Optimization of GMAW Process Parameters To Improve The Weld Penetration By Using Taguchi Method

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Abstract- *In heavy fabrication industry, GMA Welding is a very useful & important welding process and E250 &E350 is common material used for manufacturing of various parts. This research gives the detail influence of welding process parameters such as welding current, welding voltage, welding speed on the penetration in E250 & E350 mild steel materials. The experimentation of this research has been carried out by using three factors, three level Taguchi method. To analyze & optimize the welding parameters & characteristics, analysis of variance, nine runs orthogonal array & signal to noise ratio are used. Penetration is a major concern in fillet welded joints, as the penetration decides the strength of the welded joint. After analysis of penetration in all 9 welded samples, optimize parameters readings verified & found probability value within 0.05.From this research it is come to know that welding current & welding voltage is major parameters which affects the penetration in welded joints.*

Keywords- GMA Welding, Welding Current, Voltage, Welding speed Penetration, Taguchi Method, Optimization.

I. INTRODUCTION

Gas metal arc welding is a welding process which has various industrial applications. In GMAW an electric arc produced between electrode & work piece metals, this causes electrode & work piece metal to melt &join. The joining area is called as weld (Rajesh Ranjan et al.2015). GMAW process parameters affecting the quality of welding & productivity. In heavy fabrication industry penetration is one of the most important factor which should achieve during welding. The input parameters which are mainly responsible for welding penetration is welding current, welding voltage, welding speed& this parameters plays an important role in achieving the desired penetration in welded joints. In this research work,E250 & E350 mild steel materials has been used with sample size of 125 X 150X10mm .Design of experiments based on Taguchi technique is used to evaluate the data. An orthogonal array, signal to noise (S/N) ratio and analysis of variance (ANOVA) has been used to find the best welding penetration in mild steel materials by using different range of input parameters.

[1] Parametric optimization GMAW on SS AISI 410 material- they have used same base material (AISI 410) for the research & used input parameters as welding speed, wire diameter, welding current. The research had been done by using the plate thickness of 6 mm & used L16 orthogonal array to find out optimize parameters & they have get the optimize parameters as welding speed – 60 cm/min, welding current – 110amp & wire diameter is 1.2 mm. [2] The study has been done on multivariate data analysis methods such as hierarchical clustering analysis, partial least squares are used to develop classification models to and predict the weld quality based on various parameters. The models obtained using these methods are useful in classification and prediction of weld quality and can be uses in weld run monitoring. [3] .In this study, the investigation has been carried out on effect of the process parameters on the lap shear strength of AA6181-T4/Ti6Al4V single joints by using Friction spot welding. For analysis full-factorial design of experiment and analyses of variance method used. The results obtained from this study is sound joints with lap shear strength from 4769 N to 6449 N were achieved and the influence of parameters on joint was evaluated. [4] The research done on Submerged Arc Welding by using two mild steel pipes of size 12000mm (length) X 1250 mm (width) X 12 mm (thickness) with a V angle of 30° to 45° ,4 mm root height and 0.75 mm gap between the two plates. Electrode used by them is EH-14 wire 3.20 mm diameter. They have obtained the optimize parameters as welding current, 600A, Arc voltage 32 V, Welding speed 450 mm/min and electrode stick out 28 mm. [5] They have studied optimization of weld bead geometry by using test plates of size 300 × 200 × 20 mm mild steel plates. They have used five levels five factors full factorial design matrix method for optimization. The parameters used for the study is welding gun angle, contact tip to work distance, pinch, welding speed. From this research study it is observed that the developed

model can be used to predict clad bead geometry within the applied limits of process parameters. [6] The research study done on ST 37 low alloy material to evaluate the ultimate tensile strength. They have taken input parameters as Gas flow, welding current, welding voltage by using 10x75x6 mm sample sizes for the experimentation .They have obtained the results as 454.25 N/mm2 by optimize parameters are current 110 amp, voltage 22 volts, gas flow 9 Lit/min, welding speed 5.5 m/min. [7] They have done the experimental study on Galvanize steel weld ability in which they have used 0.8 mm electrode wire diameter & parameters they have used are, arc time, heat input rate, speed, welding current, welding voltage. Sample size they have used for this experimental study is 50 mm x 40 mm x 5 mm. The results obtained are when current is 100 amp, voltage is 23 V and welding speed is 209.7 mm/min. [8] This studied has been done on stainless steel 304 material by using TIG welding process. In this research they have concluded that the welding voltage has greater impact on the tensile strength. Optimum parameters they have obtained for better weld strength is Current 150 amp, voltage 28 volts, gas flow 14 lit/min.

II. TAGUCHI METHOD

We have used Taguchi method for the experimentation as the method is an efficient method for optimization of process parameters. The method was developed by Dr. Genichi Taguchi, who was a Japanese quality management consultant; the method is based on orthogonal array experiments, which gives reduced optimum setting of process control parameters. The method was selected for the experimentation because the method is cost effective, less time consuming, greater accuracy, and robust design for large scale application. By using Taguchi method for process parameters optimization Design of Experiments (DOE) were selected. For the experimentation 3 factors & 3 level Taguchi design model was used, Based on this model we have generated L9 orthogonal array & total 9 runs were taken for the experiment. Minitab 15.0 software was used to generate the orthogonal array through Taguchi Design,

III. EXPERIMENTAL METHOD

We have used Gas Metal Arc Welding process for the experimentation, as the process has high weld deposition efficiency & better weld quality with low operation cost. Experiments were carried out by using semiautomatic controlled GMAW processAK 600AMP welding machine.Copper coated steel wire of ER70 S6 grade with 1.2 mm diameter in the coil form was used for the welding. Shielding gas Ar-C02 used for shielding purpose with percentage of Ar: 82% & CO2:18%.

Mild Steel plates (E250 & E350) of IS 2062grade used as base material with specimen size of 125 x 150 x 10 mm.The welding is carried out in 2F welding position & the joint taken for welding was Tee joint.

Figure 1. GMA Welding Machine

Table 1. E250 Material Properties

Chemical Analysis	C (%)	Mn (%)	Cr (%)	Ni (%)	Mo (%)	S (%)	P (%)	Si (%)
Specified	0.23 max	1.50 max	~~~	~~~	~~~	0.050 max	0.050 max	0.40 max
Observed	0.197	0.85	0.02	0.02	0.03	0.017	0.019	0.25
Mechanical Properties	Hardness		Tensile Strength		Yield Strength		% of Elongation	
Standard	~~~		410 N/mm2 min		230 N/mm2 min		23% min	
Observed	70-75 HRB		472.5 N/mm2		240.3 N/mm2		24.10%	

Table 2. E350 Material Properties

Chemical Analysis	C (%)	Mn (%)	Cr (%)	Ni (%)	Mo (%)	S (%)	P (%)	Si (%)
Specified	0.20 max	1.55 max	~~~	~~~	~~~	0.040 max	0.040 max	0.45 max
Observed	0.18	1.2	0.02	0.03	0.04	0.023	0.033	0.35
Mechanical Properties	Hardness		Tensile Strength		Yield Strength		% of Elongation	
Standard	~~~		490 N/mm2 min		350 N/mm2 min		22% min	
Observed	79-82 HRB		510.5 N/mm2		369.3 N/mm2		25.10%	

Table 3. Filler Wire Material Properties

Material Description : Copper Coated Wire used in GMA Welding Process										
Material Specification: American Welding Society A5.18 Grade ER70-S6										
Size : Dia.1.2 mm										
Chemical Analysis	C (%)	Mn (%)	Si (%)	S(%)	P (%)	Ni (%)	Cr (%)	Mo (%)	V (%)	Cu (%)
Specified	0.06-0.15	1.40-1.85	0.80-1.15	0.035	0.025	0.15 max	0.15 max	0.15 max	0.03 max	0.5
Observed	0.08	1.49	0.85	0.008	0.014	0.04	0.03	0.001	0.007	0.15
Mechanical Properties	UTS (Mpa)		Yield Strength (Mpa)		Elongation (%)		Impact Properties (CVN) Avg.J		Temperature	
Standard	480 min		400 min		22 min		27		-30°C	
Observed	540		430		28.5		27		-30°C	

3.1Plan of Experimentation

The plan carried out for the experimentation has following steps:

1. Selection of Important Process Parameters
2. To decide the upper & lower limits process parameters
3. Development of Orthogonal Array
4. Preparation of Samples & conduct the trials
5. Inspection of Angular Distortion
6. Analyze Taguchi Design
7. Checking the Adequacy of Model
8. To find the Optimal Process Parameters

3.1.1 Selection of Important Process Parameters

The controllable process parameters were selected conduct the experiments are Current, Voltage &Wire speed. The objective of this study as discussed earlier is to optimize the welding process parameters for enhancing weld penetration. A total of the three welding process parameters were chosen as the controlling factors.

3.1.2 To decide the upper & lower limits process parameters

The selection of upper & lower limit of process parameters has been done on the basis of machine manufacturer ESAB guideline & standards which is based on filler wire diameter, shielding gas percentage & type of weld joint.

Table 4. Level of Process Parameters

Levels	Current (A)	Voltage (V)	Wire Speed (M/Min)
1	180	24	6
2	240	27.5	10
3	300	31	14

3.1.3 Development of Orthogonal Array

L9 orthogonal array was developed by using 3 factors & 3 levels Taguchi design

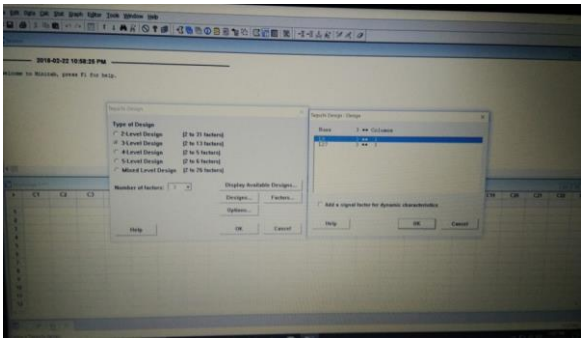

Figure 2. Orthogonal array with 3 levels, 3 factors

Experimentation for the welding process as per the parameters mentioned in orthogonal array

Table 5. Sampling plan for process parameters as per Taguchi method

Process Parameter	Sample 1	Sample 2	Sample 3	Sample 4	Sample 5	Sample 6	Sample 7	Sample 8	Sample 9
Current (A)	180	180	180	240	240	240	300	300	300
Voltage (V)	25	27.5	31	24	27.5	31	24	27.5	31
Wire Speed (M/min)	6	10	14	10	6	14	14	6	10

3.1.4 Preparation of samples & experimental trials

Total 09 Nos. of trials conducted as defined in orthogonal array sampling plan, test piece used for the trials as per the defined size (125x150x10 mm)

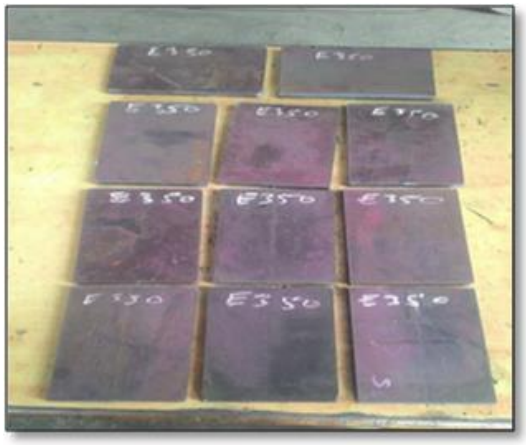

Figure 3. Sample preparation

Figure 4. Welding samples

3.1.5 Penetration Inspection

After experimentation on all 09 Nos. of samples, penetration is measured by taking cut section of all samples & using special micro scope at a laboratory.


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Date : 15/12/2017
Lab No 5215

TEST REPORT

FM/MFG/01

To,
Mr.Sayyad Sohel Jamil
MSS's CET Jalna

Subject : Sample given for testing

Part Name : Welded steel plate 10 x 10 mm Plate Sample

Test Result :

Sr.No	Details		
A	Process Details		
1	Process	Co2 Welding	
2	Thickness	A : 10.00mm	B : 10.00 mm
3	Welding Parameter		
B	Micro Analysis		Specified
1	Throat Size mm	4.60	
2	Surface or Sub Surface weld crack	No any cracks observed	nil
3	Micro Porocity Inclusion	No any porosity observed	nil
4	Welding Penetration	Plate-I 1.30mm / Plate-II 2.95mm	
	Welding Penetration with photograph		

Remarks : Our Findings are as above .

For S.N.Met.Services

Figure 5. Penetration Inspection Report

3.1.6 Analyze Taguchi design

To analyze the Taguchi Design, Signal to Noise(S/N) ratio calculated. As we required maximum penetration as a result, larger is better option was selected. After experimentation, S/N ratio calculated through the penetration reading.

Table 6. S/N Ratio Calculation

Process Parameter	Sample 1	Sample 2	Sample 3	Sample 4	Sample 5	Sample 6	Sample 7	Sample 8	Sample 9
Current A	1	1	1	2	2	2	3	3	3
Voltage B	1	2	3	1	2	3	1	2	3
Wire Speed C	1	2	3	2	3	1	3	1	2
Penetration (mm)	0.9	1.3	1.3	1.0	1.3	1.2	1.5	1.5	2.2
SNRA1	-0.915	2.278	2.278	0.000	2.278	1.583	3.521	5.575	6.684

Graph for the response table for SN Ratios & Response table for Means can be plotted as follows

Table 7. Response for S/N Ratios; Larger is Better

Level	A	B	C
1	1.2142	0.8689	2.0812
2	1.2875	3.3776	3.0424
3	5.3151	3.5703	2.6932
Delta	4.1009	2.7014	0.9613
Rank	1	3	2

Table 8. Response Table for Means

Level	A	B	C
1	1.167	1.133	1.333
2	1.167	1.500	1.500
3	1.867	1.567	1.367
Delta	0.700	0.433	0.167
Rank	1	3	2

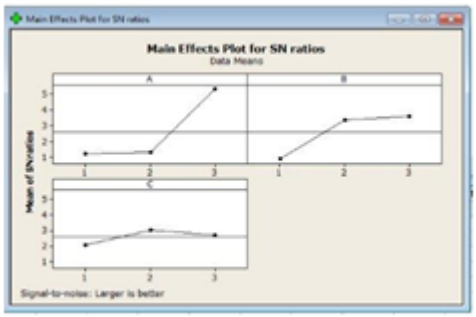

Figure 6. Main Effects Plot for S/N Ratio

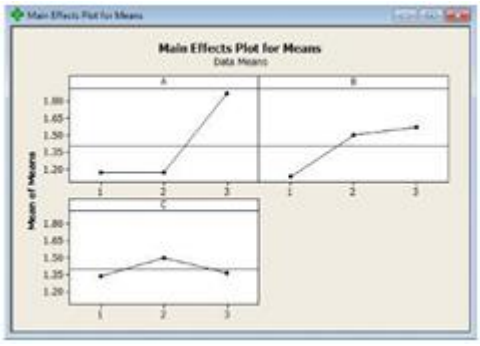

Figure 7. Main Effects Plot for Means

As per experimentation & Taguchi optimization technique it is observed that penetration observed maximum when Current is at 300 A, Voltage is at 31 V & Wire Speed is at 10 m/min.

Thus the optimum parameters for better penetration for E250 & E350 material is Current is at 300 A, Voltage is at 31 V & Wire Speed is at 10 m/min.

3.1.7 Adequacy of the model

The model checked for the adequacy by using ANOVA i.e. Analysis of Variance Method.

As per ANOVA, the value of P should be less than 0.05 for every parameter for the desired adequacy & it has been confirmed that the model is adequate from the below results.

General Linear Model: SNRA1 versus A, B,C .

Table 9. ANOVA for SNRA1

Source	DF	Seq SS	Adj SS	Adj MS	F	P
A	2	33.0447	33.0447	16.5223	287.56	0.003
B	2	13.6285	13.6285	6.8142	118.60	0.008
C	2	1.4205	1.4205	0.7103	12.36	0.075
Error	2	0.1149	0.1149	0.0575		
Total	8	48.2086				
S=0.239701 R-Sq = 99.76% R-Sq (adj) = 99.05%						

3.1.8 Optimum Process Parameters

Regardless of the category of the quality characteristic, a greater S/N ratio corresponds to better quality characteristics. Therefore, the optimal level with the greatest S/N ratio. The optimal levels of process are:

From the graph of S/N Ratio & mean values

Current - A 3 = 300 A
Voltage - B 3 = 31 V
Wire Speed- C2 = 10 M/min.

IV. CONCLUSION

The present study is carried to discuss an application of the Taguchi Method for investigating the effect of process parameter on Penetration. We have conducted various trials for the optimization of process parameters & reach to following conclusion.

1. Optimization of process parameters can be effectively done by using 3 levels, 3 factors & L9 orthogonal array
2. Better penetration observed is 2.2mm at Current 300 A, Voltage 31V, Wire Speed 10 M/min
3. Penetration varies with the parameters, means we cannot extend the current & voltage with wire speed. Proper wire speed with adequate current & voltage gives better penetration as prove in the experimentation. Wire speed is a most influencing factor for penetration

V. ACKNOWLEDGEMENT

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