Study of Effect of Submerged Arc Welding Process Parameters on Depth of Penetration of Weld and Weld Bead Width

V R Jathade[1], P M Khodke[2]
[1, 2] Department of Mechanical Engineering
[1] P. G. Scholar, GCE, Karad, 415124
[2] Professor, GCE, Karad, 415124

Abstract- *Submerged arc welding (SAW) process is important equipment in many industrial operations. The research on controlling metal transfer modes in SAW process is essential to high quality welding procedures. Quality has now become an main issue in today's manufacturing world. Experiments are conducted using submerged arc process parameters viz. welding current, arc voltage and welding speed (Trolley speed) on mild steel of 12 mm thickness, to study the effect of these parameters on penetration depth and weld bead width. The experiments are designed using Taguchi method (with Taguchi L8 orthogonal array) considering three factors and two levels.*

Keywords- Submerged arc welding, Process parameters, Design of experiments, S/N ratios, ANOVA.

I. INTRODUCTION

Submerged arc welding (SAW) process is an important process in many industrial operations. The SAW process parameters are the most important factors affecting the quality, productivity and manufacturing cost of welding joint. Weld bead size and shape are strong considerations for design and manufacturing engineers in the fabrication industry. In fact, weld geometry directly affects the complexity of weld schedules and thereby the manufacturing costs of steel structures and mechanical devices. Therefore, these parameters affecting the arc and welding bath should be estimated and their changing conditions during process must be known before in order to obtain optimum results; in fact a perfect arc can be achieved when all the parameters are in conformity. The various parameters like welding current, arc voltage, wire feed speed, travel speed, torch angle and the electrode stick out are affecting on the weld quality. Welding current is a major factor that influences the penetration. Arc voltage and welding speed are also factors that can influence the penetration [8]. Weld width increases with increase in voltage, current and wire feed rate, and decreases with increase in welding speed and nozzle-to-plate distance [1]. There is lot of work done by many researchers on submerged arc welding process. Shahnawaz alam et al. [1] Studied effect of arc voltage, current, welding speed, wire feed rate and nozzle-to-plate distance on weld bead width. Optimal parameter combination for bead geometry was studied by Sourav datta et al [2]. Ankita Singh et al. [3] was studied Taguchi's robust design coupled with fuzzy based desirability function approach for optimizing multiple bead geometry parameters of submerged arc weldment. Anirudha Ghosh et al. [4] studied multi regressions method and a neural network for developing mathematical model. Saurav Datta et al. [5] treated the percentage of fused flux in the mixture as a process parameter. Keshav Prasad [6] investigates the influence of the submerged arc welding (SAW) process parameters (welding current and welding speed) on the microstructure, hardness, and toughness of HSLA steel weld joints. S. Kumanan et al. [7] applied Taguchi technique and regression analysis to determine the optimal process parameters for submerged arc welding. Syarul Asraf Mohamat et al. [8] studied the effect of FCAW process on different parameters by using robotic welding with the variables in welding current, speed and arc voltage. The effects are on welding penetration, microstructural and hardness measurement. N.B. Mostafa et al. [9] studied prediction of weld penetration influenced by FCAW process parameters of welding current, arc voltage, nozzle to plate distance, electrode to work angle and welding speed. Abhay Sharma et al. [10] studied shop floor applicable mathematical model for deposition rate during twin-wire submerged arc welding. Saurav Datta et al. [11] solved the correlated multiple criteria optimization problem of submerged arc welding. Y. S. Tarng et al. [12] studied the use of fuzzy logic in the Taguchi method to optimize the submerged arc welding process with multiple performance characteristics. They employed an orthogonal array, the signal-to-noise ratio, multi response performance index, and analysis of variance to study the performance characteristics in the submerged arc welding process.

1] Taguchi Method

Taguchi's philosophy is an efficient tool for the design of high quality manufacturing system. Dr. Genichi Taguchi, a Japanese quality management consultant, has developed a method based on Orthogonal array experiments, which provides much reduced variance for the experiment with optimum setting of process control parameters. Thus the marriage of design of experiments (DOE) with parametric optimization of process to obtain desired results is achieved in the Taguchi method. Orthogonal array (OA) provides a set of well balanced (Minimum experimental runs) experiments and Taguchi's signal-to-noise ratios (S/N), which is logarithmic functions of desired output serve as objective functions for optimization. This technique helps in data analysis and prediction of optimum results. In order to evaluate optimal parameter settings, Taguchi method uses a statistical measure of performance called signal-to-noise ratio. The S/N ratio takes both the mean and the variability into account. The S/N ratio is the ratio of the mean (signal) to the standard deviation (noise). The standard S/N ratios generally used are as follows, Nominal is best (NB), lower the better (LB) and higher the better (HB). The optimal setting is the parameter combination, which has the highest S/N ratio.

II. EXPERIMENTAL WORK

1] Process parameters levels

The process parameters of SAW are welding current, voltage, travel speed, wire diameter, electrode stick out, flux, heat input, polarity and current type (AC or DC). Welding current directly influence the depth of penetration and extend of base metal fusion. The welding arc voltage has direct influence on the shape of bead and external appearance of bead. The travel speed has pronounced effect on weld size and penetration for given combination of current and welding voltage. Careful attention is necessary to select the welding process parameters to obtain a desirable weld quality. Though many direct and indirect parameters affect the quality of weld in SAW the major key process parameters affecting the bead geometry are arc voltage, welding current and welding speed. In the present study, three-levels of the three process parameters, i.e., current, voltage and travel speed was considered. The values of the welding process parameter at different levels are listed in table1

Level	Current (Amp)	Voltage (V)	Speed (cm/min)
1	450	28	40
2	500	32	60

Table 1 Process parameters and their levels

The experiments are designed using L8 orthogonal array. The experimental layout for the welding process parameters using the L8 orthogonal array and the experimental results for the weld bead geometry using the L8 orthogonal array are shown in Table 2.

Sr. No	Current (A)	Voltage (V)	Speed (cm/min)	Depth (mm)	Width (mm)
1	450	28	40	8.23	6.83
2	450	28	60	7.5	5.97
3	450	32	40	9.56	11.25
4	450	32	60	9.23	9.01
5	500	28	40	10.96	11.55
6	500	28	60	10.68	11.25
7	500	32	40	11.61	16.54
8	500	32	60	10.2	16.45

Table 2 L8 Orthogonal array and output responses

2] Procedure

The experiment was conducted on semiautomatic AUTO WELD MAJOR (LW) with CPRA 800 (S) Power source manufactured by Esab India. Mild steel plates (AISI 2062 grade) of dimensions 50 mm (length) x 100 mm (width) x 12 mm (height) were used as base metal. Automelt EH 14 copper coated electrode of 2.4 mm diameter was used as filler wire. Agglomerated flux, OK Flux 10.71 (L) Manufactured by ESAB INDIA Coding - AWS / SFA 5.17 was used. A square butt joint with a 1.6 mm root opening was selected to join the plates in flat position, keeping electrode perpendicular to plates. Specimens of 10 mm width were cut transverse to the welding direction from each welded plates. Weld bead profiles were traced by using an optical profile projector of 10X magnification. Measurements were made for depth of penetration and bead width. The observed values of the responses are given in Table.2.

III. ANALYSIS AND DISCUSSION

1] Signal-to-noise ratio (S/N ratio)

In order to evaluate optimal parameter settings, the Taguchi method uses a statistical measure of performance called signal-to-noise ratio. The S/N ratio developed by Dr. Taguchi is a performance measure to select control levels that best cope with noise. The S/N ratio takes both the mean and the variability into account. The S/N ratio is the ratio of the mean (signal) to the standard deviation (noise). The standard S/N ratios generally used are as follows: nominal-is-best (NB), lower-the-better (LB), and higher-the-better (HB). In this paper, the characteristic values are selected by the bead width and depth of penetration. Since a good result is obtained by the smaller bead width and deeper depth of penetration. Hence for bead width LB is preferred. For depth of penetration the HB criterion has been selected.

a) Analysis of S/N ratio for depth of penetration

Larger depth of penetration is the desirable property of the weld joint. So in case of depth of penetration, larger the better option has been chosen for calculation of S/N ratio. From table 3, optimal parameters setting for larger depth is, current = 500 amp, voltage = 32 V, Speed = 40 cm/min.

Level	Current	Voltage	Speed
1	18.68	19.29	20.00
2	20.71	20.10	19.39
Delta	2.03	0.80	0.62
Rank	1	2	3

Table 3 Response table for S/N ratios (Larger better)

b) Analysis of S/N Ratio for bead width

Higher bead width is an undesirable property of the weld bead joint because it does not provide any strength to the weld joint. So, for bead width, lower the better option is chosen for signal to noise ratio calculations. Table 4 shows the response table for S/N ratio.

Level	Current	Voltage	Speed
1	-18.08	-18.62	-20.83
2	-22.74	-22.20	-19.99
Delta	4.66	3.58	0.84
Rank	1	2	3

Table 4 Response table for S/N ratios (Smaller better)

From table 4, optimal parameters setting for smaller bead width is, current = 450 amp, voltage = 28 V,
Speed = 60 cm/min.

Source	DOF	Seq SS	Adj MS	F-Value	P-Value	Contribution (%)
Current	1	9.9681	9.9681	27.44	0.006	72.92
Voltage	1	1.3041	1.3041	3.59	0.131	9.54
Speed	1	0.9456	0.9453	2.60	0.182	6.92
Error	4	1.4529	0.3632			10.63
Total	7	13.6704				100

Table 5 Analysis of Variance for depth of penetration

c) ANOVA for Depth of Penetration

ANOVA table for depth of penetration is given in table 5 ANOVA table indicates the significance value of various input factors. If the p value given in the last column of ANOVA table is less than 0.05, this means the factor corresponding to that value of p is significant. In present study the p value for current is 0.006 coming lesser than 0.05. F value given in ANOVA table also indicates the significance of factors, higher the F value higher is the significance of that factor. Hence from table 5, current is the Significance factor

d) ANOVA for bead width

ANOVA table indicates that p value for current is minimum when bead width is taken as response. P value for current is 0.000, which is lesser than 0.05. F value for the current is also maximum, which indicates that it is a significant factor contributing to the response, which includes the ranks of the contributing factors.

Source	DOF	Seq SS	Adj MS	F-Value	P-Value	Contribution (%)
Current	1	64.582	64.5816	110.55	0.000	60.14
Voltage	1	38.940	38.9403	66.66	0.001	36.26
Speed	1	1.523	1.5225	2.61	0.182	1.42
Error	4	2.337	0.5842			2.18
Total	7					100

Table 6 Analysis of Variance for bead width

V. CONCLUSION

1] The percentage contribution of each factor is calculated by ANOVA.

a) In case of depth of penetration the current contributes 72.92%, voltage 9.54% and arc travel speed 6.92%.
b) In case of bead width the current contributes 60.14%, voltage 36.26% and arc travel speed 1.42%

2] Current is the main factor that influences the depth of penetration and bead width. Bead width and penetration depth almost linearly increases with voltage and current.

ACKNOWLEDGMENT

Author wishes thanks to RIT Islampur for their constant support and provided a facility to do experimentation on SAW. Also wishes thanks to GCE Karad technical staff for their valuable guidance in this research work.

REFERENCES

[1] Vishal Jathade, Prakash Khodke "Review on Optimization of Submerged Arc Welding Process", Journal of Advances in Science and Technology, 2017, pp. 172-176

[2] Shahnwaz Alam and Mohd.Ibrahim Khan, "Prediction of the Effect of Submerged Arc Welding Process Parameters on Weld Bead Width for MS 1018 Steel", International Journal of Engineering and Innovative Technology (IJEIT) Volume 1, Issue 5, may 2012, 2277-3754.

[3] Saurav Datta, Asish Bandyopadhyay and Pradip Kumar Pal, "Modeling and optimization of features of bead geometry including percentage dilution in submerged arc weldingusing mixture of fresh flux and fused slag", International Journal of Advanced Manufacturing Technology, 2008 DOI 10.1007/s00170-006-0917-4, 36:1080–1090.

[4] Ankita Singh, Saurav Datta, Siba Sankar Mahapatra,Tapan Singha and Gautam Majumdar, "Optimization of bead geometry of submerged arc weld using fuzzy based desirability function approach", Journal of Intelligence Manufacturing, Publish online, April 2011, DOI 10.1007/s10845-011-0535-3.

[5] Saurav Datta, Asish Bandyopadhyay and Pradip Kumar Pal, " Slag recycling in submerged arc welding and its influence on weld quality leading to parametric optimization", International Journal of Advanced Manufacturing Technology 2008, DOI 10.1007/s00170-007-1224-4, 39:229–238.

[6] Keshav Prasadand and D. K. Dwivedi, "Some investigations on microstructure and mechanical properties of submerged arc welded HSLA steel joints", International Journal of Advanced Manufacturing Technology 2008 DOI 10.1007/s00170-006-0855-1, 36:475–483.

[7] S. Kumanan, J. Edwin Raja Dhas and K. Gowthaman, "Determination of submerged arc welding process parameters using Taguchi method and regression analysis", Indian Journal of engineering and material sciences, vol. 14, June 2007, 177-183.

[8] Syarul Asraf Mohamata, Izatul Aini Ibrahima, Amalina Amira and Abdul Ghaliba, "The Effect of Flux Core Arc Welding (FCAW) processes on different Parameters",74 International Symposium on Robotics and Intelligent Sensors 2012 (IRIS 2012), 1497 – 1501.

[9] Abhay Sharma, Navneet Arora and Bhanu K. Mishra, "A practical approach towards mathematical modeling of deposition rate during twin-wire submerged arc welding", International Journal of Advanced Manufacturing Technology 2008 DOI 10.1007/s00170-006-0847-1, 36:463–474.

[10] Saurav Datta, Goutam Nandi, Asish Bandyopadhyay and Pradip Kumar Pal, "Application of PCA-based hybrid Taguchi method for correlated multicriteria optimization of submerged arc weld: a case study", International Journal of Advanced Manufacturing Technology 2009, DOI 10.1007/s00170-009-1976-0, 45:276–286.

[11] Y. S. Tarng, W. H. Yang and S. C. Juang, "The Use of Fuzzy Logic in the Taguchi Method for the Optimizations of the Submerged Arc Welding Process", International Journal of Advanced Manufacturing Technology 2000, 16:688–694.

[12] Ravinder Pal Singh, R.K. Garg and D.K. Shukla, "Parametric Effect on Mechanical Properties in Submerged arc welding process - A review", International Journal of Engineering Science and Technology (IJEST) Feb.2012, Vol. 4 No.02 0975-5462.

[13] Pranesh Bamankar, Dr. S.M. Sawant, "Study of the effect of process parameters on depth of penetration and bead width in SAW" International Journal of Advanced Engineering Research and Studies ,Vol. 4, 2013, pp. 08-10.