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Optimization of MIG Welding Process Parameters – A Taguchi Method Approach

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A B S T R A C T

The welding process variables have a crucial impact on the overall performance of the welded joint during metal inert gas (MIG) welding. Elaborate tests and analysis are necessary to achieve accurate control of the welding MIG process in order to accomplish the necessary quality characteristics in welded specimens. This study aims to investigate and evaluate the impact of welding parameters, namely welding current, welding voltage, and gas flow rate, on the ultimate tensile strength (UTS) of Mild steel materials in MIG welding. The Taguchi Approach is utilized to optimize various parameters. The experiment utilizes a L9 orthogonal array, incorporating three variable factors: welding current, welding voltage, and gas flow rate, each with three levels. The objective is to determine the optimal parameter levels that will result in the highest tensile strength. The analysis of variance (ANOVA) reveals that the welding current accounts for a significant proportion of 74.85% of the variation in tensile strength. The optimal values for welding current, welding voltage, and gas flow rate were determined to be 120 A, 30 V, and 14 L/min, respectively.

Keywords: Welding, MIG, UTS, Taguchi Method, ANOVA

1. Introduction

Welding is a rapid and economical method for permanently joining two materials. It offers versatility in design and streamlines the construction of expansive structures. It is crucial in the metal fabrication business. Currently, almost all metal goods undergo the process of welding. Industries such as aviation, automotive, construction, and manufacturing heavily rely on welding for the creation of essential products including jet engines, pipelines, autos, and airplanes. Mild steel, the prevailing type of steel, is extensively employed in industries and construction projects due to its affordability and versatile features that make it suited for a wide range of applications. Mild steel has exceptional weldability. It is utilized in the majority of welded structures, including bridges, ships, tanks, pipes, buildings, railroad cars, and automobiles. Mild steels are manufactured in larger quantities than the combined production of all other steels, and they constitute the majority of materials used in welded fabrication. The widespread utilization of steel buildings has made production prices and efficiency crucial considerations for ongoing advancement. Conventional welding methods require enhanced flexibility and intelligence in order to achieve improved adaptation and increased efficiency. In today's changing world, it is imperative for industries to maintain global competitiveness. The user's text is "[8]".

Nomenclature

MIG – Metal Inert Gas

UTS – Ultimate Tensile Strength

ANOVA – Analysis of Variance

Welding is a rapid and economical method for permanently joining two materials. It offers versatility in design and streamlines the construction of expansive structures. It is crucial in the metal fabrication business. Currently, almost all metal goods undergo the process of welding. Industries such as aerospace, motoring construction, and production heavily rely on welding for the creation of essential products including jet engines, pipelines, autos, and airplanes. Mild steel, the prevailing type of steel, is extensively employed in industries and construction projects due to its affordability and versatile features that make it suited for a wide range of applications. Mild steel has exceptional weldability. It is utilized in the majority of welded structures, including bridges, ships, tanks, pipes, buildings, railroad cars, and automobiles. Mild steels are manufactured in larger quantities than the combined production of all other steels, and they represent the vast majority of the components used in welded fabrication. The broad utilization of steel buildings has rendered production prices and efficiency crucial considerations for ongoing advancement. Conventional welding methods require enhanced flexibility and intelligence in order to achieve improved adaptation and increased efficiency. In today's changing world, it is imperative for industries to maintain global competitiveness.

In their 2018 study, Dr. P. Vijayavel et al. examined the optimization of MIG welding parameters in order to enhance the strength of welded joints. This study examines the effect of welding variables, such as welding current, welding voltage, and welding speed, on the ultimate tensile strength (UTS) of AISI 1050 mild steel material during the welding process. The Taguchi look at was employed to develop an experimental strategy. An Orthogonal array, signal to noise (S/N) ratio, and analysis of variance (ANOVA) are utilized to investigate the welding properties of the material and improve the welding settings. The computed result is shown as the contribution from each parameter, allowing for the recognition of the ideal amounts for achieving maximum tensile strength. This work demonstrates that the tensile strength of a welded junction is significantly affected by two key parameters: welding current and welding speed [2-7].

In their 2019 study, G. Shanmugasundara et al. studied the optimization of process parameters in TIG welded joints of AISI 304L - Austenitic SS using Taguchi's experimental design method. The study involved conducting trials on Austenitic SS (AISI 304L) utilizing the Tungsten inert gas (TIG) welding technique. This investigation involved the creation of butt welded joints utilizing three different levels of current, gas flow rate, and nozzle to work piece distance. The weld's quality has been evaluated based on the ultimate tensile strength of the welded specimens. The L9 orthogonal array of Taguchi's experimental design approach was employed to optimize the welding current, gas flow rate, and nozzle to work piece distance for welded joints. [8, 9].

In their study, Baloyi et al. (2021) examined a Two-staged technique for estimating the ultimate tensile strength in MIG welding of mild steel. This study proposes a two-staged technique that combines the Taguchi method and adaptive neurofuzzy inference system (ANFIS) models to optimize and predict the weld tensile strength of AISI1008 Mild steel plates. These plates have a thickness of 3 mm and are joined together through a metal inert gas (MIG) welding process. The model takes three process parameters, specifically welding voltage, welding current, and gas flow rate, as input. The output parameter of the model is the tensile strength of the welded mild steel plate. The highest achievable tensile strength of the welded joint was determined to be 99 MPa [10].

The literature study reveals a significant lack of research on the impact of MIG welding process parameters (welding current, welding voltage, and gas flow rate) on the tensile strength of mild steel materials. Furthermore, it has been noted that there is a possibility of identifying an optimal configuration of input parameters in the MIG welding process. Research indicates that there are several feasible alternatives to enhance the welding strength in the MIG welding process by utilizing the Taguchi method. This parameter optimization technique also prevents engineers or production controllers from engaging in wasteful production activities, such as inefficient use of time, and helps in producing a superior product.

2. Experimentation – TAGUCHI Method

Taguchi Design offers a robust and effective approach to creating things that function reliably and optimally under different conditions. The main objective of robust parameter design is to identify factor values that reduce variation in the response, while simultaneously changing the process to meet the target. Once you have identified the elements that contribute to variation, you can then attempt to discover optimal settings for controllable factors that will either decrease the amount of variation, make the product less responsive to changes in factors, or achieve both of these objectives simultaneously. A process formulated with this objective will yield more uniform results.

The number of experiments is determined using the Taguchi Method with the assistance of Minitab-16 Software. The three factors, namely welding current, welding voltage, and gas flow rate, are each set at three different levels.

TABLE - 1:DoE Experimental Levels

Control Factor	**Unit**	**Level**	**Level**		
			I	**II**	**III**
Current	A	3	120	140	160
Voltage	V	3	20	25	30
Gas Flow Rate	L/min	3	14	16	18

TABLE – 2: Combination of Parameters

Sr. No	**Run**	**Welding current (A)**	**Welding Voltage (V)**	**Gas Flow Rate (L/min)**
1	1	120	20	14
2	2	120	25	16
3	3	120	30	18
4	4	140	20	16

5	5	140	25	18
6	6	140	30	14
7	7	160	20	18
8	8	160	25	14
9	9	160	30	16

3. Result and Discussions

Transverse tensile specimens were prepared according to the ASTM standard. Tensile tests were performed on welded samples at room temperature using a universal tensile testing equipment, following the ASTM standard. Figure 1 displays the measurements of the welded workpiece in accordance with the ASTM Standards. The findings are recorded in Table 3.

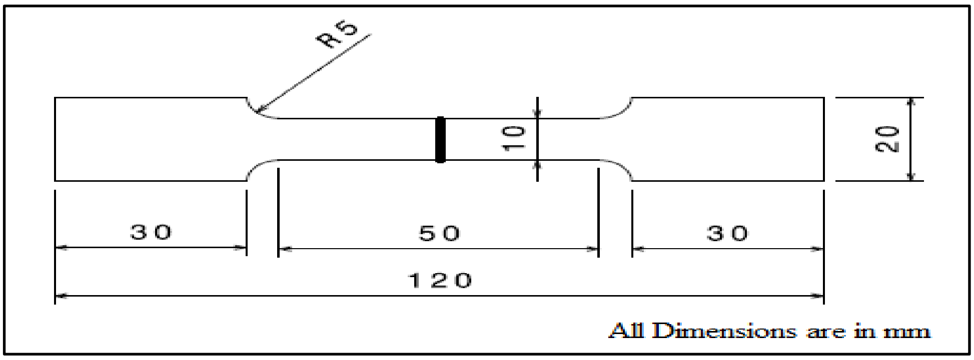

Fig. 1 – Tensile Specimen

Table 3 - Experimental Result of Tensile strength

Run	Welding current (A)	Welding Voltage (V)	Gas Flow Rate (L/min)	Tensile strength (Mpa)
1	120	20	14	378.12
2	120	25	16	361.02
3	120	30	18	365.36
4	140	20	16	341.21
5	140	25	18	330.89
6	140	30	14	360.18
7	160	20	18	329.32
8	160	25	14	339.21
9	160	30	16	325.11

The signal-to-noise ratio (S/N ratio) is computed for each level and is displayed in Table 4. The Signal to Noise (S/N) Ratio for Tensile strength is determined by utilizing the Larger the Better feature.

The Table 5 displays the Analysis of Variance (ANOVA) result for Tensile Strength. The ANOVA results for Tensile Strength indicate that the Welding current has a significant contribution of 74.85%, while the Welding voltage has a contribution of 2.53% and the Gas flow rate has a contribution of 20.54%. The residual error was determined to be 2.08%.

Table 4 - Experimental Result – S/N Ratio

Run	Welding current (A)	Welding Voltage (V)	Gas Flow Rate (L/min)	S/N Ratio Tensile strength
1	120	20	14	51.55
2	120	25	16	51.15
3	120	30	18	51.25
4	140	20	16	50.66
5	140	25	18	50.39
6	140	30	14	51.13
7	160	20	18	50.35
8	160	25	14	50.60
9	160	30	16	50.24

TABLE 5 - ANOVA results

Source	DF	Adj MS	F	P	% Contribution
Welding Current	2	1.30003	35.99	0.027	74.85%
Welding Voltage	2	0.04396	1.22	0.451	2.53%
Gas Flow Rate	2	0.35677	9.88	0.092	20.54%
Resi Error	2	0.03612			2.08%
Total	8				100
S = 0.1344, R-Sq = 97.9% R-Sq(adj) = 91.7%					

The Table 5 displays the Analysis of Variance (ANOVA) outcome for Tensile Strength. The ANOVA analysis of Tensile Strength reveals that the Welding current has a significant contribution of 74.85%, while the Welding voltage has a contribution of 2.53% and the Gas flow rate has a contribution of 20.54%. The residual error was determined to be 2.08%. The percentage contribution is also depicted in Figure 2.

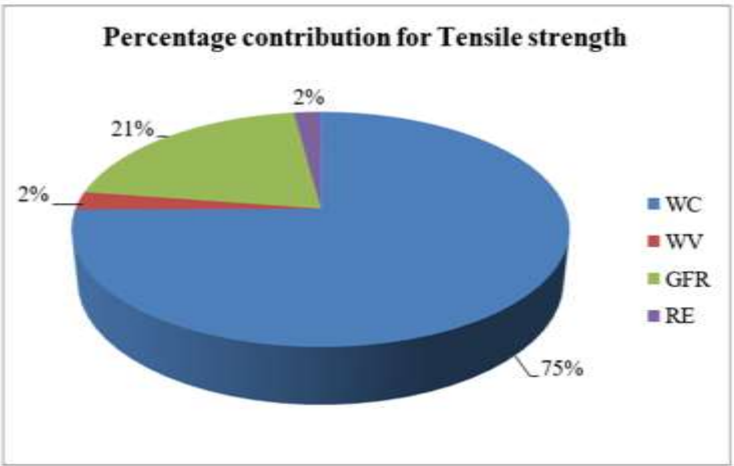

Fig. 1 ANOVA Percentage Contribution

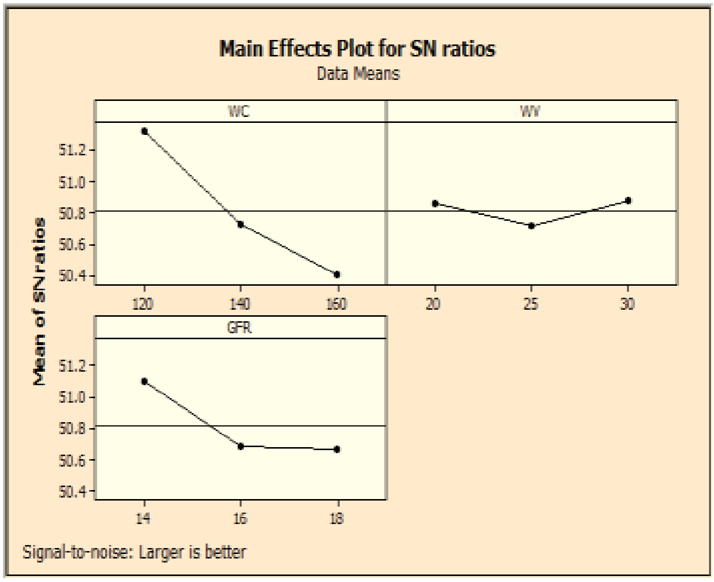

Fig. 3 Main Effect Plot for SN ratio

Figure 3 displays the primary impact of the signal-to-noise ratio on the tensile strength. The optimal cutting characteristics, as indicated in Figure 2, are achieved with a welding current of 120 A, welding voltage of 30 V, and gas flow rate of 14 L/min. Analysis reveals that the parameter with the greatest influence on Tensile Strength is Welding current, followed by Welding voltage and Gas flow rate.

A. Experimental Validation

Upon conducting the statistical analysis on the experimental data, it has been noted that there is a specific level for each factor at which the response for Tensile Strength is maximized. The table labeled as Table 6 provides the specific combination of input factor levels that will result in the most favourable settings.

TABLE 6 - Optimum machine parameters

Requirement	Current	Voltage	Gas Flow rate
Max Tensile Strength	120	30	14

The confirmation experiments were done using the optimal levels of welding parameters, and the results are presented in Table 7.

TABLE 7 - Confirmation test

Requirement	Experimental Value	Predicted Value
Max Tensile Strength	380.26	381.90

Table 7 presents a comparison between the confirmation test results and the projected values obtained by Taguchi for Tensile strength. The experimental values and projected values are closely sticking to each other. The error number must be less than 10% to ensure dependable statistical analysis. The confirmation test result confirms the successful optimization.

4. Conclusion

This study utilized the Taguchi method to determine the ideal parameters for MIG Welding of Mild steel material. The experimental data were assessed using ANOVA, and the following conclusions were derived:

Taguchi's experimental design technique was employed to determine the optimal values of process parameters in MIG Welding.

- The optimal values for welding current, welding voltage, and gas flow rate were determined to be 120 A, 30 V, and 14 L/min, respectively. Welding current is crucial in this inquiry and accounts for 74.85% of the total contribution.
- In this analysis, the gas flow rate is identified as the second most influential parameter, contributing 20.54% to the final outcome.
- The welding current has a minimal impact on the tensile strength.

- The optimal values for welding current, welding voltage, and gas flow rate are 120 A, 30 V, and 14 L/min, respectively.
- These values result in a tensile strength of 380.26 MPa.

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