Optimization of P-GMAW welding parameters using Taguchi technique for SS 316L material

Rudreshi Addamani, H V Ravindra[1], Girish A[2]

[1]Department of Mechanical Engineering, P.E.S. College of Engineering, Mandya - 571401, India

[2]Department of Mechanical Engineering, Proudhadevaraya Institute of Technology, Hospet.

ABSTRACT

In Pulsed Gas Metal Arc Welding (P-GMAW) welding, input parameters are the most important factors affecting the cost of fabrication, quality and productivity in modern high technology industries. This paper presents the influence of welding input parameters viz., welding Current (amp), Gas flow rate (GFR, LPM), Wire Feed Rate (WFR, mm/min) on weld bead joint strength of SS 316L pipes during welding. The parameters can be optimize and having the best parameters combination to get good quality weld bead joint by using DOE method. The analysis from Taguchi technique method can give the significance of the parameters as it give effect to change of the quality and strength of product. A plan of experiments based on Taguchi technique has been used to acquire the data. An Orthogonal array of L_{27} and analysis of variance (ANOVA) are employed to investigate the welding characteristics of SS 316L material and optimize the welding parameters. The response parameters considered are Ultimate Tensile Strength (UTS, N/mm^2), Yield Strength (YS, N/mm^2) and % of elongation. Finally the conformations tests have been carried out to compare the predicated values with the experimental values to confirm its effectiveness in the analysis of weld bead joint strength.

Key Words: P-GMAW, Taguchi technique, ANOVA, Tensile test.

1. INTRODUCTION

Pulsed Gas Metal Arc Welding (P-GMAW) is broadly used fabrication process, particularly in thin metal sheet industries. It offers an enhancement in quality and productivity over regular Gas Metal Arc Welding (GMAW). The process enables stable spray transfer with low mean current and low net heat input. It applies waveform control logic (Fig-1) to produce a very precise control of the arc through a broad wire feed/speed range. With precise control of arc dynamics, P-GMAW welding can be used as a high deposition rate at high travel speeds, or it can be run as a fast-follow process with fast-fill process. A variation of the spray transfer mode, pulse-spray is based on the principles of spray transfer but uses a pulsing current to melt the filler wire and allow one small molten droplet to fall with each pulse. This feature of current pulsating reduces net heat input to the base metal, so decreases undesirable effects of comparatively high heat input in MIG welding. The main setting parameters which influence weld quality or wire melting are background current (Ib), peak current (Ip), background time (Tb) and peak time (Tp). Pulsed Current Metal Inert Gas Welding is commonly used for root pass welding of tubes and pipe welding.

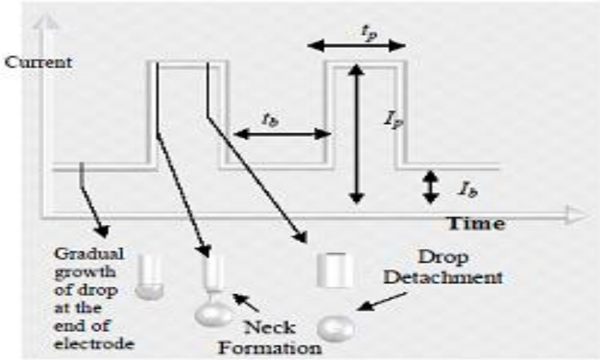

Fig.1: Pulse metal transfer phenomenon

A research work carried out on the optimization of MIG welding parameters using Taguchi design method. In this research, the input parameters considered are viz., welding current, welding voltage and welding speed and penetration depth as output variable. MS C20 was selected as work piece material. A plan of experiments based on Taguchi technique has been used to acquire the data. An orthogonal array, signal to noise(S/N) ratio and analysis of variance (ANOVA) were employed to investigate the welding characteristics of MS C20 material and optimize the welding parameters. Their experimentation results that the lower current [1]. Some of the researchers performed their analysis on optimization of resistance spot welding parameters using Taguchi method. The experiments were conducted under varying pressure, welding current and welding time. The output characteristic considered was tensile strength of the welded joint. The material used was low carbon steel sheets of 0.9mm. Their conclusion leads that the contribution of welding current holding time and pressure towards tensile strength is 61%, 28.7% and 4 % respectively as determined by the ANOVA method [2]. A work carried out to present on designing optimization of process parameters of TIG welding using Taguchi method. They considered welding current, gas flow rate and filler rod as input process parameters and optimizes their values using Taguchi method to improve the ultimate load on weld materials. Taguchi design of experiment, S/N ratio and ANOVA analysis has performed for optimizing the results. The stainless steel slabs & mild steel slabs were used as work piece material. The optimum welding condition is obtained by the Taguchi method: current= 100A, gas flow rate= 18 l/min, filler rod diameter = 2mm. Confirmation test confirmed the optimum values. [3]. some researchers presented their work on optimization of MIG welding parameters for improving welding strength. They presents the influence of welding parameters welding current, welding voltage, welding speed on ultimate strength of welded joints of AISI mild steel materials. A plan of experiments using Taguchi has decided. Experiments were performed and result was confirmed. From this study they concluded that the welding current and welding speed are the major factors affecting tensile strength of welded joints. [4]. A work has done on optimization of MIG welding parameters in order to improve yield strength of AISI 1040 mild steel. The process parameters welding current, voltage, gas flow rate and wire speed were studied. The experiments were conducted based on four factors, three level orthogonal arrays. The empirical relationship can be used to predict the yield strength of welded material [5].

2. EXPERIMENTAL SETUP

The experiments have been conducted using a Pulsed Current Lorch welding machine having 400 amperes maximum current with air type cooling and automated welding set up. In this welding machine automated Metal Inert Gas torches as well as automatic wire feeding units have provided. Trials are performed based on Taguchi L_{27} orthogonal array. Trial specimens are having dimension of 25 mm outer diameter, 22 mm inner diameters and 3 mm wall thickness. Each specimen is cut in to 150 mm long and tack welded before welding. Edge preparation was done with 60^o angle and single pass butt welding is done. Welding process was carried out by using CO2 (15%) and Argon (85%)

ISBN : 978-93-87793-87-3

gas mixture for shielding. The working ranges for the process parameters were selected based on expert's advice, literature review and with the American Welding Society (AWS) hand book. Single pass welding was performed on SS 316L pipes material by varying the process parameters as shown in Table 2. Welding and destruction (tensile test) experiments are shown in Fig. 2 and Fig. 3 respectively.

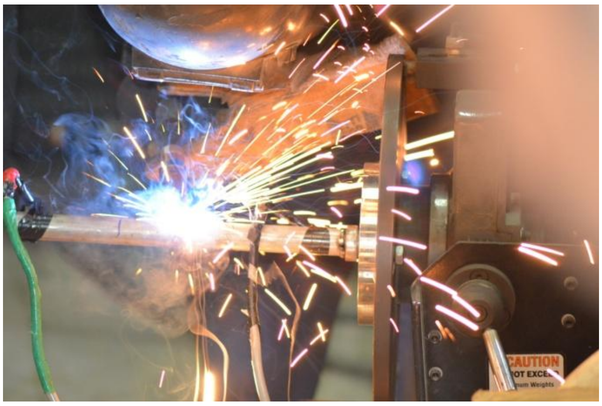

Fig. 2: Welding Experimental Setup

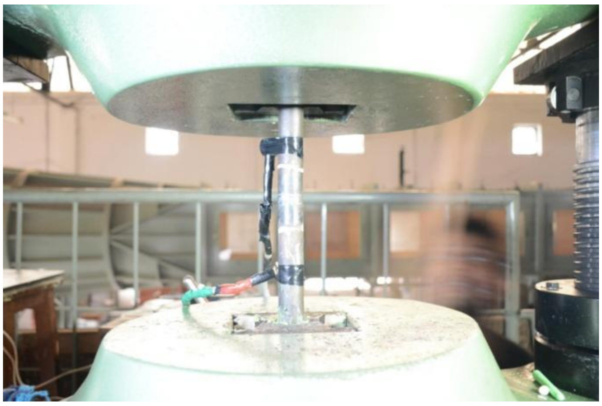

Fig. 3: Tensile Experimental Setup

2.1 MATERIAL SELECTION

The present study has been carried out with SS 316L pipes is the standard specification for stainless steel pipes for high-temperature service. Most common application of this material is in refineries and plants when gasses or fluids are transported at high temperatures and pressures.

Table.1: Chemical composition of SS304L Pipe material

C	Mn	P	S	Si	Cr	N	Mo	Ni
0.032	2.00	0.046	0.030	0.75	16.00	0.10	2.00-	12.00

Table. 2: Control Factors and their levels

Sl.No.	**Welding Parameters**	**Symbol**	**Units**	**Levels**		
				1	**2**	**3**
1	1	Current	amp	55	60	65
2	2	GFR	LPM	12	13	14
3	3	WFR	mm/min	110	115	120

2.2 PROPOSED DESIGN OF EXPERIMENT

For performing the experiments Taguchi L_{27} orthogonal array was selected for 3-factor and 3-level process parameters and which reduces the number of experiments which is given in table 3.

Table. 3: Taguchi L27 Orthogonal Array

No. of Runs	A	B	C		No. of Runs	A	B	C
1	1	1	1		15	2	2	3
2	1	1	2		16	2	3	1
3	1	1	3		17	2	3	2

4	1	2	1		18	2	3	3
5	1	2	2		19	3	1	1
6	1	2	3		20	3	1	2
7	1	3	1		21	3	1	3
8	1	3	2		22	3	2	1
9	1	3	3		23	3	2	2
10	2	1	1		24	3	2	3
11	2	1	2		25	3	3	1
12	2	1	3		26	3	3	2
13	2	2	1		27	3	3	3
14	2	2	2					

2.3 TAGUCHI METHODOLOGY

The Taguchi method developed by Genuchi Taguchi is a statistical method used to improve the product quality. Optimization of process parameters is the key step in the Taguchi method for achieving high quality without increasing cost. This is because optimization of process parameters can improve quality characteristics and the optimal process parameters obtained from the Taguchi method are insensitive to the variation of environmental conditions and other noise factors. Basically, classical process parameter design is complex and not easy to use. A large number of experiments have to be carried out when the number of process parameters increases. To solve this task, the Taguchi method uses a special design of orthogonal arrays to study the entire process parameter space with a small number of experiments only. A loss function is then defined to calculate the deviation between the experimental value and the desired value. Taguchi recommends the use of the loss function to measure the deviation of the quality characteristic from the desired value. The value of the loss function is further transformed into signal-to-noise (S/N) ratio.

2.4 S/N RATIO

The Signal to Noise ratios (S/N), which are log functions of desired output, serve as the objective functions for optimization, help in data analysis and the prediction of the optimum results. There are 2 Signal-to-Noise ratios of common interest for optimization of Static Problems.

1. Smaller the better is given by $\eta = -10 \log [(\Sigma Yi2/n]$
2. Larger the better is given by $\eta = -10 \log [(\Sigma 1/Yi2)/ n]$

Where, η = Signal to Noise ratio, Y_i= i^{th} observed value of response, n = no. of observations in a trial, y = average of observed response.

The purpose of the Analysis of Variance (ANOVA) is to examine which design parameters significantly affect the quality characteristic. This is accomplished by separating the total variability of the S/N ratios, which is measured by the sum of the squared deviations from the total mean S/N ratio, into contributions by each of the parameters and the error. The ANOVA table for UTS, YS and % of elongation are shown in table 4, 6 and 8. The response table for UTS, YS and % of elongation are shown in table 5, 7 and 9.

International Conference on Recent Innovations in Science, Engineering & Management
R.R. INSTITUTE OF TECHNOLOGY, Bengaluru (India)
10th - 11th May 2019 www.conferenceworld.in ISBN : 978-93-87793-87-3

Table 4: ANOVA Table for UTS (N/mm^2)

Source	DOF	SS	MS	F	% Contribution
A	2	0.15883	0.07942	52.5	87.5
B	2	0.01846	0.00923	6.10	10.17
C	2	0.00119	0.01564	3.25	0.65
Error	2	0.00302	0.00059	-	1.66
Total	8	0.18152	-	-	100

Table 5: Response Table for UTS (N/mm^2)

Levels	**A**	**B**	**C**
1	49.91	50.10	50.10
2	50.13	50.03	50.07
3	50.23	50.14	50.09
Delta	0.32	0.11	0.03
Rank	1	2	3

Table 6: ANOVA Table for YS (N/mm2)

Source	DOF	SS	MS	F	% Contribution
A	2	0.15883	0.07942	52.5	87.5
B	2	0.01846	0.00923	6.10	10.17
C	2	0.00119	0.01564	3.25	0.65
Error	2	0.00302	0.00059	-	1.66
Total	8	0.18152	-	-	100

Table 7: Response Table for YS (N/mm2)

Levels	A	B	C
1	49.91	50.10	50.10
2	50.13	50.03	50.07
3	50.23	50.14	50.09
Delta	0.32	0.11	0.03
Rank	1	2	3

Table 8: ANOVA Table for % of elongation

Source	DOF	SS	MS	F	% Contribution
A	2	0.15883	0.07942	52.5	87.5
B	2	0.01846	0.00923	6.10	10.17
C	2	0.00119	0.01564	3.25	0.65
Error	2	0.00302	0.00059	-	1.66
Total	8	0.18152	-	-	100

Table 9: Response Table for % of elongation

Levels	A	B	C
1	49.91	50.10	50.10
2	50.13	50.03	50.07
3	50.23	50.14	50.09
Delta	0.32	0.11	0.03
Rank	1	2	3

ISBN : 978-93-87793-87-3

3. RESULT AND DISCUSSIONS

3.1 Optimum parameter selection from s/n ratio for uts (n/mm2)

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. 4, that Ultimate Tensile Strength is highest at third level of welding current, first level of gas flow rate and first level of wire feed rate (A3B3C3).

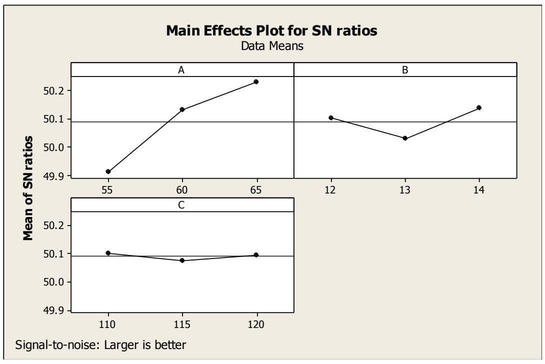

Fig. 4 : Main Effects Plot for UTS (N/mm^2)

3.2 Optimum parameter selection from S/N ratio for YS (N/mm^2)

Yield Strength is larger-the-better type quality characteristic. Therefore higher values of yield strength are considered to be optimal. It is clear from Fig. 4, that Ultimate Tensile Strength is highest at third level of welding current, first level of gas flow rate and first level of wire feed rate (A3B2C3).

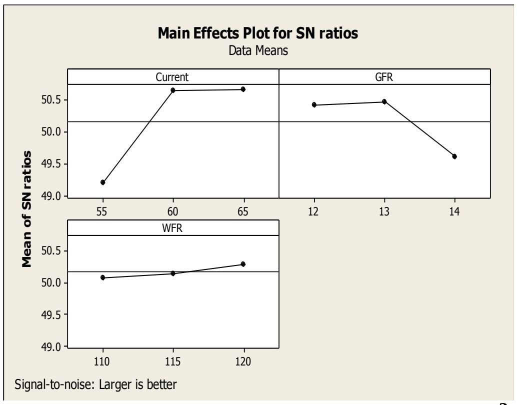

Fig. 5 : Main Effects Plot for YS (N/mm^2)

3.3 Optimum parameter selection from S/N ratio for % of elongation

% of elongation is smaller-the-better type quality characteristic. Therefore smaller values of % of elongation are considered to be optimal. It is clear from Fig. 5, that hardness of is highest at second level of welding current, first level of gas flow rate and third level of wire feed rate (A1B1C3).

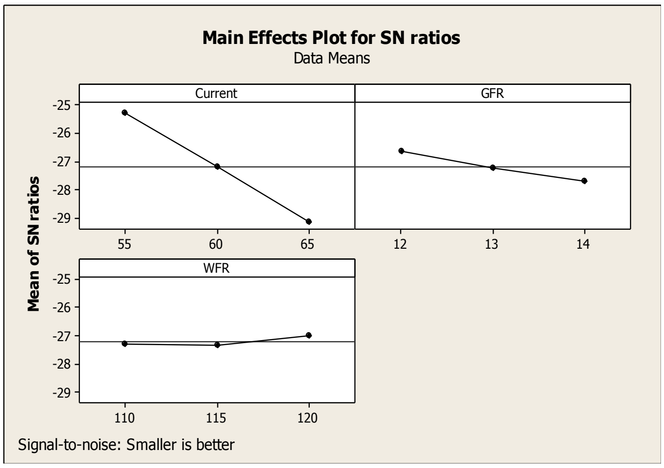

Fig. 6: Main Effects Plot for % of elongation

3.4 Analysis of Variance (ANOVA) Results for Ultimate Tensile Strength (N/mm^2)

The calculated values of Analysis of Variance for Ultimate Tensile Strength of welding joint are listed in table 4. The calculated values of ANOVA present the percentage effect of each parameter on Ultimate Tensile Strength of the joint. From the analysis, it is seen that current is the most contribution factor and the wire feed rate is the least contribution factor for Ultimate Tensile Strength of joint.

3.5 Analysis of Variance (ANOVA) Results for Yield Strength (N/mm^2)

The calculated values of Analysis of Variance for yield Strength of welding joint are listed in table 6. The calculated values of ANOVA present the percentage effect of each parameter on yield strength of the joint. From the analysis, it is seen that current is the most contribution factor and the wire feed rate is the least contribution factor for Ultimate Tensile Strength of joint.

3.6 Analysis of Variance (ANOVA) Results for % of elongation

The calculated values of Analysis of Variance for % of elongation of welding joint are listed in table 8. The calculated values of ANOVA present the percentage effect of each parameter on % of elongation of the joint. From the analysis, it is seen that current is the most contribution factor and the wire feed rate is the least contribution factor for Ultimate Tensile Strength of joint.

Table. 10: Welding performances using L27 orthogonal array

Run	Current (Amps)	GFR (LPM)	WFR (mm/min)	UTS (N/mm^2)	YS (N/mm^2)	% Elongation	Run	Current (Amps)	GFR (LPM)	WFR (mm/min)	UTS (N/mm^2	YS (N/mm^2)	% of Elongation
1	55	12	110	445	335	21	15	60	13	120	367	189	19
2	55	12	115	435	267	19	16	60	14	110	397	263	16
3	55	12	120	402	263	16	17	60	14	115	352	272	20
4	55	13	110	478	272	23	18	60	14	120	362	265	21
5	55	13	115	456	265	21	19	65	12	110	356	225	18
6	55	13	120	433	305	18	20	65	12	115	375	309	21

7	55	14	110	543	339	22	21	65	12	120	332	255	20
8	55	14	115	473	332	21	22	65	13	110	335	301	17
9	55	14	120	469	335	17	23	65	13	115	326	285	22
10	60	12	110	470	285	22	24	65	13	120	499	373	23
11	60	12	115	451	283	23	25	65	14	110	345	245	18
12	60	12	120	411	371	17	26	65	14	115	351	267	21
13	60	13	110	435	326	21	27	65	14	120	536	263	19
14	60	13	115	469	291	22							

3.7 Verification experiment

The confirmation run was conducted using same experimental setup by taking optimized parameters for the SS 316L pipes. The results obtained from the confirmation runs are tabulated in the below Table 11.

Table. 11: Results of Verification Experiment

Condition Description	Initial set of parameters			Optimized welding parameters		
	UTS (N/mm^2)	YS (N/mm^2)	% of elongation	UTS (N/mm^2)	YS (N/mm^2)	% of elongation
Level	A3B1C1	A2B1C1	A2B2C1	A3B3C3	A3B2C3	A1B1C3
Response obtained	502	268.9	20	536	373	16

4. CONCLUSION

In this present work the optimization of the process parameters for Pulsed Gas Metal Arc welding of SS 316L pipes for larger the better for UTS and YS and smaller the values with % of elongation have been reported. A Taguchi orthogonal array, the signal-to-noise (S/N) ratio and Analysis of Variance (ANOVA) were used for the optimization of welding parameters and it is found that i) optimum condition for maximum UTS is (A3B3C3) i.e. current = 65 ampere, gas flow rate = 14 LPM and wire feed rate = 120 mm/min ii) optimum condition for maximum YS is (A3B2C3) i.e. current = 65 amp, gas flow rate = 13 LPM and wire feed rate = 120 mm/min and iii) optimum condition for minimum % of elongation is (A1B1C3) i.e. current = 55 ampere, gas flow rate = 12 LPM and wire feed rate = 120 mm/min . ANOVA for UTS shows that current is the most significant factor, followed by gas flow rate. ANOVA for YS indicates that gas flow rate influences most significantly, followed by current and ANOVA for % of elongation indicates that wire feed rate influences most significantly. Conformation experiment was also conducted and verified the effectiveness of the Taguchi optimization method.

Acknowledgement

The work reported in this paper is supported by P E S College of Engineering, Mandya, through the Technical Education Quality Improvement Program [TEQIP-III] of the MHRD, Government of India.

REFERENCES

1. S.V Sapakal, M.T. Telsang,(2012),Parametric optimization of MIG welding using Taguchi design method. International Journal Of advanced Engineering Research and Studies, pp. 28-30.
2. A.K. Panday, M.I. Khan, K.M. Moeed, (2013), Optimization of resistance welding parameters using Taguchi method. International Journal of Engineering Science and Technology, pp. 243-240.
3. Nirmalendhu Choudhury, Asish Bandyopadhyay, Ramesh Rudrapati, (2014), Design optimization of process parameters for TIG welding based on Taguchi method. International Journal of Current Engineering and Technology, pp. 12-16.
4. S.R. Patil, C.A. Waghmare, (2013), Optimization of MIG welding parameters for improving strength of welded joints. International Journal of Advanced Engineering and Studies, pp.14-16.
5. Ajit Hooda, Ashwani Dhingra and Satpal Sharma, (2012) , Optimization of Welding process parameters to predict maximum yield strength in AISI 1040. International Journal of mechanical Engineering and Robotics Research India, pp. 204-212.