal chemical composition is shown in Table 1. Other materials used in the study were abrasive paper grit, MIG welding machine, E6013L electrode wire of 0.9mm, grinding machine, Universal Testing Machine (UTM) Model KUT-40 (E) Capacity 400KN and power hack saw.

2.2 Method

In this study, the metal Inert Gas (MIG) welding process is used to make weld deposits using Kaiherda MIG MAG Inverter CO₂ Welder Model E-180 with the following set up: 1.2 mm diameter of electrode wire (AWS classification ER70S-6), torch angle of 5°, nozzle to work distance of 9 mm and 100 % carbon dioxide as shielding gas. Mild steel plates of 100mm by 50mm by 6mm were used to make weld deposits. The experiment has been designed using the Taguchi's experimental design method with the selected input factors and their levels shown in Table 2. The experimental layout using L9 orthogonal array with three levels is presented in Table 3. Nine experiments consisting of five different weld deposits were carried out. The lathe machine was used to machine the weld deposits to produce tensile specimens used to conduct the required tensile tests. After the welding, the samples were cleaned from dirt and

grease using paper grit and then cut into the desired dimension with the aid of power hacksaw. The samples were then subjected to tensile test on the Universal Testing Machine. The average tensile strength values obtained from the tensile tests are presented in Table 4.

The tensile strength of the welded joints is in the category of the larger-the-better quality feature because the higher the tensile strength of the welded joints, the better the performance. The signal to noise ratio (S/N) of the larger-the-better quality feature is shown in equation (2).

$$L_f = \left(\frac{1}{n} \sum_{i=1}^n \frac{1}{y_i^2} \right) \quad (1)$$

$$S/N \text{ ratio} = -10 \log L_f \quad (2)$$

Where

n= number of tests conducted

y_i = Experimental value of the i-th quality feature

L_f = Loss function

3. RESULTS AND DISCUSSION

The result obtained for the S/N ratio for each experiment of L₉ by applying equations (1) and (2) is presented in Table 5. From the L₉ (3³) experimental layout in Table 3 and the corresponding values of signal to noise ratios in Table 5, the mean S/N ratios of the welding process parameters in their various levels were arranged as shown in Table 6. The optimum level based on the larger-the-better criterion is indicated as (opt). From Table 6, the optimum parameter levels for welding current, welding voltage and welding voltage are 52.39, 52.16 and 52.27 respectively. The optimal parameters setting using Taguchi L₉ orthogonal array is A₃B₂C₂.

Fig. 1 shows the main effect plot of welding current on tensile strength. From the plot, it is observed that the tensile strength of the weld increases gradually as welding current is increased from 160 A to 240 A. As a result, the optimal parameter setting for the welding current was found at 240 A (A₃). Fig. 2 shows the main effect plot of the welding voltage on tensile strength of the specimen. From Fig. 2, it was observed that as the welding voltage is gradually increased from 20 V to 25 V, the S/N ratio of the weld increased from 51.73 dB to 52.16 dB. But as the welding voltage is further increased from 25 V to 30 V, a gradual decrease in S/N ratio from 52.16dB to 51.91 dB was observed. This is

due to increase in granule size. The optimal parameter setting for welding voltage is therefore 25 V (B_2). In Fig. 3, the main effect plot of the welding speed on the tensile strength of the welded joints is shown. From Fig. 3, it was found that the signal-noise ratio of tensile strength increases when the welding speed is increased from 0.005 m/s to 0.010 m/s. However, on further increase of the welding speed from 0.01 m/s to 0.015 m/s, a sudden drop in S/N ratio was observed. Thus, the optimal setting for the welding speed is 0.010 m/s (C_2). This observation is supported by Kumar et al. [9].

3.1 Prediction of Tensile Strength at Optimum

From the analysis of the S/N ratios for tensile strength of the test samples by the application of the Taguchi method, the optimal levels of welding parameters were predicted as $A_3B_2C_2$; welding current of 240 A, welding voltage of 25 V and welding speed of 0.010 m/s. The predicted mean tensile strength of the weld using the optimal levels of the welding parameters can be computed using [12] as:

$$\mu_{TS} = \mu + (A_{3avg} - \mu) + (B_{2avg} - \mu) + (C_{2avg} - \mu) \quad (3)$$

Where

$$U_{TS} = \text{Mean tensile strength}$$

μ = Mean of all data points

A_{3avg} = Average of all data points having A_3 level

B_{2avg} = Average of all data points having B_2 level

C_{2avg} = Average of all data points having C_2 level

From Table 4,

$$\mu = 396 \text{ N/mm}^2$$

$$A_{3avg} = 417 \text{ N/mm}^2$$

$$B_{2avg} = 406 \text{ N/mm}^2$$

$$C_{2avg} = 411 \text{ N/mm}^2$$

From equation (4), the mean tensile strength is calculated as follows:

$$U_{TS} = 396 + (417 - 396) + (406 - 396) + (411 - 396)$$

$$U_{TS} = 442 \text{ N/mm}^2$$

The predicted mean tensile strength at $A_3B_2C_2$ is 442 N/mm²

3.2 Confirmation Experiment

To validate the results obtained, a confirmation experiment was conducted using the optimal setting $A_3B_2C_2$ obtained from previous experiments. The result of the confirmation experiment is shown in Table 7.

Table 1. Chemical composition of base metal AA10119

Element	Carbon	Manganese	Silicon	Sulphur	Phosphorus
Percentage	0.17	0.95	0.22	0.01	0.015

Table 2. Welding parameters and their levels

Symbol	Input factor	Unit	Level 1	Level 2	Level 3
A	Welding current	A	160	200	240
B	Welding voltage	V	20	25	30
C	Welding speed	m/s	0.005	0.010	0.015

Table 3. Experimental layout using $L_9(3^3)$ orthogonal array

Experiment Number	Welding current (A)	Welding voltage (V)	Welding speed (m/s)
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

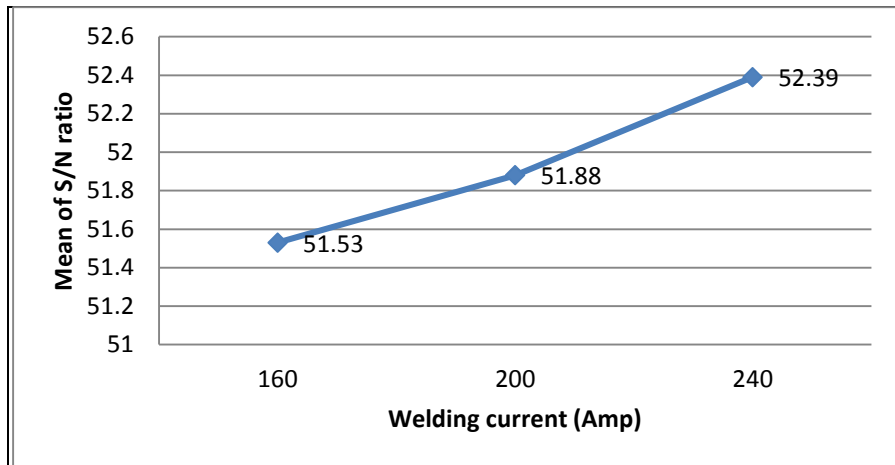


Fig. 1. Main effect plot of the welding current (Factor A)

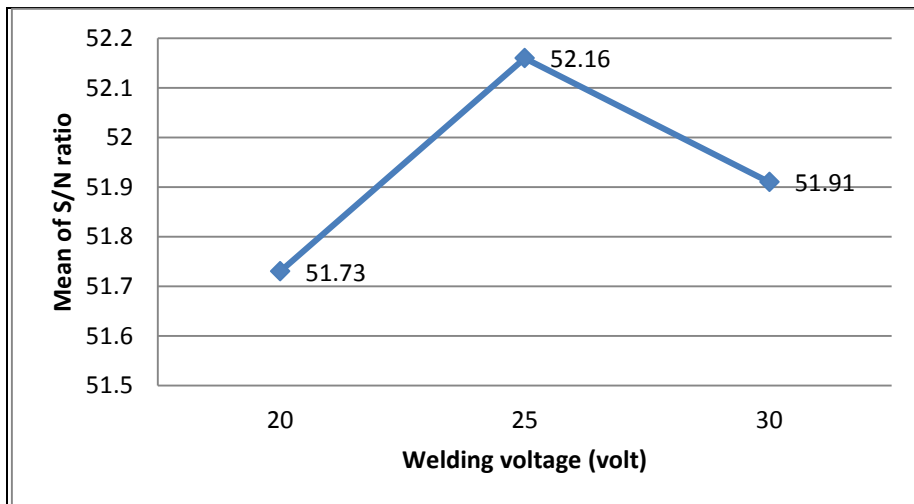


Fig. 2. Main effect plot of the welding voltage (Factor B)

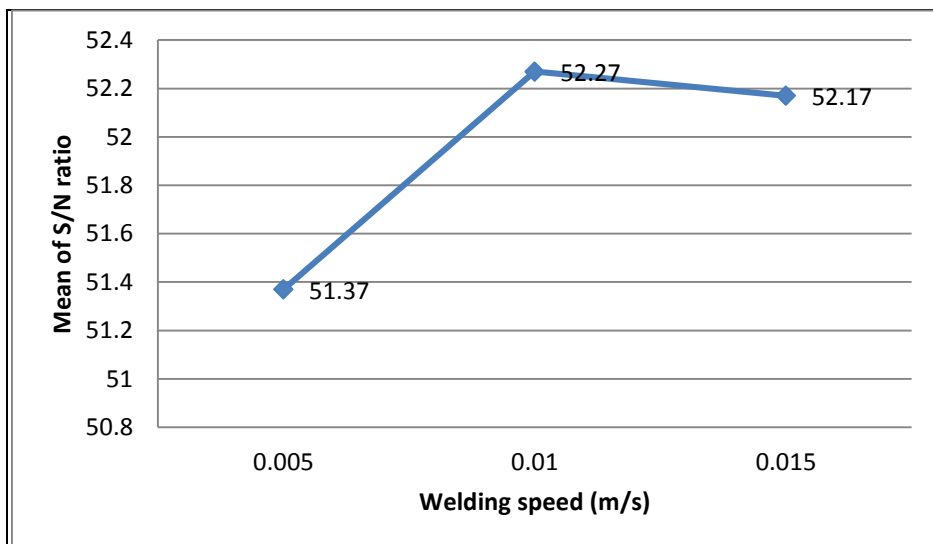


Fig. 3. Main effect plot of the welding speed (Factor C)

Table 4. Average tensile strength results of test samples at various factor setting

Experiment number	Welding current (A)	Welding voltage(V)	Welding speed (m/s)	Average Tensile strength(N/mm ²)
1	160	20	0.005	338
2	160	25	0.010	415
3	160	30	0.015	383
4	200	20	0.010	395
5	200	25	0.015	405
6	200	30	0.005	378
7	240	20	0.015	431
8	240	25	0.005	397
9	240	30	0.010	422

Table 5. The S/N ratios for tensile strength at various levels

Experiment Number	Welding current (A)	Welding voltage (V)	Welding speed (m/s)	Mean Tensile strength (N/mm ²)	S/N ratio (dB)
1	160	20	0.005	338	50.58
2	160	25	0.010	415	52.36
3	160	30	0.015	383	51.66
4	200	20	0.010	395	51.93
5	200	25	0.015	405	52.15
6	200	30	0.005	378	51.55
7	240	20	0.015	431	52.69
8	240	25	0.005	397	51.98
9	240	30	0.010	422	52.51

Table 6. The Mean S/N ratio for tensile strength and their levels

Symbol	Process parameter	Mean S/N ratio (dB)			Max-Min	Rank
		Level 1	Level 2	Level 3		
A	Welding current (A)	51.53	51.88	52.39*	0.86	2
B	Welding voltage (V)	51.73	52.16*	51.91	0.43	3
C	Welding speed (m/s)	51.37	52.27*	52.17	0.9	1

Table 7. Results of the confirmation experiment

Experiment Number	Welding current (A)	Welding voltage (V)	Welding speed (m/s)	Tensile strength (N/mm ²)
1	240	25	0.010	441.54
2	240	25	0.010	442.37

4. CONCLUSION

The effect metal inert gas welding process parameters on the tensile strength of AA10119 mild steel welded joints has been studied. The considered process parameters were welding current, welding voltage and welding speed. The Taguchi's L9 orthogonal array was used for the design of the experiments. From the study, the following important conclusions were made:

1. Welding speed and welding current had the most significant influence on the tensile strength of the welded joints, while the welding voltage was the least significant parameter. The percentage contribution of welding speed, welding current and welding voltage were 41.1 %, 39.27 % and 19.63 % respectively.
2. From the study, it was found that increase in welding current increases the tensile strength of the welded joints, while the

further increase in welding voltage and welding speed caused a gradual decrease in the tensile strength of the test samples.

3. The optimum process parameters suggested were welding current of 240 A, welding voltage of 25 V and welding speed of 0.010 m/s.
4. The mean tensile strength of the welded joints at the suggested optimum parameters was predicted to be 442 N/mm².
5. A confirmation test was also conducted to validate the optimum parameters settings.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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