Research Paper

STUDY OF THE EFFECT OF PROCESS PARAMETERS ON DEPTH OF PENETRATION AND BEAD WIDTH IN SAW (SUBMERGED ARC WELDING) PROCESS

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ABSTRACT

Submerged arc welding (SAW) process is an important component 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 important 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. The experiments are designed using Taguchi method (with Taguchi L_9 orthogonal array) considering three factors and three levels.

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

1. INTRODUCTION

Submerged arc welding (SAW) process is an important component in many industrial operations. The research on controlling metal transfer modes in SAW process is essential to high quality welding procedures. The SAW parameters are the most important factors affecting the quality, productivity and cost of welding joint. Weld bead size and shape are important 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. Aniruddha Ghosh et al.[4] 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. Saurav Datta et al.[13] Applied Taguchi philosophy for obtaining optimal parametric combinations to achieve desired weld bead geometry and dimensions related to the heat affected zone (HAZ), such as HAZ width in submerged arc welding. Ravinder Pal Singh et al.[14] studied a comprehensive review of parameters of submerged arc welding and their effect on weld quality.

1.1 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.

2. EXPERIMENTATION

2.1 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 on 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

Table 1. Process parameters levels

Level	Current (amp)	Voltage (v)	Speed (mm/min.)
1	300	28	300
2	340	32	400
3	380	36	500

The experiments are designed using L_9 orthogonal array. The experimental layout for the welding process parameters using the L_9 orthogonal array and the experimental results for the weld bead geometry using the L_9 orthogonal array are shown in Table 2.

2.2 Procedure

The experiment was conducted on semiautomatic AUTO WELD MAJOR (LW) with CPRA 800 (S) Power source manufactured by Esab India. Mild steel plates of dimensions 50 mm (length) x 50 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. These specimens were cleaned, ground, polished and etched with 10% nital (90% alcohol + 10% of nitric acid).Weld bead profiles were traced by using an optical microscope at 20X magnification. Measurements were made for depth of penetration and bead width. The observed values of the responses are given in Table.2.

Table 2. L_9 Orthogonal array design and output responses

Run	Current	Voltage	Speed	Depth (mm)	Width (mm)
1	300	28	300	2.23	7.49
2	300	32	400	3.73	9.46
3	300	36	500	1.72	8.37
4	340	28	400	3.59	11.23
5	340	32	500	3.22	9.43
6	340	36	300	4.36	15.35
7	380	28	500	5.20	10.77
8	380	32	300	9.42	16.89
9	380	36	400	7.93	16.09

3. ANALYSIS AND DISCUSSION

3.1 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.

3.1.1 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 = 380 amp, voltage = 32 V, Speed = 400 mm/min.

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

Levels	Current	Voltage	Speed
1	7.704	10.796	13.079
2	11.350	13.691	13.507
3	17.262	11.829	9.729
Delta	9.559	2.895	3.778
Rank	1	3	2

3.1.2 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.

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

Levels	Current	Voltage	Speed
1	-18.49	-19.71	-21.92
2	-21.41	-21.19	-21.55
3	-23.11	-22.10	-19.53
Delta	4.62	2.39	2.39
Rank	1	3	2

From table 4, optimal parameters setting for smaller bead width is, current = 300 amp, voltage = 28 V, speed = 500 mm/min.

Table 5. Analysis of Variance for depth of penetration

Source	DOF	Seq. SS	Adj. MS	F	P	% Contribution
I	2	40.3113	20.1556	92.93	0.011	77.03
V	2	4.7925	2.3962	11.05	0.083	9.16
S	2	6.7941	3.3970	15.66	0.060	12.99
Error	2	0.4338	0.2169			
Total	8	52.3316				

3.1.3 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 0.011 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.

3.1.4 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 *0.037,* 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.

Table 6. Analysis of Variance for bead width

Source	DOF	Seq. SS	Adj. MS	F	P	% Contribution
I	2	57.094	28.547	26.29	0.037	57.33
V	2	18.034	9.017	8.30	0.107	18.11
S	2	22.295	11.147	10.27	0.089	22.39
Error	2	2.171	1.086			
Total	8	99.595				

4. CONCLUSIONS

The results shows penetration will be at maximum value when welding current and arc voltage are at their maximum possible value and welding speed is at its minimum value. The physical reasons for the above results are discussed below-

- Increase in welding current increases the depth of penetration. It is known that molten metal droplets transferring from the electrode to the plate are strongly overheated. It can be reasonably assumed that this extra heat contributes to more melting of the work piece. As current increases the temperature of the droplets and hence the heat content of the droplets increases which results in more heat being transferred to the base plate. Increase in current reduces the size but increases the momentum of the droplets which on striking the weld pool causes a deeper penetration or indentation. The increase in penetration as current increased could also be attributed to the fact that enhanced arc force and heat input per unit length of the weld bead resulted in higher current density that caused melting a larger volume of the base metal and hence deeper penetration.
- Current is main factor influence the bead width. Bead width almost linearly increases with arc voltage and current and decreases, with welding speed.
- Optimal parameters setting for larger depth is, current = 380 amp, voltage = 32 V, Speed = 400 mm/min.
- Optimal parameters setting for smaller bead width is, current = 300 amp, voltage = 28 V, speed = 500 mm/min.

REFERENCES:

1. 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.
2. 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.
3. 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.
4. Aniruddha Ghosh, Somnath, Chattopadhyaya, R.K.Das and P.K.Sarkar, "Prediction of Submerged Arc Welding Yield Parameters through Graphical Technique", Procedia Engineering, October 2011, 2797–2802.
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", International Symposium on Robotics and Intelligent Sensors 2012 (IRIS 2012), 1497 – 1501.
9. N.B. Mostafa and M.N. Khajavi, " Optimization of welding parameters for weld penetration in FCAW", Journal of achievements in materials and manufacturing engineering, vol.16, issue 1-2, may- June 2006, 132-136.
10. 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.
11. 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.
12. 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.
13. Saurav Datta, Asish Bandyopadhyay and Pradip Kumar Pal, "Grey-based Taguchi method for optimization of bead geometry in submerged arc bead-on-plate welding", International Journal of Advanced Manufacturing Technology 2008 DOI 10.1007/s00170-007-1283-6, 39:1136–1143.
14. 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.
15. Abhay Sharma, Ajay Kumar Chaudhary , Navneet Arora and Bhanu K. Mishra, "Estimation of heat source model parameters for twin-wire submerged arc welding", International Journal of Advanced Manufacturing Technology 2009 DOI 10.1007/s00170-009-2046-3, 45:1096–1103.
16. N. Murugana and V. Gunaraj, "Prediction and control of weld bead geometry and shape relationships in submerged arc welding of pipes", Journal of Materials Processing Technology 2005, 168:478–487.