Parametric Study of MIG Welding on Mild Steel (IS-2062 Grade A)

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Abstract

Metal Inert Gas (MIG) welding is a widely employed arc welding process that uses a consumable metal electrode to produce the weld. MIG welding produces very good quality weld when compared to other welding technologies with precise welding and comparatively little heat affected zone. MIG welding has become a popular choice of welding processes when high quality, precision welding is required at a comparatively lower cost. MIG welding is dependent on various input parameters but in the present work input parameters selected were welding current and weld time because these are the two major parameters which affect the weld quality. MIG welding finds its greatest application in welding both ferrous and non-ferrous metals and thus the most widely used arc welding process. A Taguchi Method (2 factors 3 levels) Design of Experiment (DOE) has been applied in this context to examine different welding defects through various tests like Hardness, Ultrasonography, Dye Penetration Test and tensile testing to examine its effect in each case. Finally using the Taguchi results have been optimized and through experiments and testing the best alternative with minimum welding defects and maximum yield strength and hardness number is reported successfully in the present work.

Keywords: Metal Inert Gas welding, welding current, welding voltage, Taguchi Method, yield strength, hardness number

1. Introduction

Gas Metal Arc Welding (GMAW), sometimes referred to by its subtypes Metal Inert Gas (MIG)welding or Metal Active Gas (MAG) welding, is a semi-automatic or automatic 0020 Arc welding process in which a continuous and consumable wire electrode and a shielding gas are fed through a welding gun. A constant voltage, direct current power source is most commonly used with GMAW, but constant current systems, as well as alternating current, can be used. Originally developed for welding aluminium and other non-ferrous materials in the 1940s, GMAW was soon applied to steels because it allowed for lower welding time compared to other welding processes. Today, GMAW is the most common industrial welding process, preferred for its versatility, speed and the relative ease of adapting the process to robotic automation. The automobile industry in particular uses GMAW welding almost exclusively. Unlike welding processes that do not employ a shielding gas, such as shielded metal arc welding, it is rarely used outdoors. A related process, flux cored arc welding, often does not utilize a shielding gas, instead employing a hollow electrode wire that is filled with flux on the inside. Generally, it is unsuitable for welding outdoors, because the movement of the surrounding air can dissipate the shielding gas and thus make welding more difficult, while also decreasing the quality of the weld. The problem can be alleviated to some extent by increasing the shielding gas output, but this can be expensive and may also affect the quality of the weld.

2. Identified gaps in literature [1-8]

After a comprehensive study of the existing literature, a number of gaps have been observed in machining of MIG.The researchers have carried out most of the work on MIG welding, monitoring and control but very limited work has been reported taking into account multiple parameters simultaneously. Limited work has been done on MIG Welding on Stainless Steel IS-2062, which is a commonly used grade of Stainless Steel. Most of the research work on MIG Welding has been on a limited range of current and voltage. After studying the existing literature we found that there is a scope to improve and optimize the MIG welding on Stainless Steel, giving better welding performance and more varied applications. Multi-response optimization of MIG welding process is another thrust area which has been given less attention in past studies.

3. Objective

The objective of the paper is to investigate the effect of the welding parameters viz., welding time, current input and voltage input on output performances such as ultimate tensile strength, hardness and weld quality during MIG welding of Mild Steel (IS-2062 Grade A).

4. Methodology

The methodology follows different steps. At first, we chose the base material as Mild Steel (IS-2062 Grade A) and cut out 9 samples with dimensions of 250 mm x 100 mm x 10 mm.From the previous study we gathered information about the parameters that could be altered. The parameters altered in this case are current, time and voltage. After selecting the parameters, we referred to the machine manual as to obtain ranges of the values we could use, considering this very model and manufacturer of the MIG welding machine.After obtaining the values, we started the MIG welding process, carefully monitoring and altering the parameters for different samples. Having completed the welding and giving enough time for the samples to return to room temperature. All samples were air-cooled, so as to maintain almost uniform grain structure for all samples. We started with the Non-Destructive tests. The Dye Penetration Test was done as per ASTM-E-165. The Ultrasonic examination was done using the Pulse-Echo Contact method as per ASME-Sec-VIII-U W53 Appendix 12.Then Brinell Hardness Test was conducted as per ASTM A-370/14.This was followed by destructive tests. Reduced section tensile test, transverse root bend test and transverse face bend test were conducted. By employing a statistical method of optimization called the Response Surface Methodology we are able to point out the specific values of the parameters at which the best results for welding could be obtained.Finally, we compared the experimental results with the theoretical data and verified that at the obtained optimised conditions we get the best possible weld quality for this material.

5. Material data

The material used for our project is Mild Steel (IS-2062 Grade A). According to the standard, the material used is hot rolled medium and high tensile structural steel.

The processes used in the steel making, casting and further hot rolling into steel plates, strips, sections, flats, bars, etc. are left to the discretion of the manufacturer/supplier. If required, secondary refining in the form of ladle refining, vacuum degassing may follow steel making. The products may be rolled and supplied in as-rolled/normalizing/normalizing rolling/controlled rolling/accelerated cooling conditions as per the agreement between the purchaser and the manufacturer/supplier. The mass of steel shall be calculated on the basis that steel weighs 7.85 g/cm^3. [9]

6. Result & analysis

Table 1. Observation Table

Sample No.	Current (A)	Voltage (V)	Time (s)	UTS (MPa)	BHN (Weld Portion)	BHN (Base Metal)	DP Test **	Ultrasonic Test **	Root Bend Test **	Face Bend Test **
1.	2	3	41	386*	170	164	5	5	5	5
2.	2	5	45	424	172	170	5	5	5	5
3.	2	9	57	500	176	176	5	5	5	5
4.	6	3	57	493	176	176	5	5	5	5
5.	6	5	45	494	176	174	5	5	5	5
6.	6	9	41	496	174	170	5	5	5	5
7.	10	3	57	504	180	176	5	5	5	5
8.	10	5	45	525	184	178	5	5	5	5
9.	10	9	41	567	192	184	5	5	5	5

*The minimum required value of UTS for IS 2062 Grade A is 410 MPa.

** These test reports do not have numeric values. On a scale of 1 to 5, with 5 being the best, they have been graded as satisfactory or poor.

6.2 Impact of current, voltage and time on ultimate tensile strength (mpA)

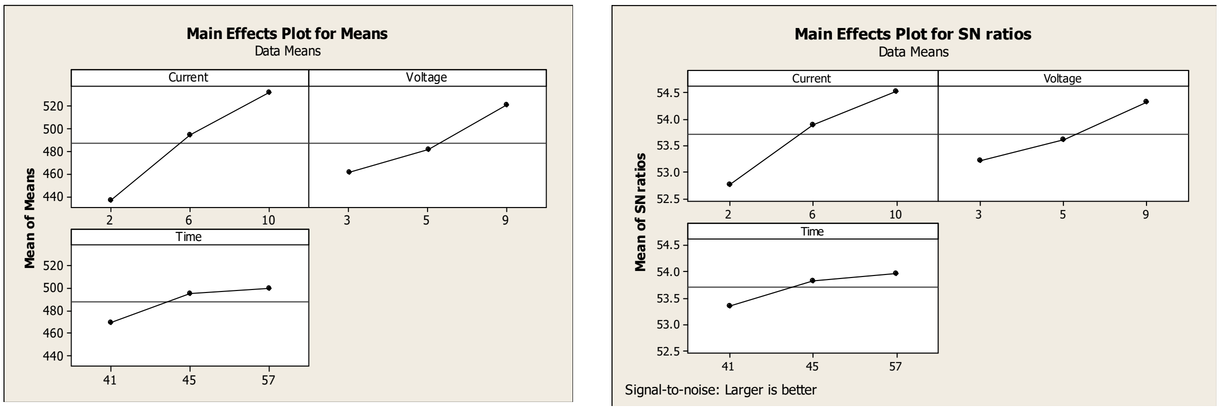

Fig.1 Main Effects Plot for SN Ratios on Ultimate Tensile Strength

From these graphs it is clearly understood that a directly proportional relationship exists. An increase in current, voltage and time results in an increase in UTS. At the current value of 10A, Voltage at 9V and time at 41s, UTS is found to be maximum with a value of 567 MPa.

6.3 Impact of current, voltage and time on Brinell hardness

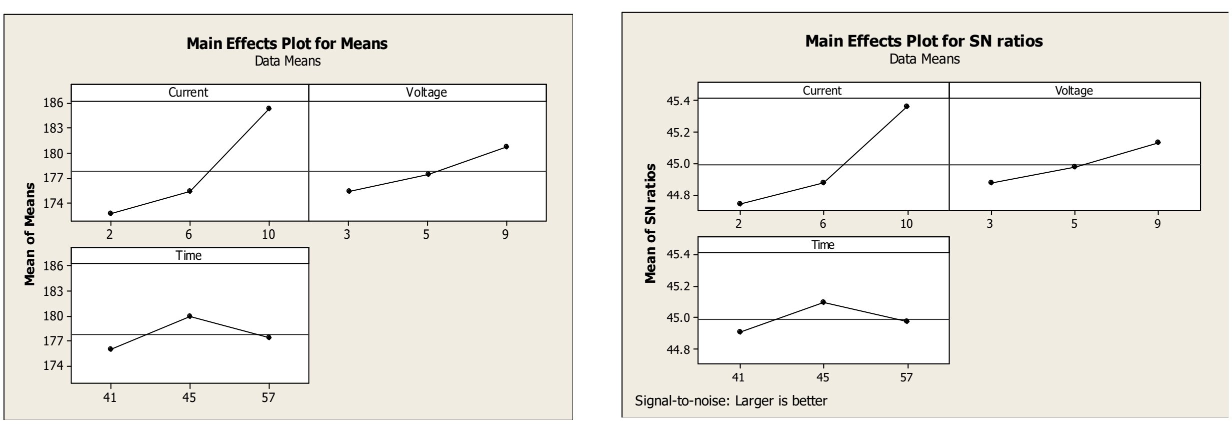

Fig.2 Main Effects Plot for Means on Brinell Hardness

From these graphs it is clearly understood that a directly proportional relationship exists. An increase in current, voltage and time results in an increase in Hardness. At the current value of 10A, voltage at 9V and time at 41s, Hardness is found to be maximum with a value of 192 BHN.

6.4 TAGUCHI DESIGN

Taguchi Orthogonal Array Design

L9 (3*3)

Factors: 3 Runs: 9

Columns of L9 (3**4) Array 1 2 3

6.5 Taguchi analysis: UTS versus current, Voltage, Time

Table 2. Response table for means

Level	Current	Voltage	Time
1	52.75	53.21	53.35
2	53.88	53.61	53.83
3	54.51	54.32	53.97
Delta	1.75	1.11	0.62
Rank	1	2	3

Level	Current	Voltage	Time
1	436.7	461.0	469.0
2	494.3	481.0	494.7
3	532.0	521.0	499.3
Delta	95.3	60.0	30.3
Rank	1	2	3

From the above main effects plot for S/N ratios and response table for S/N ratios obtained from Taguchi Analysis using L9 Orthogonal Array on MINITAB v16.0 we found that we'll get best UTS result on input parameters- Current as 10 A, Voltage as 9VandTime as 41 respectively.

The S/N ratios for UTS are calculated as given in Equation. Taguchi method is used to analysis the result of response of machining parameter for "Larger is better" criteria using MINITAB v16.0 software.

$$\mathrm{L.B.}\ \eta = -10\log_{10}(\mathrm{sum}(1/y^2)/n) \qquad \ldots\ldots\ldots\ 1)$$

where, η denotes the S/N ratios calculated from observed values, y_i represents the experimentally observed value of the i^{th} experiment and n=1 is the repeated number of each experiment in L-9 Orthogonal Array.

6.6 Taguchi analysis: BHN versus current, voltage, time

Table 3. Response Table for Signal to Noise Ratio (Larger is better)

Level	Current	Voltage	Time
1	44.74	44.87	44.91
2	44.88	44.97	45.10
3	45.36	45.13	44.98
Delta	0.61	0.25	0.19
Rank	1	2	3

Table 4. Response Table for Means

Level	**Current**	**Voltage**	**Time**
1	172.7	175.3	176.0
2	175.3	177.3	180.0
3	185.3	180.7	177.3
Delta	12.7	5.3	4.0
Rank	1	2	3

From the above main effects plot for S/N ratios and response table for S/N ratios obtained from Taguchi Analysis using L9 Orthogonal Array on MINITAB v16.0 we found that we get best hardness result on input parameters - current as 10 A, voltage as 9 V and time as 41 respectively.

7. Conclusion

The present research work describes the use of Taguchi method and statistical techniques for analyzing and optimizing the maximum tensile strength and maximum hardness in MIG welding of mild steel. The signal-to-noise (S/N) ratio and analysis of means were used for the optimization of welding parameters of Current, Voltage and Time. From the study, the following conclusions are drawn. For both Hardness and Tensile Strength, the effect of current is found to be the maximum, the effect of time is found to be the least and the voltage is found to have effect more than current and less than time. At A9B9C9 (current value of 10A, voltage at 9V and time at 41s), the welding joint is having the maximum tensile strength of

567Mpa and hardness number of 192BHN.Welding joint has the equal or more hardness than the base metal. Confirmation test confirms the improvement of hardness and residual stresses which also indicate the validity of the present optimization procedure by using Taguchi method.The present work would provide a valuable literature for future work in this field and also for the process of MIG Welding in industrial and practical uses

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