Optimization of Process Parameters of Submerged ARC Welding on AISI 1018

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Abstract— Submerged arc welding is more preferable because of its natural virtues like effortless control of high quality, smooth finish, deep penetration and variable. The quality of weld depends on the bead geometry of the weld which in turn depends on the process parameters. Quality has now turn into an important issue in today's manufacturing world. Welding input parameters play a very important role in determining the quality of a weld joint. The present study uses welding current, arc voltage, welding speed and nozzle to plate distance parameters on AISI 1018 steel. The experiments are designed using Taguchi method by using Taguchi L27 orthogonal array considering four factors and three levels. To automate a welding process, which is the present trend in fabrication industry, it is essential that mathematical models have to be developed to relate the process variables to the weld bead parameters. The objective of the present work is to investigate the effects of the various SAW process parameters on the machining quality and to obtain the optimal sets of process parameters so that the quality of machined parts can be optimized.

Key words: Submerged arc welding (SAW); Taguchi methodology; Weld bead geometry; Process parameters; Weld quality

I. INTRODUCTION

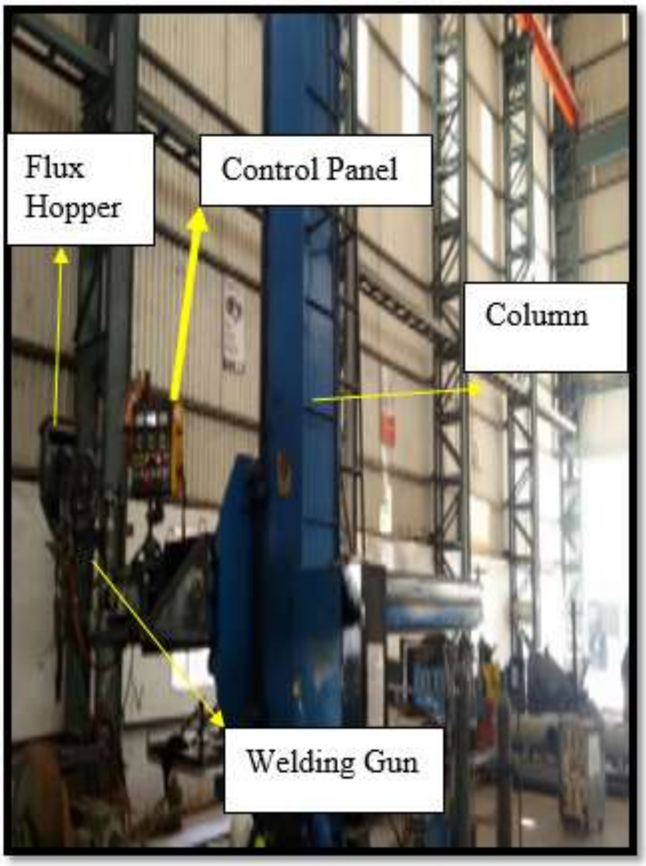

Fig. 1: Single wire submerged arc welding

Submerged arc welding is basically an arc welding process. Submerged arc welding is the efficient welding process for fabrication industries. In submerged arc welding process joint is produced by heating application with an electric arc and arc set up model between a bare metal electrode and the work piece. The basic components of submerged arc welding are welding gun, power source, flux hopper electrode wire, granular flux and control panel. As per the name given arc is merged under a layer of granular flux in submerged arc welding. The power source can be a transformer for AC welding or a rectifier motor generator for DC welding. The consumables are a bare, maybe coppered, continuous electrode and a granular welding flux fed to the joint by a hose from a flux hopper. The arc burns in a cavity filled gases like CO2, CO and etc. formed by breakdown on the total flux and metal fumes.

Use of these technology and social implications in the national prospective. The effective process parameters include Arc current, Arc voltage, Welding speed, nozzle to plate distance, Wire feed rate and flux basicity index. The present study gives research of the effect of these parameters on weld bead geometry (Penetration, Bead width, Bead height). Submerged arc welding is one of the oldest automatic welding process during 1930 s and it contributes to approximately 10% of the total welding needs the world. It is generally used for welding of low carbon steels, high strength low alloy steels, nickel base alloys and stainless steels. Apart from coalescence this process can be used for cladding applications to increase corrosion resistance and wear resistance on the surfaces. Weld produced are uniform, ductile, sound and good impact resistance.

II. LITERATURE SURVEY

A. Optimization of Vickers Hardness and Impact Strength of Silica based Fluxes for Submerged Arc Welding by Taguchi method (Aditya Kumar et al.)[1]

Aditya Kumar, Sachin Maheshwari, Satish kumar Sharma present a paper on Optimization of Vickers Hardness and Impact Strength of Silica based Fluxes for Submerged Arc Welding by Taguchi method. This paper reveals that flux composition plays a deciding role for good quality weld. In this paper study both factors were taken into consideration. SiO_2-Al_2O_3-CaO flux system was used. In a SiO_2 based flux and NiO, MnO and MgO were added in different proportions. They were used input parameters as follows: Current(A), Trolley speed (cm/min.), Electrode stick out (min.), Flux(sio$_2$ based) The responses were: Vicker hardness number)(VHN) Impact strength. In this study a constant DC voltage submerged arc welding machine was used for welding the mild steel plate of 300 x 150 x 20 mm using 3.15mm diameter wire of grade EL8 DIN8557: SI. Experiments were designed according to Taguchi L9 orthogonal array, while varying voltage at two levels in addition to alloying elements. Voltage was considered as a noise factor. Using ANOVA, effect of each flux alloying elements was revealed for Vickers hardness and impact strength of the weld. Optimal levels of NiO, MnO and MgO were selected using S/N analysis. The following conclusion drawn from the following study: MnO and MgO plays major role in deciding VHN of the weld. Similarly for impact strength MnO and MgO has played a deciding role for impact strength with NiO less effective.Impact strength has shown a clear decrement in the value with increase of voltage. [1]

B. "The use of grey-based Taguchi methods to determine submerged arc welding process parameters in hardfacing .(S. Tarng et al.)[2]

S. Tarng, S.C. Juang, C.H. Chang (2002) present a paper on "The use of grey-based Taguchi methods to determine submerged arc welding process parameters in hard facing." They have studied and investigated that the use of the grey-based Taguchi method to obtain the submerged arc welding (SAW) process parameters with consideration of multiple performance characteristics has been studied in this paper. A grey relational analysis of the S/N ratios can convert the optimization of the multiple performance characteristics into the optimization of a single performance characteristic known as the grey relational grade. A grey relational grade obtained from the grey relational analysis is used as the performance characteristic in the Taguchi design of experiment method. In this paper arc current, welding speed, arc voltage, preheat temperature and electrode stick out are use as input parameters and responses are deposition rate, dilution and hardness. Then, optimal process parameters are determined by using the parameter design proposed by the Taguchi method. Experimental results have shown that optimal submerged arc welding (SAW) process parameters in hard facing can be determined effectively so as to improving multiple weld qualities through this new approach. On experimentation and investigation it was concluded that arc current, welding speed, and electrode stick-out are the significant welding process parameters for affecting the multiple performance Characteristics. It is also shown that the performance characteristics of the submerged arc welding (SAW) process such as Deposition rate, dilution, and hardness are improved together by using the method proposed by this study.[2]

C. "Optimization of parameters of submerged arc weld using nonconventional Techniques" (J. Edwin Raja Dhas et al.)[3]

J. Edwin Raja Dhas, S. Kumanan present a paper on "Optimization of parameters of submerged arc weld using nonconventional Techniques" They have investigated that the effect of weld input parameters such as welding current, welding speed, electrode stick out and welding current on geometry of weld bead. A relationship between them is thought to be complicated because of the non-linear characteristics. In this paper trial-and-error methods to obtain optimal conditions incur considerable time and cost. In order to overcome these problems, non-traditional methods have been suggested. Bead-on-plate Welds were carried out on mild steel plates using semi-automatic submerged arc welding (SAW) machine. Data were collected as per taguchi's design of experiments and regression analysis was carried out to establish input–output relationships of the process. By this relationship, an attempt was made to minimize weld bead width which is a good indicator of bead geometry, using optimization procedures based on the genetic algorithm (GA) and particle swarm optimization (PSO) algorithm to obtain optimal weld parameters. On Experimentation and investigation it was concluded that the developed PSO algorithm is a powerful tool in experimental welding optimization, even when experimenter does not have to model the process. These tools find a good scope in the welding shop floor environment to set the initial process parameter for the weld. [3]

D. "Sensitivity analysis of submerged arc welding process parameters" (Serdar Karaoglu et al.)[4]

Serdar Karaoglua et al. [4] has investigated that the sensitivity analysis of Input parameters and fine tuning requirements of the Input parameters for optimum weld bead geometry. Changeable process Input parameters such as welding current, welding voltage and welding speed are used as Input parameters in this study. The output parameters are width, height and penetration of the weld bead. In this Experimental part of the study is based on three level factorial design of three process parameters. In order to investigate the effects of input (process) parameters on output parameters, which determine the weld bead geometry, a mathematical model is constructed by using multiple curvilinear regression analysis. After carrying out a sensitivity analysis using developed empirical equations, relative effects of input parameters on output parameters are obtained. Effects of all three design parameters on the bead width and bead height show that even small changes in these Input parameters plays an important role in the quality of welding operation. The result also shows that the penetration is almost non-sensitive to the variations in voltage and speed. It was conclude that Bead width is more sensitive to voltage and speed variations than that of bead height and Penetration. All three Input process parameters have effects in determining the bead height. In order to decrease the bead height, higher values of voltage and speed can be considered. Current is the most important parameter in determining the penetration. Voltage and speed cannot be effectively used to control penetration.[4]

E. "Prediction and control of weld bead geometry and shape relationships in Submerged arc welding of pipes"(N. Murugan et al.)[5]

N. Murugana et.al. [5] has investigated that it is very essential that mathematical models have to be enveloped to relate the process variables to the weld bead parameters or output parameters. Because of its high productivity, smooth finish, high reliability and deep penetration submerged arc welding (SAW) has become a natural choice in industries for fabrication, especially for welding of pipes. In this study they selected welding speed, Arc voltage, Wire feed rate, and nozzle to plate distance as input parameters and responses are bead width, reinforcement and penetration. Mathematical models have been developed for submerged arc welding (SAW) of pipes using five level factorial techniques to predict three critical dimensions of the weld bead geometry and shape relationships. The models developed have been checked for their adequacy and significance by using the F-test and the ttest, respectively.

Main and interaction effects of the input process parameters on bead geometry and shape factors are presented in graphical form and using which not only the prediction of important weld bead dimensions and shape relationships but also the controlling of the weld bead quality by selecting appropriate process parameter values are possible. On experimentation and investigation it was concluded that out of the four process variables considered, wire feed rate had a significant positive effect but welding speed had an appreciable negative effect on most of the important bead parameters, Reinforcement form factor, penetration size factor, penetration and bead width all increased with the increase in wire feed rate for all values of welding speed but this increasing rate of the bead parameters with the increase in wire feed rate(F), gradually decreased with the increase in welding speed(S).[5]

F. "Application of response surface methodology for predicting weld Bead quality in submerged arc welding of pipes"(V. Gunaraj et al.)[6]

V. Gunaraj et al. [6] has studied and investigated that the use of response surface methodology(RSM) by designing a four-factor five-level central composite rotatable design matrix with full replication for planning, conduction, execution and development of mathematical models. These are important not only for predicting the weld bead quality but also for selecting optimum process parameters for achieving the desired quality and process optimization. This paper use input parameter as the open-circuit voltage (V), the wire feed rate (F), the welding speed (S) and the nozzleto- plate distance (N), as input parameter and the penetration (P), the reinforcement (R), the width (W) and the percentage dilution (D) are as output parameters. This study used IS 2062 as base material. Response surface methodology (RSM) is a important technique to determine and represent the cause and effect relationship between true mean responses and input control variables influencing the responses as a two or three dimensional hyper surface. Submerged arc welding (SAW) is used mostly in industry to join metals in the manufacture of pipes of different length and diameters. The main problem faced in the manufacture of pipes by the submerged arc welding (SAW) process is the selection of the optimum combination of input parameters for achievement of the required qualities of weld. This problem can be solved by the development of mathematical models through effective and strategic planning and the execution of experiments by response surface methodology (RSM). On Experimentation and investigation it was concluded that all of the responses viz. penetration (P), reinforcement (R), bead width (W), and dilution (D) decrease with increase in welding speed. As the nozzle-toplate distance increases, penetration (P), width (W), and dilution (D) decrease, but Reinforcement(R) increases. An increase in the wire feed rate results in an increase in penetration (P), reinforcement (R), and dilution (D), but width (W) remains unaltered.[6]

III. EXPERIMENTAL SETUP

An AISI 1018 material plates were used as Work piece. Experiments were carried out on single wire submerged arc welding machine at CHEM process systems Pvt. Ltd., Ahmedabad. In this study Welding current, Arc voltage, Welding Speed, Nozzle to Plate distance have selected as input factors. The paper shows works on bead geometry like penetration, Bead geometry, Bead height. First of all cut 27 standard test coupons for submerged arc welding . This 27 test coupons having size 110*100*12 mm were made by using metal cutting band show machine.27 test reading were design by Taguchi L27 orthogonal array.

Fig. 2: SAW welding operation

Symbol	Process input parameters	Unit	Level 1	Level 2	Level 3
C	Welding current	Amperes	290	350	410
V	Arc voltage	Volts	28	32	36
S	Welding speed	mm/min	300	400	500
D	Nozzle to plate distance	Mm	30	33	36

Table 1: Process input parameters and their levels

IV. EXPERIMENTAL DESIGN AND RESULT

No.	welding current	Arc voltage	Welding speed	Nozzle to plate distance	Penetration	Bead width	Bead height
1	290	28	300	30	6.41	15.83	2.12
2	290	28	300	30	6.52	15.92	2.09
3	290	28	300	30	6.49	15.79	1.79
4	290	32	400	33	5.87	16.23	1.12
5	290	32	400	33	6.10	16.37	1.23
6	290	32	400	33	5.89	16.34	1.12
7	290	36	500	36	4.58	16.67	1.10
8	290	36	500	36	4.23	16.32	1.22
9	290	36	500	36	4.38	16.41	1.2
10	350	28	400	36	6.32	15.9	3.01

						8	
11	350	28	400	36	6.41	15.39	2.59
12	350	28	400	36	6.39	15.63	3.01
13	350	32	500	30	6.32	16.57	1.23
14	350	32	500	30	6.20	16.43	1.62
15	350	32	500	30	6.54	16.38	1.21
16	350	36	300	33	6.72	17.2	1.96
17	350	36	300	33	6.91	16.92	1.25
18	350	36	300	33	6.85	17.17	2.09
19	410	28	500	33	6.71	15.78	2.59
20	410	28	500	33	6.54	15.39	2.68
21	410	28	500	33	6.62	15.63	2.96
22	410	32	300	36	6.72	16.64	2.27
23	410	32	300	36	7.20	16.78	2.51
24	410	32	300	36	6.97	16.93	2.59
25	410	36	400	30	6.92	16.79	1.22
26	410	36	400	30	7	17.34	1.6
27	410	36	400	30	6.79	16.89	1.00

Table 2: Reading table design by Taguchi L27 orthogonal array

V. RESULTS & DISCUSSION

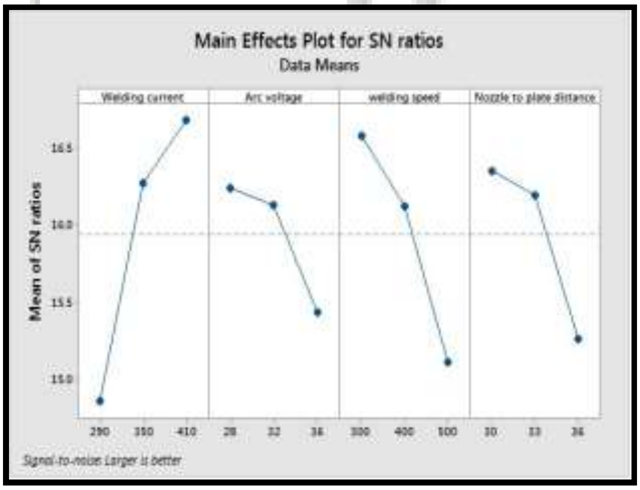

Fig. 3: Main Effects Plot for SN ratio of Penetration

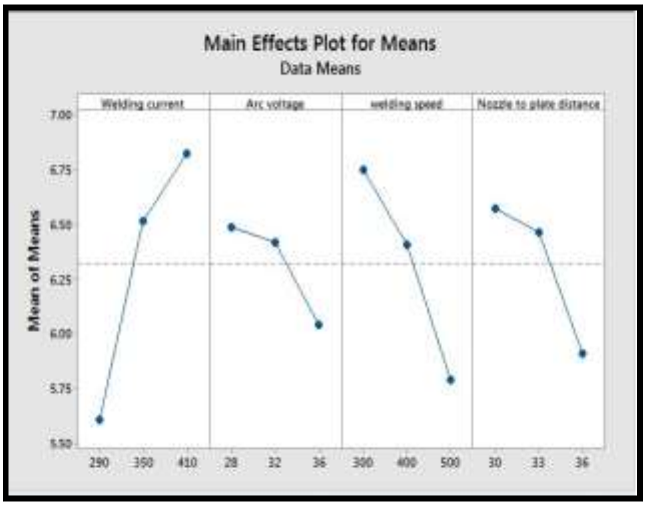

Fig. 4: Main Effects Plot of Penetration

Above analysis shows the percentage contribution of individual parameters on Penetration.. The percentage contribution of Welding current 47.67 %, Arc voltage is 6.9 % , Welding speed is 28.17 % and Nozzle to plate distance is 15.07 %. And error is 2.2 % .this error is due to human ineffectiveness.

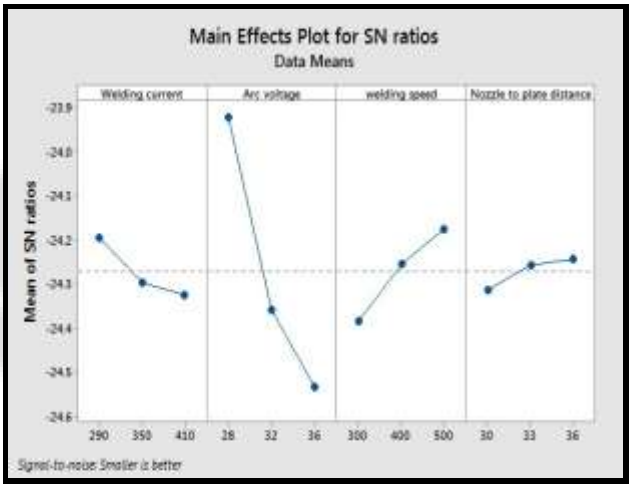

Fig. 5: Main effect plot for SN ratio of Bead Width

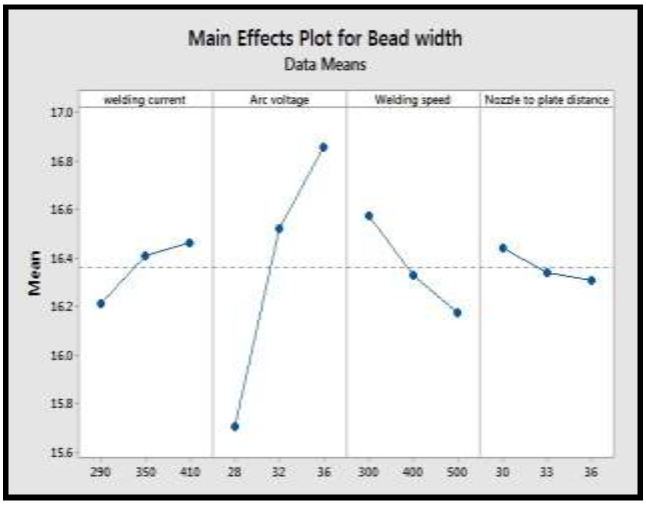

Fig. 6: Main Effects Plot of Bead width

Above analysis shows the percentage contribution of individual parameters on Bead width.The percentage contribution of Welding current 3.98 %, Arc voltage is 78.19 % , Welding speed is 9.07 % and Nozzle to plate distance is 1.06 %. And error is 7.67 % .This error is due to human ineffectiveness.

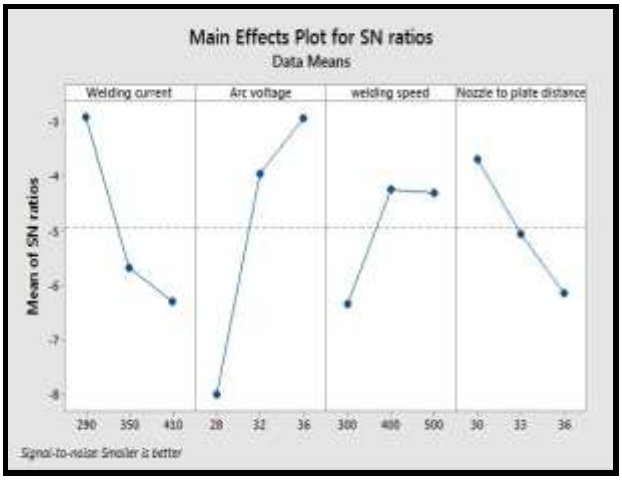

Fig. 7: Main effect plot for SN ratio of Bead Height

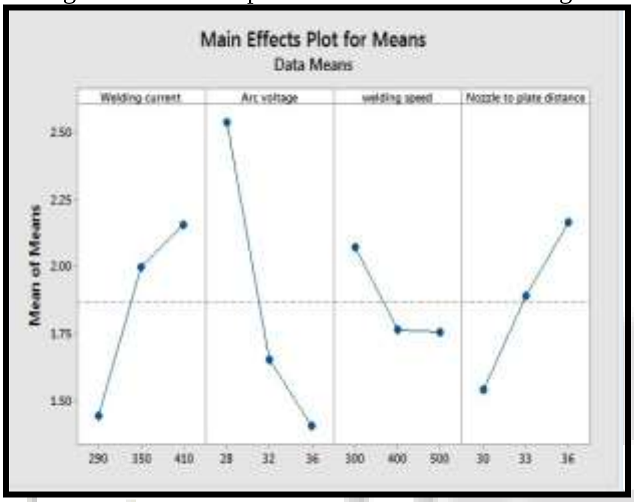

Fig. 8: Main Effects Plot of Bead Height

Above analysis shows the percentage contribution of individual parameters on Bead height. The percentage contribution of Welding current 20.57 %, Arc voltage is 51.91 % , Welding speed is 4.78 % and Nozzle to plate distance is 14.34 %. And error is 8.38 % .This error is due to human ineffectiveness

VI. CONCLUSION

This paper has presented the application of Taguchi technique to determine the optimal process parameters for SAW process. Experimentation was done according to the Taguchi's design of experiments. Using the signal-to-noise ratio and the ANOVA technique the influence of each welding parameters are studied.

Following conclusion can be drawn from above study:

- Welding Current is the most important parameter in determining the penetration. Increased 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.
- Arc Voltage had a significant positive effect on Bead width. Bead width rapidly increases with voltage and slowly increases with current. Bead width decrease with Welding speed and nozzle to plate distance.
- Bead Height increases with increase in Nozzle to plate distance. Bead height reduces with increase in voltage and welding speed Out of the four process variable considered, Welding speed had a negative effect on all the important bead parameters.

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