EXPERIMENTAL STUDY AND OPTIMIZATION OF PROCESS PARAMETERS MIG PROCESS USING TAGUCHI METHOD

ABSTRACT

Gas metal arc welding (GMAW), also known as Metal inert gas (MIG) is a fusion welding process having wide applications in the industries. Gas Metal arc welding is a popular choice of welding process when high level of weld quality or considerable precision welding operation is required. The present study is to investigate the influence of Gas metal arc welding parameters such as welding voltage(volt), and Wirespeed (inch/min) and Gas flowrate (Litres/mm) on the quality of weld. The optimization for Gas metal arc (GMAW) welding process parameters of low carbon steel work piece AISI 1012 using Taguchi method. A plan of experiments based on Taguchi technique has been used to acquire the data with help of minitab software. An Orthogonal array and signal to noise (S/N) ratio are employed to investigate the welding characteristics of AISI 1012 low carbon steel plate and optimize the welding parameters. The experiments were planned as per Taguchi L9 orthogonal array by considering three (3) input parameters which are Voltage (volt), and Wirespeed (inch/min) and Gas flowrate (Litres/mm). The experimental results shows that, the maximum impact strength base on “smaller the better criteria” was 0.075 J/mm², maximum hardness base on “larger the better criteria” was 1.955KN/mm², and maximum ultimate tensile strength (UTS) base on “larger the better criteria” was 154.214 KPa/mm² was obtained for the weld joints fabricated. Conformation experiment was also conducted and verified the effectiveness of the Taguchi optimization method.

1.0 INTRODUCTION

Welding is a commonly use process for joining materials (metals) using a large variety of applications. Welding occurs in several locations, from outdoors settings on rural farms and construction sites to inside locations, such as factories, industries and job shops. Welding processes are fairly simple to understand and it basic techniques can be learned quickly with ease. Welding is the joining of metals at a molecular level (Ibrahim, 2009). A weld is a homogeneous bond between two or more pieces of metal, where the strength of the welded joint exceeds the strength of the base pieces of metal. This research is to make the steel metal (low carbon steel plate) to be easily welded and compatible with the use of MIG welding process and optimizing the process parameters using **TAGUCHI** method.

Gas Metal arc welding (GMAW), also known as Metal inert gas (MIG) welding is a popular choice of welding process when high level of weld quality or considerable precision welding operation is required (khanna, 2013) as shown in figure 1.1. In present investigation as best set of process parameters for MIG welding is observed using Taguchi's L9 orthogonal arrays. The selected input parameters are Voltage, welding speed and Gas flow rate. Mechanical testing was also performed on the weldments, which are; **Impact test, Tensile test** and **Hardness test.** The regression relation between input parameters and mechanical test values are designed with the help of Taguchi method.

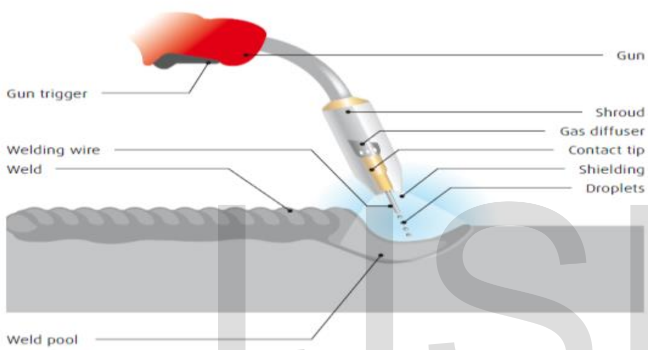

Figure 1.1 MIG welding process diagram

Several pairs of specimen (low carbon steel plate) were welded using Gas metal arc welding process (GMAW) based on design of experiment of ASME IX. The Taguchi method is a powerful tool that uses a special design to study the parameter space with small number of experiments through ***orthogonal arrays***. In the factorial design, the number of factors and levels increases exponentially. This technique provides an efficient, simple and systematic approach to optimize design for quality, performance and cost. To reduce the large number of experiments, an orthogonal array is developed by Taguchi method. In present experiment, Signal-to-Noise ratio has been used to examine the effect of each factor on a particular response. The signal shows the effect of each factor on the response, whereas noise is the measure of the influence on the deviation from the average responses. Signal-to-Noise ratio is based upon the following; **Lower-the-better, Larger- the- better and Nominal-the better criteria**. In current study, responses are associated with the strength of the weld joint, which should be high as possible so the larger-the- better criteria have been chosen as the strength of the weld joint which is generally expected to be high (kumar et al., 2014)

Our goal is to conduct an experimental study on MIG welding process and optimizing the process parameters with the use of TAGUCHI METHOD to produce weld of high quality.

It objectives are;

- Optimizing the process parameters for MIG welding.
- Optimization of Low Carbon Steel (AISI 1012) using MIG welding process
- To analysis and optimizing the data with the use of **MINITAB** software.

Taguchi is a powerful and efficient method for optimizing the process, quality and performance output of manufacturing processes and product. Quality control is considered to be an effective approach to improve product quality at a relatively low cost. The Taguchi method is one of the conventional approaches for this purpose (Kumar et al., 2017).

2.0 EXPERIMENTAL

2.1 Material Selection

For the purpose of this project various materials were put into consideration as regarding cost and performance efficiency and was agreed that low carbon steel (AISI 1012) is most suitable with the chemical composition as shown in table 2.1

Table 2.1. Chemical composition of low carbon steel (AISI 1012)

ELEMENT	WEIGHT PERCENT (%)
Carbon	0.154
Manganese	0.541
Phosphorus	0.015
Sulphur	0.029
Iron	98.7
Nitrogen	0.119
Silicon	0.05
Chromium	0.75

2.2 Equipment

The apparatus used includes; Low carbon steel plates AISI 1012 (10mm), Multipurpose welding machine, Plier, PPE(Personal protective equipment), Wire brush, Core wire electrode (ER70S-6), E6013 electrode (3.20mm), Emery paper, Cutting disk, Polish disk, Grinding machine, Adjustable spanner, MINITAB software, and Argon Gas

2.3 Methods

The Taguchi method of quality control is an approach to engineering that emphasizes the roles of research and development (R&D), and product design and development in reducing the occurrence of defects and failures in manufactured goods. This method, developed by Japanese engineer and statistician Genichi Taguchi, considers design to be more important than the manufacturing process in quality control and aims to eliminate variances in production before they can occur.

- **Signal-to-noise ratio for static designs**

A signal-to-noise ratio is a measure of robustness, which can be used to identify the control factor settings that minimize the effect of noise on the response. Minitab calculates a separate signal-to-noise (S/N) ratio for each combination of control factor levels in the design. You can choose from different S/N ratios, depending on the goal of your experiment. In all cases, you want to maximize the S/N ratio. For static designs, Minitab provides four S/N ratios: Smaller is better, Larger is better, and two Nominal is best ratios.

✓ Larger is better

The signal-to-noise (S/N) ratio is calculated for each factor level combination. The formula for the larger-is-better S/N ratio using base 10 log is:

$$S/N = -10*\log(\Sigma(1/Y^2)/n)$$

Where; Y = responses for the given factor level combination and

n = number of responses in the factor level combination.

✓ Smaller is better

The signal-to-noise (S/N) ratio is calculated for each factor level combination. The formula for the smaller-is-better S/N ratio using base 10 log is:

$$S/N = -10*\log(\Sigma(Y^2)/n)$$

2.4 Experimental parameter

In this research work, the signal to noise ratio will be study on as "input parameters" are the signal ratio, or also the control factor and the "output parameter" are the noise ratio.

In this research work, three (3) different level of Welding voltage, Gas flowrate, and Wirespeed as shown in table 3.2 were use and optimize as shown in table 3.3. MIG welding will be done on nine (9) coupons using the input parameter given in table 3.3 after which mechanical test will be conducted on each coupons.

- Input parameters are
  - ✓ Welding voltage (volts)
  - ✓ Gas flow rate(Litres/min) and
  - ✓ Wire speed(inch/min)
- Output parameters are
  - ✓ Ultimate Tensile strength (UTS)
  - ✓ Impact strength and
  - ✓ Hardness

Table 2.2 Control Factors and their level

Variables	Units	level		
		1	2	3
Voltage	Volt	22	24	26
Gas flowrate	Litre/min	8	10	12
Wirespeed	Inch/min	180	200	230

2.5 Design of Experiment

For performing the experiments Taguchi L9 orthogonal array was selected for 3-factor which is also the input parameter and 3-level process parameters and which reduces the number of experiments which is given in table 3.3. In the table below, MIG welding will be done on each plates using the parameters generated from the Minitab software via Taguchi method, which will create a total number of nine (9) coupons. After welding, each coupons will be cut to produces three (3) specimen for mechanical testing.

Table 2.3 Taguchi L9 Orthogonal Array

Voltage (volts)	Gas flowrate (L/min)	Wire Speed (inch/min)
1	1	1
1	2	2
1	3	3
2	1	2
2	2	3
2	3	1
3	1	3
3	2	1

2.6 Experimental Work

Experiments were conducted using ESAB MIG 630c welding machine by AC power supply as shown in figure 2.1. Test pieces of width 100 mm, length 300 mm with wall thickness of 10mm were cut in to length of each 150 mm initially with an edge preparation of 60 degree and tack welded. Filler metal (wire) ER70S-6 of 1.0 mm diameter was used for welding. Argon (100%) gas was used for shielding. Single pass welding was performed on plates by varying the initial parameters. The working ranges for the process parameters were selected from the American Welding Society handbook. Based on the designed L9 orthogonal array combination, a series of joining processes was performed with MIG welding machine. Ultimate Tensile Strength, impact testing and hardness (brinell hardness) are considered as objectives or as the output parameter. For the calculation of the responses i.e. ultimate tensile strength, impact strength and hardness of welded specimens, as tensile test were performed using Universal Testing Machine, hardness test was performed using Universal Testing Machine, and impact test was performed using the izod-charpy testing machine. The results of Ultimate Tensile Strength, impact test and hardness are shown in table 2.4

Table 2.4 Experimental design matrix and results

	Voltage (volt)	Gas flow (L/min)	Wire Speed (inch/min)	Hardness BHN (KN/mm²)	SNRA1	Impact strength (J/mm²)	SNRA2	UTS (KPa/mm²)	SNRA3
1	22	8	180	1.566	3.89584	0.095	20.2255	126.9	42.0692
2	22	10	200	1.591	4.03340	0.093	20.6303	134.3	42.5615
3	22	12	230	1.557	3.84577	0.098	20.1755	121.9	41.7201
4	24	8	200	1.617	4.17420	0.080	21.9382	133.3	42.4966
5	24	10	230	1.745	4.83591	0.089	21.0122	111.9	40.9766
6	24	12	180	1.697	4.59364	0.075	22.5144	146.8	43.3345
7	26	8	230	1.679	4.50101	0.084	21.5144	129.3	42.2320
8	26	10	180	1.955	5.82294	0.086	21.3100	144.3	43.1853
9	26	12	200	1.877	5.46929	0.091	20.8192	154.2	43.7617

Figure2.1 welding machine

3.0 RESULTS AND DISCUSSION

The following are the results gotten from the testing carry out;

3.1. Optimum parameter selection from S/N ratio for Hardness

Hardness is larger-the-better type quality characteristic. Therefore higher values of Hardness are considered to be optimal. It is clear from Fig. 3.1, that hardness is highest at third level of welding voltage, second level of gas flow rate and first level of wire speed rate (A3B2C1).

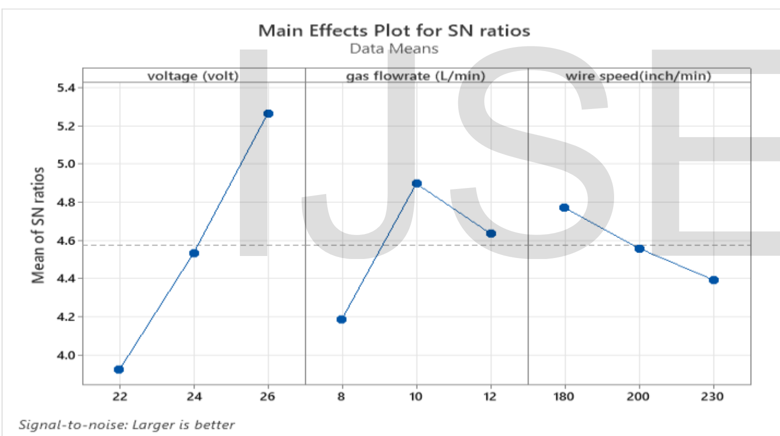

Fig. 3.1: Main Effects Plot for hardness of the weld

Table 3.1 also shows the parameter that has more effect on the Hardness as; voltage is ranks first, gas flow rate as second and wire speed as third.

Table 3.1 Response Table for Hardness of the weld

Response Table for Signal to Noise Ratios

Larger is better

Level	voltage (volt)	gas flowrate (L/min)	wire speed(inch/min)
1	3.925	4.190	4.771
2	4.535	4.897	4.559
3	5.264	4.636	4.394
Delta	1.339	0.707	0.377
Rank	1	2	3

3.2. Optimum parameter selection from S/N ratio for UTS

Ultimate Tensile Strength is larger-the-better type quality characteristic. Therefore higher values of Ultimate Tensile Strength are considered to be optimal. It is clear from Fig. 3.2, that Ultimate Tensile Strength is highest at third level of welding voltage, third level of gas flow rate and second level of wire feed rate (A3B3C2).

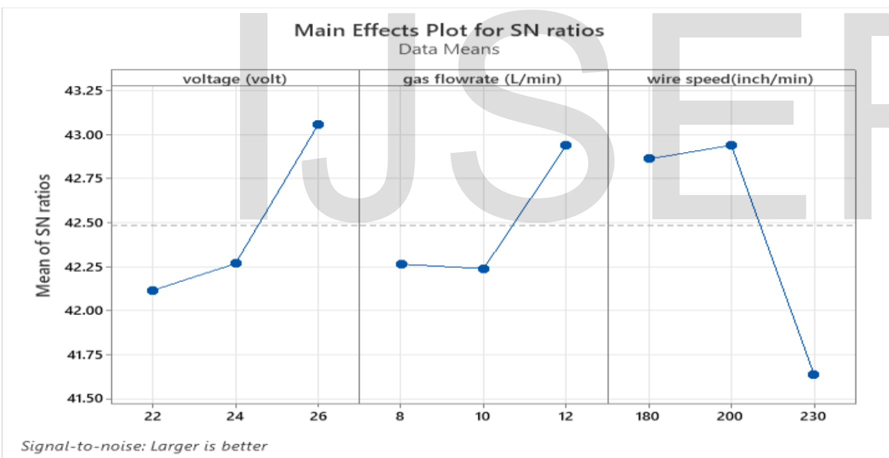

Fig.3.2: Main Effects Plot for UTS of the weld

Table 3.2 also shows the parameter that has more effect on the Ultimate Tensile strength as; wire speed is ranks first, voltage as second and gas flow rate as third.

Table 3.2 Response Table for UTS of the weld

Response Table for Signal to Noise Ratios

Larger is better

Level	voltage (volt)	gas flowrate (L/min)	wire speed(inch/min)
1	42.12	42.27	42.86
2	42.27	42.24	42.94
3	43.06	42.94	41.64
Delta	0.94	0.70	1.30
Rank	2	3	1

3.3. Optimum parameter selection from S/N ratio for Impact strength.

Impact strength is smaller-the-better type quality characteristic. Therefore lowest values of Impact strength are considered to be optimal. It is clear from Fig. 3.3, that Impact Strength is highest at second level of welding voltage, first level of gas flow rate and first level of wire feed rate (A2B1C1).

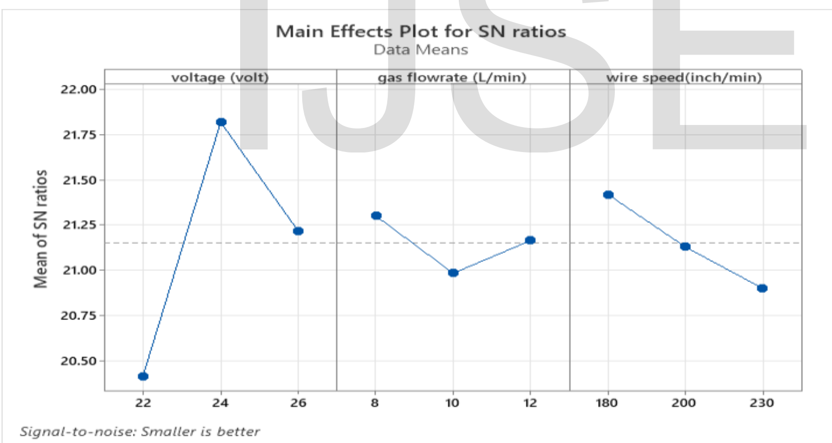

Fig.3.3: Main Effects Plot for Impact strength

Table 3.3 also shows the parameter that has more effect on the impact strength as; voltage is ranks first, wire speed as second and gas flow rate as third.

Table 3.3 Response Table for Impact strength of the weld

Response Table for Signal to Noise Ratios

Smaller is better

Level	voltage (volt)	gas flowrate (L/min)	wire speed(inch/min)
1	20.42	21.30	21.42
2	21.82	20.98	21.13
3	21.21	21.16	20.90
Delta	1.40	0.32	0.52
Rank	1	3	2

CONCLUSION

In this present work the optimization of the process parameters for Gas Metal Arc welding of AISI 1012 plate with smaller the better impact strength, larger the better Ultimate Tensile Strength and larger the better hardness has been reported. A Taguchi orthogonal array and signal-to-noise (S/N) ratio were used for the optimization of welding parameters and it is found that;

- Optimum condition for maximum Hardness is (A3B2C1) i.e. voltage = 26 volts, gas flow rate = 10 LPM and wire feed rate = 180 inch/min
- Optimum condition for maximum UTS is (A3B3C2) i.e. voltage = 26 volts, gas flow rate = 12 LPM and wire feed rate = 200 inch/min.
- Optimum condition for maximum impact strength is (A2B1C1) i.e. voltage= 24 volts, gas flow rate = 8 LPM and wire feed rate = 180 inch/min.

Conformation experiment was also conducted and verified the effectiveness of the Taguchi optimization method.

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