OPTIMIZATION OF PROCESS PARAMETERS OF METAL INERT GAS WELDING BY TAGUCHI METHOD ON CRC STEEL IS 513 GR D

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ABSTRACT

GMAW (Gas Metal Arc Welding) was developed during the early 1940's and technology was taken from the TIG welding process that was already around at the time. MIG (Metal Inert Gas) welding, also known as MAG (Metal Active Gas) and in the USA as GMAW is a welding process that is now widely used for welding a variety of materials, ferrous and non ferrous. Gas metal arc welding is one of the conventional and traditional methods to join materials. In this work we presents Optimization of process parameters of metal inert gas welding by Taguchi method on Bead width and Bead height on CRC steel IS 513 GR 'D' material. A plan of experiments based on Taguchi technique has been used. An Orthogonal array (L9), signal to noise (S/N) ratio and analysis of variance (ANOVA) are employed to study and optimize the welding parameters. The result computed is in form of contribution from each parameter, through which optimal parameters are identified for Bead width and Bead height.

Keywords: ANOVA (Analysis of Variance), GMAW, Optimization, S/N Ratio, Taguchi Method

1 INTRODUCTION

Gas metal arc welding is one of the conventional and traditional methods to join materials. A wide range of materials may be joined by Gas metal arc welding—similar metals, dissimilar metals, alloys, and nonmetals. In the present scenario demand of the joining of similar materials continuously increases due to their advantages, which can produce high yield strength, deeper penetration, continuous welding at higher speed and small welding defects. The essential feature of the process is in which a continuous and consumable wire electrode and a shielding gas are feed 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 [1].

There are four primary methods of metal transfer in GMAW, Each of which has distinct properties and corresponding advantages and limitations.

1. Globular 2.Short-circuiting 3.Spray 4.Pulsed-spray

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[2,3]. Principle working of MIG welding process as shown in figure1.1.

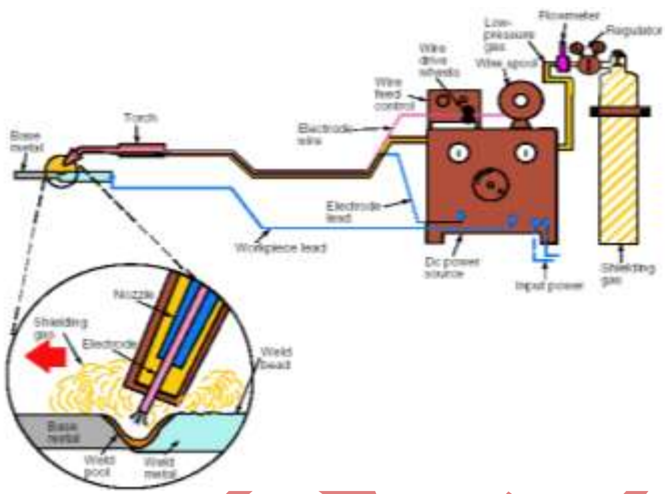


Figure 1.1 MIG welding process

II TAGUCHI'S DESIGN METHOD

Taguchi Technique is used to plan the experiments. The Taguchi method has become a influential tool for improving output during research and development, so that better quality products can be produced quickly and at minimum cost. Taguchi has envisaged a new method of conducting the design of experiments which are based on well defined guidelines. This method uses a special set of arrays called orthogonal arrays. These standard arrays stipulate the way of conducting the minimal number of experiments which could give the full information of all the factors that affect the performance parameter.[4, 5].

III METHODLOGY

The present investigation has been made in the following sequence to achieve the objective.

- Selection of base material.
- Identify MIG welding process parameters & their levels.
- Select the orthogonal array
- Perform the experiments as per the selected orthogonal array.
- Statistical analysis by MINITAB 16

After performing GMAW operation, the specimens were cut from the welded plate to carry out various tests. The following are the tests carried out to achieve the objective:

- Bead height Test
- Bead width Test

IV EXPERIMENTATION

4.1 Selection of Base Material

Material for the sample to be welded was CRC steel IS 513 GR 'D' having composition as given in Table 4.1

Grade	%C	%Mn	%S	%P	%Si	%Al	Hardness (Vpn)	Ys (Mpa)	UTS (Mpa)	% El
IS 513 GR 'D'	0.040	0.180	0.015	0.010	0.025	0.070	103.0	212.0	325.0	43.00

Table 4.1 Chemical Composition of Specimen Material CRC Steel IS 513 GR 'D'

4.2 Identify MIG welding process parameters & their levels

The selection of the welding variables should be made after the base metal. The number of variables considered in welding process are welding current, welding voltage, wire speed, welding speed, wire extension, type of shielding gas, wire electrode size. In the present study, the experimental plan has three variables, namely, Welding current, welding voltage, Wire extension.

4.3 Taguchi Orthogonal array L9(3^3) after assignment of parameters

Samples No.	Control parameters and levels		
	A(welding current)	B(welding voltage)	C(Wire extension)
1	150	22	10
2	150	24	12
3	150	26	14
4	170	22	12
5	170	24	14
6	170	26	10
7	190	22	14
8	190	24	10
9	190	26	12

Table 4.2 Taguchi Orthogonal array L9 (3^3)

4.4 Perform the experiments as per the selected orthogonal array

Experiments were conducted on MIG welding machine equipment. The MIG welding PANA-AUTO, KR II 400 PANASONIC ARC machine setup consist of machining base ,the equipment's DC output source, Wire feed unit, Torch, Work return welding lead, Shielding gas supply. The MIG torch can be air cooled or water cooled. We used air cooled torch which 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. 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. In this study, we use Argon (80%)-Carbon

Figure 4.1 Welded Samples

Dioxide (20%) mixer as per the material characteristics. Copper electrode wire of 1.0 mm diameter was used. The selection of the welding electrode wire based on the matching the mechanical properties and physical characteristics of the base metal The experimental plan has three variables, namely, Welding current, welding voltage, Wire extension. The MIG welding samples as shown in figure 4.1.

4.5 Specimen cutting and lapping process

For further investigation i.e. Bead height & Bead width test. The Welded specimen of necessary dimension was marked on welded plate. The welded plate was accurately placed on work table and separated the specimen out from welding plates by cutter. Lapping is a machining process, in which two surfaces are rubbed together with an abrasive between them, by hand movement or by way of a machine. It is a surface finishing process.

V RESULT & DISCUSION

The aim of the experimental plan is to find the optimize parameters those are influencing the Bead height and bead width of weldment. The experiments were developed based on an orthogonal array, with the aim of relating the influence of Welding Current, Welding Voltage and Wire extension.

5.1 Results of Statistical Analysis of Experiments

The results for various combinations of process parameters were obtained by conducting the experiment as per the orthogonal array (L9). The measured results were analyzed using the software MINITAB 16 specially used for the design of experiment applications. To measure the quality characteristics, the experimental values are transformed into signal to noise ratio. The influence of control parameters such as Welding Current, Welding Voltage & Wire extension on Bead height and width has been analyzed using Response table for signal to noise ratio.

The response tables show the average of each response characteristic (S/N ratios) for each level of each factor. The tables include ranks based on Delta statistics, which compare the relative magnitude of effects. The Delta statistic is the highest minus the lowest average for each factor. Minitab assigns ranks based on Delta values; rank 1 to the highest Delta value, rank 2 to the second highest, and so on. Use the level averages in the response tables to determine which level of each factor provides the best result.

5.2 Taguchi analysis for Bead height

Sampl e No.	Welding current (Amp.)	Welding voltage(volts)	Wire extensio n(mm)	Bead height (mm)	S/N RATIO
1	150	22	10	1.52	-3.63687
2	150	24	12	1.92	-5.66602
3	150	26	14	1.51	-3.57953
4	170	22	12	1.45	-3.22736
5	170	24	14	1.24	-1.86843
6	170	26	10	1.21	-1.65570
7	190	22	14	1.51	-3.57953
8	190	24	10	1.35	-2.60667
9	190	26	12	1.6	-4.08239

Table 5.1 Result for Bead height

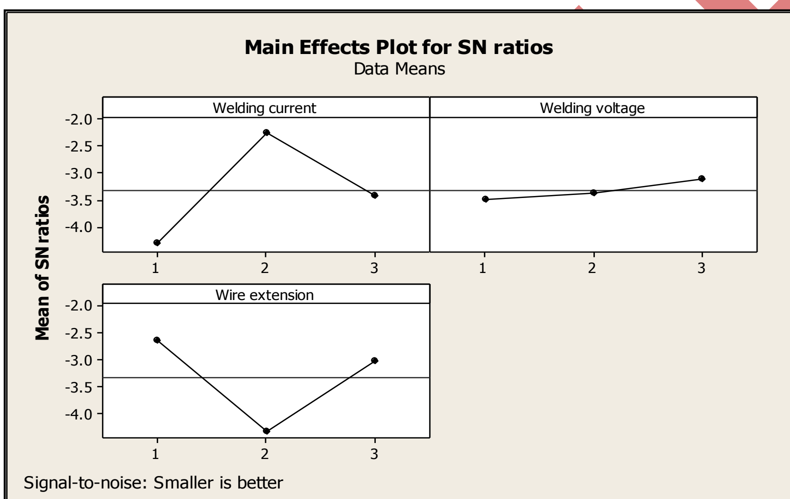
5.2.1 Response table for Signal to Noise Ratio (Bead height):- Smaller is better

Level	Welding current	welding voltage	wire extension
1	-4.294	-3.481	**-2.633**
2	**-2.251**	-3.38	-4.325
3	-3.423	**-3.106**	-3.009
Delta	2.044	0.375	1.692
Rank	1	3	2

Table 5.2 Response table for S/N Ratio (Bead height)

Table 5.2 shows the experimental analysis for Bead height. In our experimental analysis, the ranks indicate that welding current has the greatest influence on the S/N ratio. For S/N ratio, wire extension has the next greatest influence and welding voltage has least influence. Here, because our aim is to smaller the bead height, we want factor levels that produce the highest S/N Ratio. Taguchi experiments, we always want to maximize the S/N ratio. The level averages in the response tables show that the S/N ratio were maximized when the welding current was 170 amps, the Welding voltage was 26 volts and the wire extension was 10 mm. So, the optimal parameters combination of bead height for CRC steel 513 GR 'D' was welding current 170 amps, the Welding voltage 26 volts and the wire extension 10 mm.

5.2.2 Main Effects plots for S/N Ratio (Bead height)



5.2.3 Analysis of variance for S/N ratios (Bead height)

Source	DF	Seq SS	Adj SS	Adj MS	F	P	% Contribution
Welding current	2	6.3101	6.3101	3.155	14.31	0.065	54
Welding voltage	2	0.2264	0.2264	0.1132	0.51	0.661	2
Wire extension	2	4.737	4.737	2.3685	10.74	0.085	40
Residual error	2	0.441	0.441	0.2205			4
total	8	11.7145					100

Table 5.3 ANOVA for S/N ratio for bead height

Table 5.3 shows the result of the analysis of variance (ANOVA) for the bead height. The main purpose of analysis of variance is to investigate the influence of the design parameters on bead height by indicating that which parameters is significantly affected the quality characteristics.

5.2.4 Pie Chart for %age Contribution of Different Parameters for bead height

The purpose of ANOVA is to investigate which welding process parameters significantly affect the quality characteristics. This is accomplished by separating the total variability of the S/N Ratios, which is measured by the sum of squared deviations from the total mean of the S/N ratio, into contributions by each welding process parameter and the error. The percentage contribution by each of the welding process parameters in the total sum of the squared deviations can be used to evaluate the importance of the process parameter change on the quality characteristic.

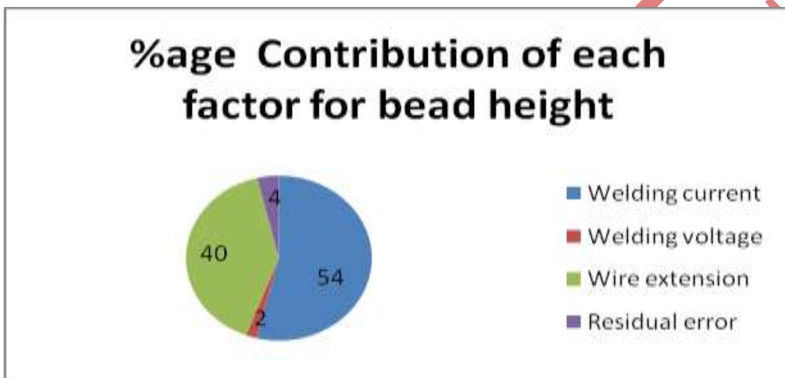


Figure 5.1 %age Contribution of each factor for bead height

From figure 5.1 we can conclude that Welding current is significantly affects the bead height with contribution of 54% followed by wire extension with contribution of 40% and welding voltage with contribution of 02%. The residual error was 04%.This error is due to human ineffectiveness, machine vibration and environment effects. These are the optimize results of different process parameter for Bead height.

5.3 Taguchi analysis for Bead width:

Sample No.	Welding current(Amp.)	Welding voltage(volts)	Wire extension (mm)	Bead width (mm)	S/N RATIO
1	150	22	10	5.77	-15.22351
2	150	24	12	8.61	-18.70006
3	150	26	14	9.26	-19.33221
4	170	22	12	7.47	-17.46641
5	170	24	14	7.92	-17.97450
6	170	26	10	7.41	-17.39636
7	190	22	14	7.92	-17.97450
8	190	24	10	6.05	-15.63510
9	190	26	12	6.43	-16.16421

Table 5.4 Result for Bead width

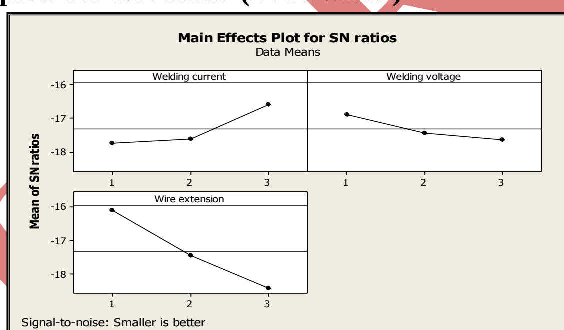
5.3.1 Response table for Signal to Noise Ratio (Bead width):- Smaller is better

Level	Welding current	welding voltage	wire extension
1	-17.75	**-16.89**	**-16.08**
2	-17.61	-17.44	-17.44
3	**-16.59**	-17.63	-18.43
Delta	1.16	0.74	2.34
Rank	2	3	1

Table5.5 Response table for S/N Ratio (Bead width)

Table 5.5 shows the experimental analysis for Bead width. In our experimental analysis, the ranks indicate that wire extension has the greatest influence on the S/N ratio. For S/N ratio, welding current has the next greatest influence and welding voltage has least influence. Here, because our aim is to smaller the bead width, we want factor levels that produce the highest S/N Ratio. Taguchi experiments, we always want to maximize the S/N ratio. The level averages in the response tables show that the S/N ratio were maximized when the welding current was 190 amps, the Welding voltage was 22 volts and the wire extension was 10 mm. So, the optimal parameters combination of bead width for CRC steel 513 GR 'D' was welding current 190 amps, the Welding voltage 22 volts and the wire extension 10 mm.

5.3.2 Main Effects plots for S/N Ratio (Bead width)



5.3.3 Analysis of variance for S/N ratios (Bead width)

Source	DF	Seq SS	Adj SS	Adj MS	F	P	% Contribution
Welding Current	2	2.4093	2.4093	1.2047	0.63	0.613	16
Welding Voltage	2	0.8903	0.8903	0.4451	0.23	0.811	6
Wire Extension	2	8.2983	8.2983	4.1492	2.18	0.315	54
Residual error	2	3.8096	3.8096	1.9048			25
Total	8	15.4075					100

Table 5.6 ANOVA for S/N ratio for Bead width

Table 5.6 shows the result of the analysis of variance (ANOVA) for the bead width. The main purpose of analysis of variance is to investigate the influence of the design parameters on bead width by indicating that which parameters is significantly affected the quality characteristics.

5.3.4 Pie Chart for %age Contribution of Different Parameters for bead width

The purpose of ANOVA is to investigate which welding process parameters significantly affect the quality characteristics. This is accomplished by separating the total variability of the S/N Ratios, which is measured by the sum of squared deviations from the total mean of the S/N ratio, into contributions by each welding process parameter and the error. The percentage contribution by each of the welding process parameters in the total sum of the squared deviations can be used to evaluate the importance of the process parameter change on the quality characteristic.

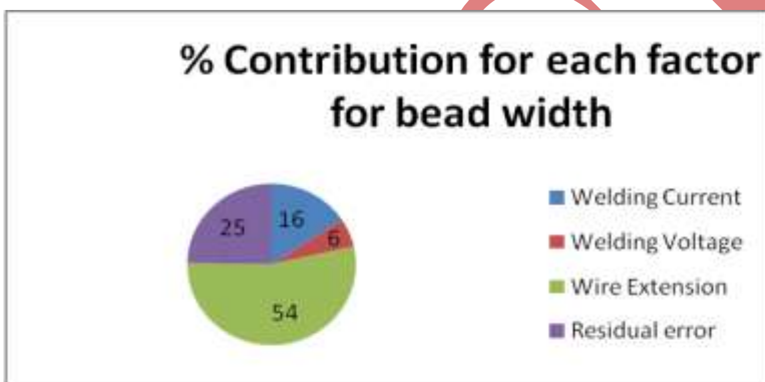


Figure 5.2 %age Contribution of each factor for bead width

From figure 5.2 we can conclude that Wire extension is significantly affects the bead width with contribution of 54% followed by welding current with contribution of 16% and welding voltage with contribution of 06%.The residual error was 25%.This error is due to human ineffectiveness , machine vibration and environment effects. These are the optimize results of different process parameters for Bead width.

VI CONCLUSION

The following conclusions can be drawn based on the experimental results of this research work:

1. So, the optimal parameters combination of bead height for CRC steel 513 GR 'D' was welding current 170 amps, the Welding voltage 26 volts and the wire extension 10 mm.

Welding current is significantly affects the bead height with contribution of 54% followed by wire extension with contribution of 40% and welding voltage with contribution of 02%. These are the optimized results of different process parameter for Bead height.

2. So, the optimal parameters combination of bead width for CRC steel 513 GR ‘D’ was welding current 190 amps, the Welding voltage 22 volts and the wire extension 10 mm. Wire extension is significantly affects the bead width with contribution of 54% followed by welding current with contribution of 16% and welding voltage with contribution of 06%. These are the optimized results of different process parameters for Bead width.

VII FUTURE SCOPE

Gas metal arc welding is one of the conventional and traditional methods to join materials. A wide range of materials may be joined by Gas metal arc welding—similar metals, dissimilar metals, alloys, and nonmetals. In the present scenario demand of the joining of similar materials continuously increases due to their advantages, which can produce high yield strength, deeper penetration, continuous welding at higher speed and small welding defects.

Thus Design of experiments by Taguchi method was successfully used to find the optimum welding parameters for Bead width and Bead height of CRC steel IS 513 GR ‘D’. An Orthogonal array (L9), signal to noise (S/N) ratio and analysis of variance (ANOVA) are employed to study and optimize the welding parameters.

So, for future further work in MIG Welding , we will optimized other process parameters like Welding speed, type of shielding gas, size of electrode, gas flow rate, electrode angle etc. which are not used in present analysis and the optimization will be carried out for different materials by same method or by other optimization techniques. Confirmation tests shall also be conducted to validate the optimum parameter settings**.**

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