Application of Signal to Noise Ratio Methodology for Optimization of MIG Welding Process Parameters

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ABSTRACT

The present study is to search out the optimization process parameters for Metal inert gas welding (MIG). The optimization of MIG welding process parameters are for alloy steel work piece using grey relational analysis method. Sixteen experimental runs based on an orthogonal array Taguchi method were performed. This paper presents the effect of welding parameters like wire diameter, welding current, arc voltage, welding speed, and gas flow rate optimization based on bead geometry of welding joint. The objective function have been chosen in relation to parameters of MIG welding bead geometry Tensile strength, Bead width, Bead height, Penetration and Heat affected zone (HAZ) for quality target. Optimal parameters collection of the MIG operation was obtained via grey relational analysis. By analysis the grey relational grade, preprocessed data, and grey relational coefficient of grey relational controllable process ratio on the individual quality characteristic targets additionally. The signal to noise ratio (S/N ratio) is also applied to identify the most significant factor and predicted optimal parameter setting. Experiment with the optimized parameter setting, which have been obtained from the analysis, are giving to validate the results. The confirmation test is conducted and found the results closer to the optimize results. These results showed the successful implementation of methodology.

Keywords:-MIG Welding, Grey relational analysis, Taguchi orthogonal array, Signal to Noise Ratios (S/N ratio).

I. INTRODUCTION

Gas metal arc welding is a gas shielded process that can be effectively used in all positions. The shielding gas can be both inert gas like argon and active gases like argon-oxygen mixture and argon-carbon-di-oxide which are chemically reactive. It can be used on nearly all metals including carbon steel, stainless steel, alloy steel, and aluminum. Arc travel speed is typically 30-38 cm/minute and weld metal deposition rate varies from 1.25 kg/hrwhen welding out of position to 5.5 kg/hr in flat position.

MIG welding is a well-established semi-automatic process. Continuous welding with coiled wire helps high metal depositions rate and high welding speed. MIG gives less distortion and there is no slag removal and its associated difficulties like interference with accurate jigging. Because of the good heat input control, MIG can be used for non-ferrous welding with good results. However, since the torch has to be very near to the job, there is a constraint where access ability is limited. Spatter is high and so deposition efficiency is less. Absence of slag in solid wire welding processes allows a higher cooling rate of the weld zone and hence joints made with the process on hard enable steels are susceptible to weld metal cracking. The filler wire is generally connected to the positive polarity of DC source forming one of the electrodes. The work piece is connected to the negative polarity. The power source could be constant voltage DC power source, with electrode positive and it yields a stable arc and smooth metal transfer with least spatter for the entire current range. AC power source gives the problem of erratic arc. So is DC power source also with electrode negative. Power source are rated at 60 percent duty cycle for semi-automatic and at 100 percent duty cycle for automatic continuous operation with maximum amperage of 600 amps and 1000 to 2000 amps respectively. [11]

II. SCHEME OF INVESTIGATION

In order to maximize the quality characteristics, the present investigation has been made in the following sequence.

- Selection of base material.
- Identify the importance MIG welding process parameters.
- Find the upper and lower limits (i.e. range) of the identified process parameters.
- Select the orthogonal array (design of matrix).
- Conduct the experiments as per the selected orthogonal array.
- Record the quality characteristics (i.e. material properties).
- Find the optimum condition for MIG welding.
- Conduct the confirmation test.
- Identify the significant factors.
- Check the adequacy of the developed models.

III. GREY RELATIONAL ANALYSIS

III.1 DATA PREPROCESSING

Grey data processing must be performed before Grey correlation coefficients can be calculated. A series of various units must be transformed to be dimensionless. Usually, each series is normalized by dividing the data in the original series by their average. Let the original reference sequence and sequence for comparison be represented as $x_0(k)$ and $x_i(k)$, *i*=1, 2. . .*m*; *k*=1, 2, . . ., *n*, respectively, where *m* is the total number of experiment to be considered, and *n* is the total number of observation data. Data preprocessing converts the original sequence to a comparable sequence. Several methodologies of preprocessing data can be used in Grey relation analysis, dependingon the characteristics of the original sequence. If the target value of the original sequence is "the-larger-the-better", then the original sequence is normalized as follows. [2]

$$x_i^*(k) = \frac{x_i^{(O)}(k) - \min.\, x_i^{(O)}(k)}{\max.\, x_i^{(O)}(k) - \min.\, x_i^{(O)}(k)} \quad (1)$$

If the purpose is "the-smaller-the-better", then the original sequence is normalized as follows

$$x_i^*(k) = \frac{\max.\, x_i^{(O)}(k) - x_i^{(O)}(k)}{\max.\, x_i^{(O)}(k) - \min.\, x_i^{(O)}(k)} \quad (2)$$

However, if there is "a specific target value" then the original sequence is normalized using.

$$x_i^*(k) = 1 - \frac{\left|x_i^{(O)}(k) - OB\right|}{\max.\left\{\max.\, x_i^{(O)}(k) - OB,\ OB - \min.\, x_i^{(O)}(k)\right\}} \quad (3)$$

Where OB is the target value.Alternatively, the original sequence can be normalized the simplest methodology that is the values of the original sequence can be divided by the first value of the sequence, $x_i^{(O)}(1)$.

$$x_i^*(k) = \frac{x_i^{(O)}(k)}{x_i^{(O)}(1)} \quad (4)$$

Where $x_i^{(O)}(k)$ is the original sequence, $x_i^*(k)$ the sequence after the data preprocessing, max. $x_i^{(O)}(k)$ The largest value of $x_i^{(O)}(k)$, min . $x_i^{(O)}(k)$: the smallest value of $x_i^{(O)}(k)$.

III.2. CALCULATION OF GREY RELATIONAL COEFFICIENT AND GREY RELATIONAL GRADES:

Following the data preprocessing, a Grey relational coefficient can be calculated using the preprocessed sequences. The Grey relational coefficient is defined as follows.

$$\gamma\left(x_0^*(k), x_i^*(k)\right) = \frac{\Delta_{\min.} + \zeta\,\Delta_{\max.}}{\Delta_{0i}(k) + \zeta\,\Delta_{\max.}}$$

$$0 < \gamma\left(x_0^*(k), x_i^*(k)\right) \leq 1 \quad (5)$$

Where $\Delta_{0i}(k)$ is the deviation sequence of reference sequence $x_0^*(k)$ and comparability sequence $x_i^*(k)$, namely?

$$\Delta_{0i}(k) = \left|x_0^*(k) - x_i^*(k)\right|, \qquad \Delta_{\max.} = \max_{\forall j \in i}.\ \max_{\forall k}.\ \left|x_0^*(k) - x_j^*(k)\right|,$$

$$\Delta_{\min.} = \min_{\forall j \in i}.\ \min_{\forall k}.\ \left|x_0^*(k) - x_j^*(k)\right|,$$

ζ is the distinguishing coefficient, $\zeta \in [0,1]$

A Grey relational grade is a weighted sum of the Grey relational coefficients, and is defined as follows.

$$\gamma\left(x_0^*, x_i^*\right) = \sum_{k=1}^{n} \beta_k \gamma\left(x_0^*(k), x_i^*(k)\right)$$

$$\sum_{k=1}^{n} \beta_k = 1 \quad (6)$$

Here, the Grey relational grade $\gamma\left(x_0^*, x_i^*\right)$ represents the level of correlation between the reference and comparability sequences. If the two sequences are identical, then the value of the Grey relational grade equals to one. The Grey relational grade also indicates the degree of influence exerted by the comparability sequence on the reference sequence.

Consequently, if a particular comparability sequence is more important to the reference sequence than other comparability sequences, the Grey relational grade for that comparability sequence and the reference sequence will exceed that for other Grey value of data difference between the sequences, and can be used to approximate the correlation between the sequences.

III.3 SIGNAL TO NOISE RATIO (S/N Ratio) CALCULATION

Quality Characteristics:

S/N characteristics formulated for three different categories are as follows:

Larger Is Best Characteristics:

Data sequence for penetration, which are higher-the-better performance characters are pre-processed as per Eq. 1

S/N= -10 log((1/n) (Σ $(1/x^2)$)…………………………..1

Nominal and smaller are best characteristics:

Data sequence for HAZ, which are characteristics lower-the-better performance characteristics, are pre-processed as per Eq.1&2

S/N= -10 log (x/s^2x)……………………………………..2

S/N= -10 log (1/n) (Σ (x^2))……………………………..3

Where $y^>$ is average of observed data x, sx^2 is variance of x, and n is number of observations.[1]

IV. EXPERIMENTAL PROCEDURES

IV.1 EXPERIMENTAL SETUP

Experiments were conducted MIG welding machine equipment which is shown in fig 1. The MIG welding L&T, ZUPER ARC machine setup consist of machining base ,the equipment's DC output source, Wire feed unit, Torch, Work return welding lead, Shielding gas supply, (normally from cylinder).power source have a Main supply line, on/off switch, Transformer, Rectifier, Welding regulator. Most modern wire feed units control the wire feed speed via a DC motor and thruster control PCB to provide continuous control of Armature volts and hence RPM of motor. The MIG torch can be air cooled or water cooled and most modern air cooled torches have a single cable in which the welding wire slides through a liner. Gas flows around the outside of this liner and around the tube the liner sits in the power braid and trigger wires. MIG torch combination have a gas nozzle, contact tip, contact tip holder, liner, swan neck, trigger, and gun plug, trigger cables, current cable, gas hose. The shielding gas should also have a pronounced effect on the following aspects of the welding operation and the resultant weld. Arc characteristics, Mode of Metal Transfer, Penetration and Weld Head profile, Speed of Welding, Undercutting Tendency, and Cleaning Action Weld Metal Mechanical Properties. A basic position or starting point would be Aluminum – Argon, Magnesium – Helium, Copper Alloys – Argon – Helium Mix, Steel – Carbon dioxide not commonly used, Today, Argon-Carbon dioxide mix is preferred.

Figure 1: MIG welding machine setup

IV. 2 SELECTION OF MATERIAL

In this study two alloy steel plate of length 250 mm width 40 mm 1.2 mm thickness and height is equivalent to plate thickness made of Alloy steel which is a high carbon alloy steel with high degree of hardness and which rises the temperature of the tool tip to visible read heat. Ordinary high carbon and low alloys tool steels do not withstand the heating effect and readily lose hardness. But high speed steels have the property to withstand this heating effect without losing hardness. So called high speed steels are of composition that have good wear resistance and retain their hardness of high temperature. A superior brand of high speed steel has the following composition as per ISS Carbon (0.70%), Tungsten (18.00%), Chromium (4.00%), and Vanadium (1.00%).

IV.3 RECORD OF QUALITY CHARACTERISTICS

To evaluate the quality of MIG welds measurement of weld pool geometry are performed. In this study the bead width, bead height, penetration and heat affected zone (HAZ) of weld pool are used to describe the weld pool geometry measured by Bridge cam gauge (BCG). These parameters measured accurately and one time measured by (BCG).

Tensile specimen of necessary dimension as per ASTM E8M were separated out from welding coupon plates and test were measured on 400 KN computer control universal testing machine. The specimen loaded at the rate of 1.5 KN/min as per ASTM specification. So that tensile specimen under goes deformation. The specimen finally fails after necking and load vs displacement was recorded. Higher tensile property is the better quality characteristic.

IV.4 SELECTION OF THE MIG WELDING PARAMETERS AND THEIR LEVELS

In this study, the experimental plan has five variables, namely, Wire diameter, Welding current, Arc voltage, Welding speed, and Gas flow rate. On the basis of preliminary experiment conducted by using one variable at a time approach, the feasible range for the welding parameters was defined by the Wire diameter (0.8-1.2mm), Welding current (80-110amp), Arc voltage (18-19.5VOLT), Welding speed (45-55cm/min), Gas flow rate (10-15ltr/min). In the MIG welding parameters were selected, shown in Table-1.

Table 1: Parameters and their levels

Notation	Process Parameter	Level 1	Level 2	Level 3	Level 4
A	Wire diameter (mm)	0.8	0.9	1.0	1.2
B	Welding current (amp)	80	90	100	110
C	Arc voltage (volt)	18	18.5	19	19.5
D	Welding speed (cm/mm)	45	48	51	55
E	Gas flow rate (ltr/min)	10	13	14	15

V. EXPERIMENTAL DESIGN

The application of design-of-experiments (DOE) to demand as of right anxious planning, best ground-plan of the experiment and table shown. The choose design matrix based on Taguchi L16 (4^5) orthogonal array consist 16 set of code condition and the experimental result for the response Tensile strength, Bead width, Bead height, penetration, and heat affected zone (HAZ) in process parameter. In the present study there 12 degree of freedom owing to the four level welding parameters.While the reciprocal action between the parameters is neglected. Once the DOF are known the next step is choose an appropriate orthogonal array. The DOF for the orthogonal array should be greater than or at least equal to those process parameters. In this study an L16 orthogonal array is used because it has 15 degree of freedom in the welding parameters. The experiment output for the process parameter is shown in Table 2.

Figure 2 :Work piece of steel alloy

Table2. Experimental layout using L16 orthogonal array

Experiment No.	A	B	C	D	E
1	1	1	1	1	1
2	1	2	2	2	2
3	1	3	3	3	3
4	1	4	4	4	4
5	2	1	2	3	4
6	2	2	1	4	3
7	2	3	4	1	2
8	2	4	3	2	1
9	3	1	3	4	2
10	3	2	4	3	1
11	3	3	1	2	4
12	3	4	2	1	3
13	4	1	4	2	3
14	4	2	3	1	4
15	4	3	2	4	1
16	4	4	1	3	2

V.1 EXPERIMENTAL RESULTS

Table 3. Experimental results for steel alloy

Sr. No.	Tensile strength (N/mm^2) Larger is better	Bead width (mm) Smaller is better	Bead height (mm) Smaller is better	Penetration (mm) Larger is better	HAZ (mm) Smaller is better
1	260.12	8.10	0.251	1.263	5.621
2	262.17	8.19	0.259	1.264	5.720
3	271.16	8.61	0.273	1.277	5.800
4	269.27	8.50	0.260	1.278	5.770
5	265.71	8.43	0.251	1.273	5.765
6	272.18	8.65	0.275	1.288	5.806
7	252.17	7.19	0.203	0.985	3.868
8	272.00	8.61	0.281	1.291	5.996
9	257.19	7.21	0.210	1.05	4.380
10	262.11	8.10	0.235	1.212	5.720
11	281.16	8.91	0.294	1.306	6.127
12	277.91	8.77	0.288	1.298	6.099
13	261.33	8.05	0.231	1.239	5.712
14	271.16	8.51	0.271	1.281	5.937
15	255.34	7.05	0.210	0.998	4.367
16	267.14	8.43	0.255	1.235	5.766

Table 4. Preprocessed data results for steel alloy

Experiment No.	Tensile strength	Bead width	Bead height	Penetration	HAZ
1	0.274	0.435	0.225	0.866	0.223
2	0.344	0.387	0.183	0.869	0.180
3	0.655	0.161	0.109	0.909	0.144
4	0.589	0.220	0.178	0.912	0.158
5	0.467	0.258	0.225	0.897	0.160
6	0.690	0.139	0.099	0.943	0.142
7	0	0.924	1	0	1
8	0.684	0.161	0.068	0.953	0.057
9	0.173	0.913	0.439	0.202	0.773
10	0.342	0.435	0.308	0.707	0.180
11	1	0	0	1	0
12	0.887	0.075	0.031	0.975	0.012
13	0.315	0.462	0.329	0.791	0.183
14	0.655	0.215	0.120	0.922	0.084
15	0.109	1	0.439	0.040	0.779
16	0.516	0.258	0.204	0.778	0.159

Table 5. Grey relational coefficient for steel alloy

Experiment No	Tensile strength	Bead width	Bead height	Penetration	HAZ
1	0.645	0.534	0.689	0.366	0.691
2	0.592	0.563	0.732	0.365	0.735
3	0.432	0.756	0.821	0.354	0.776
4	0.459	0.694	0.737	0.354	0.759
5	0.517	0.659	0.689	0.357	0.757
6	0.420	0.782	0.834	0.346	0.778
7	1	0.351	0.333	1	0.333
8	0.422	0.756	0.880	0.344	0.897
9	0.742	0.353	0.532	0.712	0.892
10	0.593	0.534	0.618	0.414	0.735
11	0.333	1	1	0.333	1
12	0.360	0.869	0.941	0.338	0.976
13	0.613	0.519	0.603	0.387	0.732
14	0.432	0.699	0.806	0.351	0.856
15	0.821	0.333	0.532	0.925	0.390
16	0.492	0.659	0.710	0.391	0.758

Table 6. Grey relational grade for steel alloy

Experiment No.	A	B	C	D	E	Grey relational grade
1	1	1	1	1	1	0.585
2	1	2	2	2	2	0.597
3	1	3	3	3	3	0.627
4	1	4	4	4	4	0.600
5	2	1	2	3	4	0.595
6	2	2	1	4	3	0.632
7	2	3	4	1	2	0.603
8	2	4	3	2	1	0.659
9	3	1	3	4	2	0.546
10	3	2	4	3	1	0.578
11	3	3	1	2	4	0.733
12	3	4	2	1	3	0.696
13	4	1	4	2	3	0.570
14	4	2	3	1	4	0.628
15	4	3	2	4	1	0.600
16	4	4	1	3	2	0.602

Table7. Signal to noise ratio table for grey relational grade

Sr. No.	A	B	C	D	E	GRG	SNRA1	MEAN 1
1	1	1	1	1	1	0.585	-4.65688	0.585
2	1	2	2	2	2	0.597	-4.48051	0.597
3	1	3	3	3	3	0.627	-4.05465	0.627
4	1	4	4	4	4	0.600	-4.43697	0.600
5	2	1	2	3	4	0.595	-4.50966	0.595
6	2	2	1	4	3	0.632	-3.98566	0.632
7	2	3	4	1	2	0.603	-4.39365	0.603
8	2	4	3	2	1	0.659	-3.62229	0.659
9	3	1	3	4	2	0.546	-5.25615	0.546
10	3	2	4	3	1	0.578	-4.76144	0.578
11	3	3	1	2	4	0.733	-2.69792	0.733
12	3	4	2	1	3	0.696	-3.14782	0.696
13	4	1	4	2	3	0.570	-4.88250	0.570
14	4	2	3	1	4	0.628	-4.04081	0.628
15	4	3	2	4	1	0.600	-4.43697	0.600
16	4	4	1	3	2	0.602	-4.40807	0.602

V .2 Signal to noise ratio (S/N ratio)

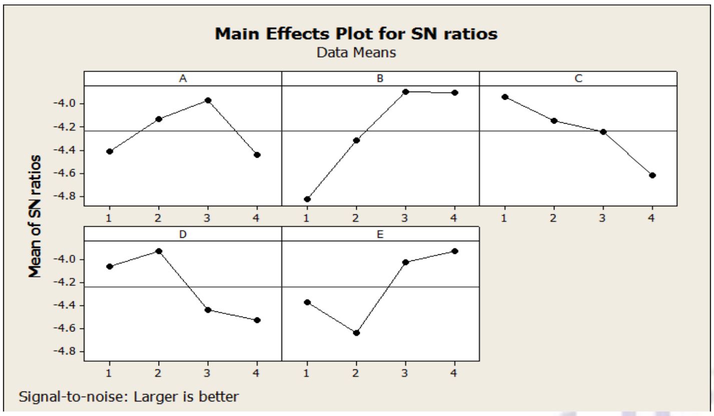
Signal-to-Noise ratio (S/N ratio) was introduced by Sir Michael A Choma. The purpose of the Signal-to-Noise ratio (S/N ratio) is to investigate which design parameters significantly affect the quality characteristic.

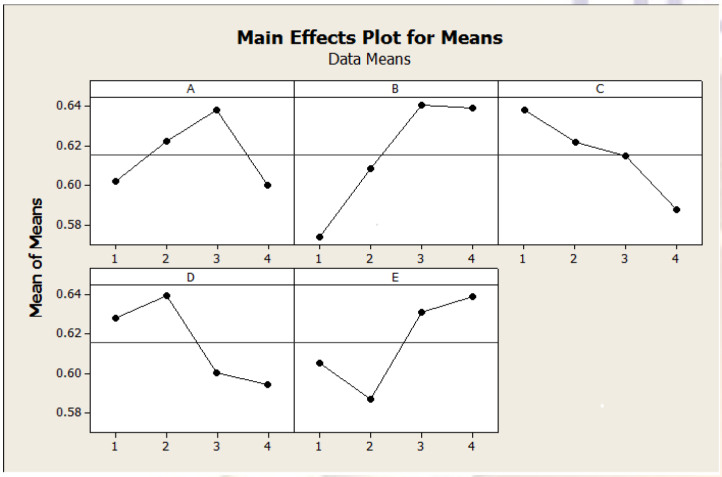
Table 8. Response table for signal to noise ratio

Levels	A	B	C	D	E
1	-4.407	-4.826	-3.937	-4.060	-4.369
2	-4.128	-4.317	-4.144	-3.921	-4.635
3	-3.966	-3.896	-4.243	-4.433	-4.018
4	-4.442	-3.904	-4.619	-4.529	-3.921
Delta	0.476	0.930	0.682	0.608	0.713
Rank	5	1	3	4	2

Table 9. Response table for signal to noise ratio means

Levels	A	B	C	D	E
1	0.6022	0.5740	0.6380	0.6280	0.6055
2	0.6222	0.6088	0.6220	0.6398	0.5870
3	0.6382	0.6407	0.6150	0.6005	0.6312
4	0.6000	0.6392	0.5877	0.5945	0.6390
Delta	0.0383	0.0667	0.0503	0.0453	0.0520
Rank	5	1	3	4	2





VI. RESULT AND DISCUSSION

After identifying the most influential parameters, the final phase is to verify the Tensile strength, Bead width, Bead height, Penetration and Heat affected zone by conducting the confirmation experiments. The *A3B3C1D2E4* is an optimal parameter combination for steel alloy of the MIG welding process via the Grey relational analysis. Therefore, the condition *A3B3C1D2E4* of the optimal parameter combination of the MIG welding process was treated as a confirmation test. If the optimal setting for steel alloy with a Wire diameter 1mm, Welding current 100 A, Arc voltage 18 V, Welding speed 48 cm/min, and Gas flow rate 15 ltr/min is used, the final work piece gives the Bead width (5.99mm), Bead height (0.145mm) and HAZ (2.969mm) minimum , Tensile strength (280.16N/mm^2) and Penetration (2.276mm) is maximum.

VII. CONCLUSION

In the present study, Taguchi optimization technique pair with grey relational analysis has been adopted for evaluating parametric complex to carry out acceptable Tensile strength and Penetration higher is better. Bead width, Bead height and Heat affected zone (HAZ) lower is better of the alloy steel element to acquire by using Metal inert gas welding. After identify the predict optimal parameter setting with the help of signal to noise ratio (S/N ratio) the most significant factor also found the results closer to the optimize results.. So it is most significant factor in this result.

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