Experimental Investigation for Parametric Optimization of Gas metal arc welding process by using Taguchi technique on mild steel Fe 410

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Abstract – *This paper presents the effect of welding parameters such as welding current, welding voltage and gas flow rate on depth of penetration and ultimate tensile strength using Taguchi technique. Two types of oxides $MgCO_3$ and Cr_2O_3 were used to examine the effects of activating flux on penetration in mild steel Fe 410 of size 100×65×6 mm by GMAW with a V-groove weld joint design. The Cr_2O_3 was found to be the best activating flux resulting in maximum penetration. Using Cr_2O_3 nine experimental runs (L9) based on orthogonal array was carried out. The most significant factor and predicted optimal parameter setting was identified by applying ANOVA and S/N ratio. It has been found that for penetration the most influencing parameter was current, voltage and gas flow rate respectively. For tensile strength the dominating factor was current, then gas flow rate and voltage respectively. The results were found near to the optimize results after conducting the confirmation experiment.*

***Key Words*: Gas metal arc welding (GMAW), Taguchi technique, Depth of penetration, Ultimate tensile strength (UTS), Activating flux, Signal to noise ratio (S/N ratio), Analysis of variance (ANOVA)**

1. INTRODUCTION

Gas metal arc welding is also called as metal inert gas welding (MIG) or metal active gas (MAG) welding that is one of the arc welding process widely used in many industries. Through a welding gun a continuous and consumable electrode wire and a shielding gas such as CO_2, Argon, Helium or a combination of this is fed. The source of heat is arc that is generated between work piece and electrode. Shielding gas protects the weld pool against the atmospheric contamination. The most essential factors that affects the welding cost, productivity and quality are MIG welding parameters. The effect of factors i.e. parameters on response penetration and tensile strength is been presented. Input parameters are current, voltage and gas flow rate based on literature review and economical suitability of industrial application while the output parameters are penetration and UTS. Mild steel Fe 410 of size 100×65×6mm which has vast application in various sectors has been used as a work piece. To determine the best process parameter, design of experiment is suitable method. ANOVA defines the contribution of each input parameters to attain optimal conditions. Optimal parameters are found by analysing S/N ratio.

1.1 Literature Review

Her-Yeuh Huang. [1] studied the effect of A-flux on AISI 1020 carbon steel of 5mm thickness by GMAW. The input parameters were current, voltage, speed and joint gap while the output parameters were penetration, weld area, angular distortion, tensile strength, hardness, welding arc. Joint gap was not found to be an important parameter. $MgCO_3$ gave best result than Fe_2O_3 and SiO_2. Due to A-flux there was increase in penetration and weld area while decrease in angular distortion further better tensile strength and hardness was achieved.

Sunil R. *Wadhokar*. [2]Performed parametric optimization on AISI 410 martensitic stainless steel of 5mm thickness by Taguchi technique using GMAW process. Influence of process parameters on penetration has been investigated by taking welding speed, welding current and wire diameter as input parameters. The most significant factor and predicted optimal parameter setting is identified by applying ANOVA and S/N ratio. By conducting the confirmation test the results were found to be closer to the optimize results.

Nabendu Ghosh et al. [3] has done research in MIG welding on AISI 409 ferritic stainless steel material of 3mm thickness for studying and analysing the effect of welding parameters like gas flow rate, nozzle to plate distance, and welding current. It has been found that for UTS, current is dominant factor, then gas flow rate. While for percentage elongation, gas flow rate has more influence than current.

Rahul Malik *et al.* [4] studied optimization for hardness and tensile strength by using taguchi method on mild steel and high speed steel using MIG welding. For tensile strength the greatest effect in decreasing order was: voltage, current and gas flow rate respectively. For hardness the most influencing parameter was current then voltage and lastly gas flow rate.

Izzatul Aini Ibrahim *et al.* [5] investigated the effect of various parameters on hardness, penetration and microstructure by using robotic GMAW on mild steel material. Depth of penetration was increased by increasing the current while arc voltage and welding speed were the other factors contributing to it.

Erdal Karadeniz *et al.* [6] investigated the effect of welding parameters on depth of penetration of 2.5mm thick 6842 steel material. The depth of penetration was increased by increasing the current, other parameters also have an effect on penetration. With increase in speed the depth of penetration was first increased and then decreased.

Shubham Gothi *et al.* [7] study has been done to find out the influence of current, voltage, and gas flow rate on penetration using AISI 1018 mild steel of 8mm thickness. It has been found that penetration increases with current and voltage while with increase in gas flow rate it increases and then decreases.

2. MATERIAL AND EXPERIMENTAL PROCEDURE

Material Selection:

Fe 410 mild steel has been used for the experimentation having dimensions as 100×65×6 mm thickness. The chemical composition of Fe 410 mild steel is given in Table I.

Table -1: Chemical Composition

Material	Fe 410 mild steel
C	0.11
Mn	0.56
Cr	0.05
Ni	0.05
Mo	0.011
S	0.018
P	0.019
Si	0.20

Experimental procedure:

By using power arc MIG 400 welding machine experiments were performed at MANISHA METAL INDUSTRIES, MIDC, Waluj, Aurangabad.

Sample of 100×65×6 mm Fe 410 mild steel material plate has been used as it has a wide scale of application in industries. On optical emission spectrometer machine the sample was confirmed for Fe 410 from S.N. METALLURGICAL SERVICES, B-70, MIDC, Waluj, Aurangabad, and in table-1 chemical composition examination results are shown. The MS Fe 410 sheet is cut into the required shape by cutting process. The edges are smoothen, V-groove 60◦ angle was given and burr was removed by grinding operation. On the backside of plate tracking was done to prevent distortion of welded sample. Lastly the pieces were cleaned by acetone. At the joint fine paste of flux and acetone was applied with the help of brush and welding was done.

Fig -1: Gas metal arc welding Process Setup

Design of Experiment by Taguchi Technique:

For the DOE, Taguchi technique in mini tab 17 was applied that reduces the number of experiments that are to be performed. According to the no. of factors and their levels the corresponding orthogonal array is chosen from the set of predefined orthogonal array. In this experiment 3 factors along with their 3 levels are chosen for which the corresponding OA is L9 as shown in the table-3. The levels for DOE is shown in table-2.

Fig -2: Welded Samples

Table -2: Levels for DOE

Factors \Levels	Low (1)	Medium (2)	High (3)
Welding Current (Amp)	150	180	210
Welding Voltage (Volts)	20	25	30
Gas flow rate (Lit/min.)	15	17	19

The parameters that significantly affects the quality characteristics was investigated by S/N ratio. The higher the depth of penetration and UTS, better will be the welding performance. So larger-the-better signal to noise ratio is selected for maximizing the response.

Table -3: L9 Orthogonal Array

No. of Experiments	1 Welding Current	2 Welding Velocity	3 Gas Flow Rate
1	150	20	15
2	150	25	17
3	150	30	19
4	180	20	17
5	180	25	19
6	180	30	15
7	210	20	19
8	210	25	15
9	210	30	17

Table -4: Experimental Results for penetration

I	V	GFR	Penetration (mm)	S/N ratio
150	20	15	4.1560	12.3735
150	25	17	4.1137	12.2847
150	30	19	4.1884	12.4410
180	20	17	3.2310	10.1867
180	25	19	4.3779	12.8253
180	30	15	3.6913	11.3436
210	20	19	4.6745	13.3947
210	25	15	5.3210	14.5199
210	30	17	4.0714	12.1949

Where: I-Current (Amp), V-Voltage (Volt), GFR-gas flow rate (l/min)

Generalized penetration equation in terms of current, voltage and gas flow rate obtained from regression analysis is:

Penetration = 2.58 + 0.00894 Current - 0.0037 Voltage + 0.006 Gas flow rate

Table -5: Experimental Results for UTS

I	V	GFR	UTS (N/mm^2)	S/N ratio
150	20	15	310.03	49.8281
150	25	17	320.01	50.1033
150	30	19	365.21	51.2509
180	20	17	391.50	51.8546
180	25	19	318.05	50.0499
180	30	15	325.88	50.2612
210	20	19	308.75	49.7921
210	25	15	166.10	44.4074
210	30	17	316.13	49.9973

Generalized UTS equation in terms of current, voltage and gas flow rate obtained from regression analysis is:

UTS = 251-1.135 Current – 0.10 Voltage + 15.8 Gas flow rate

3. RESULTS AND DISCUSSION

ANOVA and Main effect plots:

Each experiment has a combination of various factor levels, it is necessary to differentiate the individual effect of all variables, which may be done by adding performance parameter values for respective levels. ANOVA of Fe 410 mild steel material data for penetration is shown in Table IV.

Fig.3 shows that effect of the current is more on penetration followed by voltage then gas flow rate.

Table -4: ANOVA for Penetration of Fe 410 mild steel material

Source	**DF**	**Adj SS**	**Adj MS**	**F**	**P**
Current	2	1.28707	0.643533	113.40	0.009
Voltage	2	0.72708	0.363540	64.06	0.015
GFR	2	0.71167	0.355833	62.70	0.016
Error	2	0.01135	0.005675		
Total	8	2.73716			
S=0.0753313		R-Sq=99.59%		R-Sq(adj)=98.34%	

Fig.4 shows that effect of the current is more on UTS followed by gas flow rate then voltage.

Table -5: ANOVA for UTS of Fe 410 mild steel material

Source	**DF**	**Adj SS**	**Adj MS**	**F**	**P**
Current	2	11455.2	5727.58	65.26	0.015
Voltage	2	9303.1	4651.57	53.00	0.019
GFR	2	9808.7	4904.36	55.88	0.018
Error	2	175.5	87.77		
Total	8	30742.5			
S=9.36866		R-Sq=99.43%		R-Sq(adj)=97.72%	

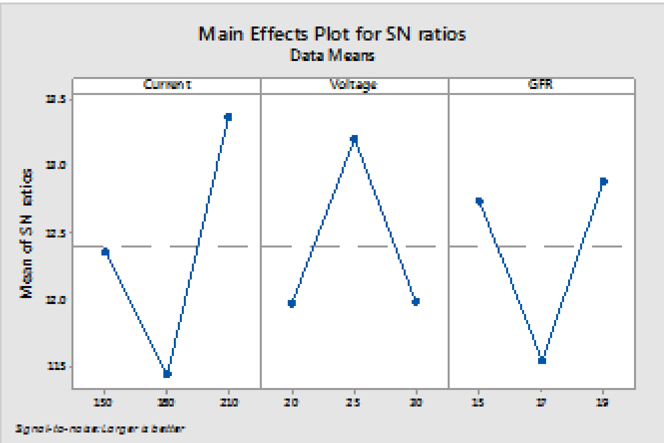

Fig -3: Effect of various parameters on S/N ratio for Penetration

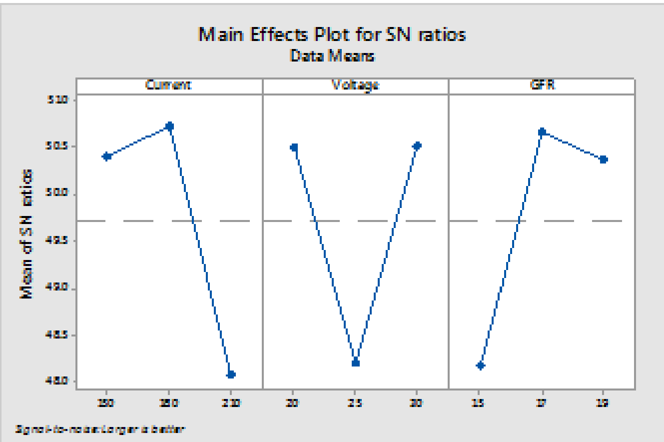

Fig -4: Effect of various parameters on S/N ratio for UTS

Greater S/N ratio corresponds to better quality characteristic, therefore the optimal levels has the greatest S/N ratio. From fig-3 to obtain the optimum value of penetration, the values of variables taken from the graph are current=210A, voltage=25V, Gas flow rate=19 Lit/min.

From fig-4 to obtain the optimum value of UTS, the values of variables taken from the graph are current=180A, voltage=30V, gas flow rate=17 Lit/min.

For both penetration and UTS, the optimal process parameters was not found in the orthogonal array so the confirmation experiment was carry out. After Confirmation test the actual penetration and UTS was 4.5398 mm and 314.13 N/mm^2 respectively. The results were found to be valid due to small difference between the actual and predicted values of penetration and UTS.

Table -5: Optimum values of wear rate

Response	Optimum value				Actual Value
	Current (A)	Voltage (V)	Gas flow rate (Lit/min)	Optimum Value for response	
Penetration (mm)	210	25	15	4.4789	4.5398
UTS (N/mm^2)	180	20	17	312.3	314.13

4. CONCLUSIONS

1. The percentage contribution of various parameters for penetration are as follows: Current=47.02%, Voltage=26.56%, Gas flow rate=26%. Current was found to be the most influencing parameter followed by voltage and gas flow rate for penetration. With increase in current the heat input also raises, leading to increase in penetration. Proper melting of weld deposit is not ensured by too low heat input. While large weld pool is formed due to high heat input that leads to flow of metal infront of the arc preventing the melting of base metal.

2. The percentage contribution of various parameters for UTS are as follows: Current=37.26%, Voltage=30.26%, Gas flow rate=31.90%. The most dominating factor was current followed by gas flow rate and then voltage. Against atmospheric contamination better protection can be obtained by increasing the GFR that yields better quality weld. However chances of gas absorption from the atmosphere and uncontrolled protection of weld pool and arc may occur due to increase in GFR that causes turbulence.

3. The optimum conditions for penetration are current=210A, Voltage=25V, Gas flow rate=19 Lit/min.

4. The optimum conditions for UTS are current=180A, Voltage=30V, Gas flow rate=17 Lit/min.

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