International Journal of Latest Trends in Engineering and Technology
Special Issue AFTMME-2017, pp. 323-329
e-ISSN:2278-621X

EFFECT OF INPUT PARAMETERS ON BEAD GEOMETRY IN SUBMERGED ARC WELDING OF SS-316L

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Abstract-Submerged arc welding (SAW) is the most widely used welding method in industries. The SAW process is preferred because it offers high production rate, high melting efficiency, ease of automation and low operator skill requirement. The present work is aimed to optimize the weld bead geometry of SS 316L input parameters by varying the input parameters (welding current, voltage and speed) in SAW. Central composite design (CCD) technique of response surface methodology (RSM) is used for the design of experiments, with the help of Design Expert DX 6.0.8 software. The welding beads were developed on small specimens of SS 316L with the help of SAW, using input parameters, as per the design table. The ANOVA for each output parameter are developed.
Keywords: Submerged arc welding,central composite design, weld bead geometry.

1. INTRODUCTION

The most prevalent in industry welding processes that employ an electric arc are shielded metal arc welding, gas metal arc welding, flux cored arc welding, submerged arc welding (SAW) and gas tungsten arc welding[1]. Submerged arc welding is a well-established process capable of manufacturing quality welds in an extensive range of thicknesses in ferrous, stainless steels, and even some non-ferrous metals. The process consists of an arc that is formed when an electric current passes continuously between a welding wire and the workpieces. To prevent the weld pool from atmospheric contamination, the tip of the welding wire, and the weld joint are fully covered by a layer of a granular flux[2]. The SAW process is preferred because it has high deposition rate, high production rate, high melting efficiency ability to weld impenetrable sections, ease of automation and low operator skill requirement for longer weld runs with high mechanical properties with minimum distortion[3]. SAW is commonly used in applications such as structural members in ships, manufacture of pressure vessels, bridge beams, massive water pipes, thin sheet shells[1]. Welding parameters like arc voltage, welding current and travel speed, are the main variables to analyse and study of process parameters of bead geometry response such as, bead reinforcement, bead width and bead penetration. The study of weld bead geometry is important, because it determines the stress carrying capacity of a weld [4].The literature is available on weld bead geometry in SAW, that indicates the different kind of effect of SAW input parameters on different materials (like SA387, mild steel, API X65, SS310 etc.)[5-10].

In the present work, SS316L was used as work material which was welded with SAW process. Diameter 3.14mm SS316L wire is used for welding. Process parameters namely - current, voltage, speed of welding are considered as the input variable parameters. Central composite design (CCD) technique of response surface methodology (RSM) was used for design of experiments and the results obtained after experimentation are analysed using Design Expert software 6.0.8. Effect of input variable parameters on the weld bead geometry is studied in the work.

2. EXPERIMENTATION

The numbers of runs were randomized through CCD technique using the software Design Expert DX6.0.8. The minimum and maximum values of the considered input SAW parameters (current, voltage and speed) were decided on the basis of pilot runs and also from the extensive literature review of SAW and are encapsulated in**Table 1**.

Table 1: Maximum and minimum values of welding input parameters.

S. No.	Input SAW Parameter	Minimum Value	Maximum Value
1	Current (I)	100	400
2	Voltage (V)	25	35
3	Speed (S)	20	25

The design table for performing SAW experiments, as obtained through Design Expert software DX 6.0.8 is shown **Error! Not a valid bookmark self-reference.**.

The experiments were conducted to obtain bead-on-plate weldment on SS-316L plates (150×40×9 mm) by SAW. The experiments were performed in SAW machine of TORNADO make having model number SAW M800. The electrode wire

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of diameter 3.2 mm of SS-316L and standard flux were used, which is an agglomerated flux, automelt GR-4 with a chemical composition of (C-0.08%, Mn-1.00%, Sn-0.25%).

Table 2: Design table obtained through Design Expert DX 6.0.8.

Run	Current(I) Amp	Voltage(V) Volts	Speed (S) m/h
1	400	31.5	22.5
2	250	31.5	22.5
3	250	31.5	22.5
4	250	31.5	25
5	250	31.5	22.5
6	100	35	25
7	400	35	25
8	400	28	20
9	100	28	25
10	250	31.5	22
11	250	31.5	20
12	250	31.5	22
13	250	35	22
14	100	28	20
15	400	28	25
16	250	28	22.5
17	100	31.5	22.5
18	250	31.5	22.5
19	100	35	20
20	400	35	20

After welding the transverse sections of the weld plate were cut by slitting wheel on the surface grinding machine.For measurement of weld bead geometry, the cross-sectional surfaces of the specimens were prepared as per the standard ASTM-E3-11 [11]. The specimens subsequently were ground by a series of finer grades of emery papers and then polished on the polishing machine. To contrast the grain boundaries and clearly distinguish the weld zone from the base metal zone, etching of the polished cross-sectional surface of each specimen was carried out.The bead geometry was measured by planimeter.

3. RESULTS AND DISCUSSION

The results are obtained in terms of parameters of weld bead geometry of the weldment. The average values of weld geometry parameters show that the change in input parameters during welding, directly affects each parameter of weld bead geometry.

3.1 ANOVA For Different Weld Bead Parameters

The ANOVA, as developed through design expert 6.0.8 software for the analysis of the effect of various input parameters on the output response (bead geometry), are reported in the succeeding sub-sections for each parameter.

3.2 ANOVA for weld bead width.

The Model F-value of 20.53 indicates that model is significant and there is only a 0.01% possibility that a "Model F-Value" this large could rise due to noise.

The model terms AC, C, B and A are significant when the value of "Probability > F" is less than 0.0500. The value greater than 0.10 makes the model terms insignificant.

3.3 ANOVA for weld bead penetration

Due to the presence of noise, only for 0.04% chances, a large value of "Model F-value" could occur. The model is considered to be significant as the Model F-value is 11.28. The values of "Prob > F" lesser than 0.05 indicate that the model terms BC, A^2 and A are significant.

3.4 ANOVA for weld bead reinforcement

There is about 0.16% possibility that a large value of "Model F-value" could occur, due to the presence of noise. The model is considered to be significant as the Model F-value is 7.97. The values of "Prob > F" lesser than 0.05 indicate that the model terms AC, AB, B^2, C, B and A are significant.

4. DISCUSSION

4.1 Effect of Interaction between Current and Voltage on Weld Bead Width

The 2D contour and 3D plots of current versus voltage, show the effect of variation of input parameters current (A) and voltage (B) simultaneously on the output response (bead width) by keeping the welding speed fixed at 22.50 m/h. It can be discerned from graphs that bead width directly varies with the variation in current and voltage, these input parameters have significant impact over bead width.

It can be observed that at lower current and voltage values such as 100 Amp. and 28 V, a lower bead width is obtained, but as the value of current rises from 100 to 400 Amp. (keeping the same voltage), the obtained width increases gradually. But the similar increase in weld bead width is not that much steep with the increase in current at higher voltage value of 35 V. Similarly observation was made by **Singh and Pandey [12]**that high welding current results in increase in heat input that results in larger molten pool thus increases the bead width. It is clear from the**Fig.1**that bead width increased with an increase in arc voltage from 28 to 35 V at constant travel speed 22.5 m/h, respectively. This may be due to the increase in the arc length due to with increase in arc voltage, which spreads the arc on larger surface area leading to increase in bead width.

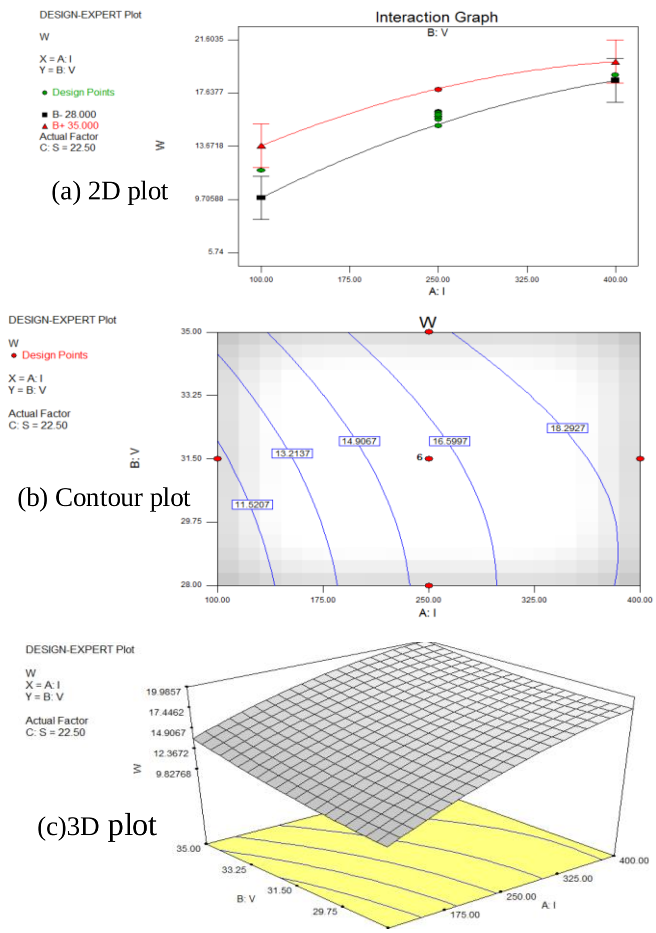

Fig.1: Effect of current (A) and voltage (B) on width.

4.2 Effect of Interaction between Current and Voltage on Bead Penetration

The 2D, contour and 3D graphs between current, voltage and penetration as shown in Fig.2gives the overall surface profile of the bead penetration during SAW.

From plot, it is clear that when current and voltage at 100 Amp and 28 V respectively, the penetration increases but it decreases shortly. At almost all the voltage values, with the increase in current the penetration also increases (see Fig.2). At lower voltage values (28 V), the increase in penetration with the increase in current (upto 200 Amp) is not so much visible but beyond current value of 200 Amp. upto 400 Amp. The penetration increases rapidly. The value of penetration increased more with increasing the current as compared to voltage. The observed variation in penetration is negligible. Similarly observed byUma and Abbas [4]that bead penetration increases gradually as the value of voltage increases, and at the highest value of voltage, it decreases. As current rises the temperature which results in more heat transferred to the base metal. At high values of current a deeper penetration can be obtained. Also from Fig.2 it can be concluded that, the increasing penetration when current increases from 250A to 400A. That increment in current value with other variables remaining constant, results in increased depth ofpenetration.

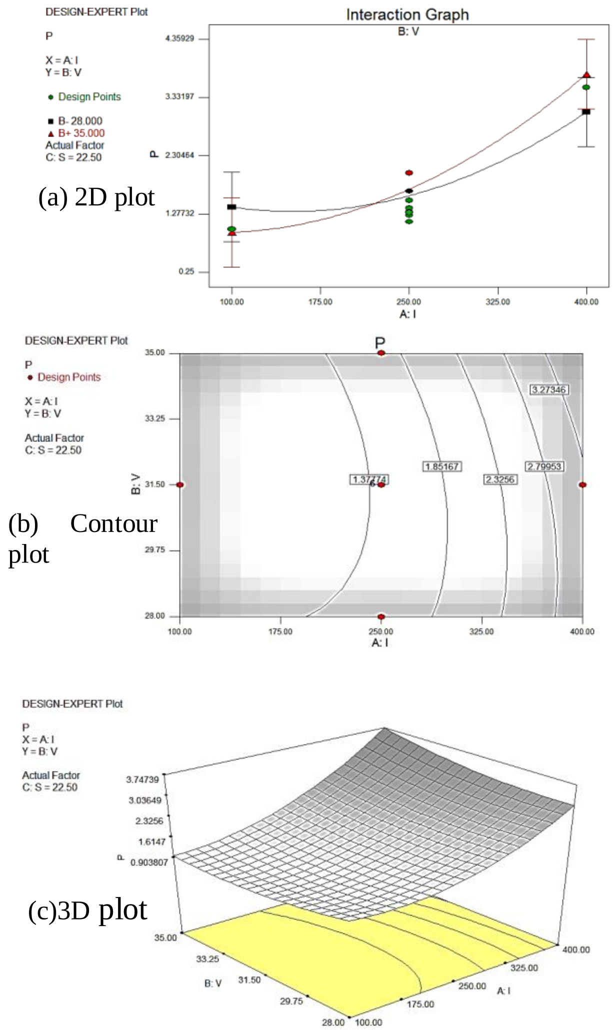

Fig.2: Effect of current (A) and voltage (B) on penetration.

4.3 Effect of Interaction between Current and Voltage on Bead Reinforcement

The 2D, contour and 3D current versus voltage plots show the effect of variation of input parameters current (A) and voltage (B) simultaneously on the output response (bead reinforcement) by keeping the welding speed fixed at 22.50 m/h (see**Fig.3**). A little variation in reinforcement can be observed with the variation in current at lower values of voltage (28 V). At 100 Amp current, the reinforcement increases as the voltage is decreased from 35 V to 28 V, however the increase is more at very low values of voltage. At current value of 400Amp, the value of reinforcement first decreases and the increases, when the voltage is increased from 20 V to 35 V, however the variation is not that much visible.**[Singh and Pandey [12]]**reported thatdecreasing trend of reinforcement with increase in arc voltage can be attributed to the fact that at higher voltage arc becomes longer and spread on a larger surface area resulting increase in bead width and decrease in reinforcement. The similar observation is made in the present work, the increase in bead width with the increase in voltage, which can be clearly seen in **Fig.1**.

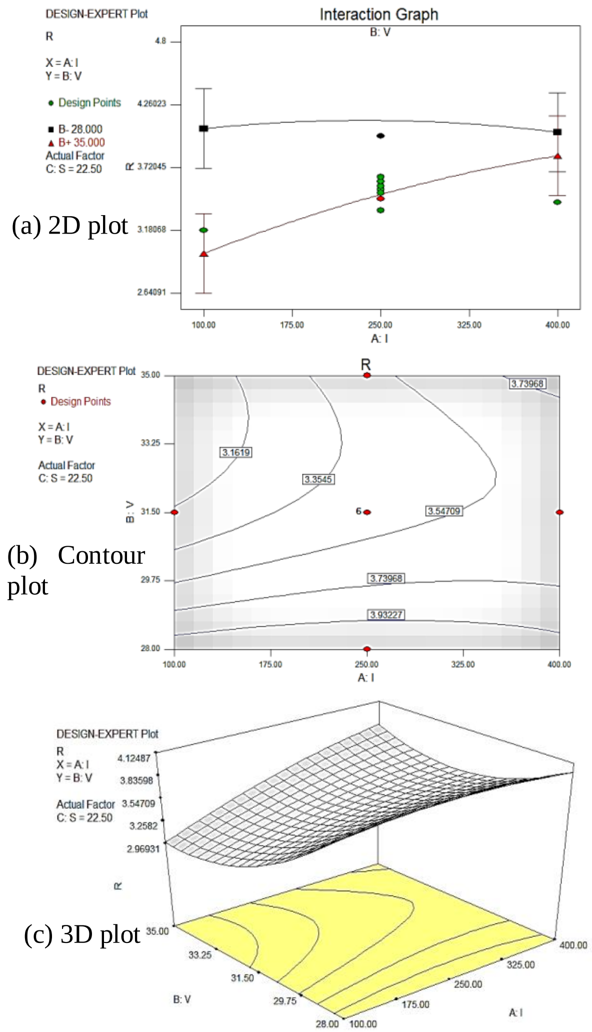

Fig.3: Effect of current (A) and voltage (B) on reinforcement.

5. OPTIMIZATION OF INPUT PARAMETERS

Central composite design technique of RSM is used for optimization of process parameters for obtaining desired weld bead geometry. The upper and lower limits of process parameters and the desired levels of weld bead geometry adopted in optimization are given inTable 3.

Table 3: Parameters with Upper and Lower Working Limits.

Parameter	Goal	Lower limit	Upper limit
Current (I)	is in range	100ampere	400ampere
Voltage (V)	is in range	28volts	35volts
Speed (S)	is in range	20m/h	25m/h
Width (W)	Mini-mize	5.74mm	19.02mm
Penetration (P)	Maxi-mize	0.25mm	4.12mm
Reinforce-ment	Mini-mize	2.98mm	4.8mm

6. DESIRABILITY

Desirability is an objective function that ranges from zero to one at goal. The numerical optimization discovers a point that maximizes the desirability function. Six optimal solutions developed by the designexpert DX 6.0.8 software through CCD technique of RSM are shown in theTable 4.

Table 4: Optimal Solutions obtained through Design Expert Software.

Exp. No	I	V	S	W	P	R	Desir-ability
1	261.32	35.00	25.00	15.2513	1.80888	3.37291	0.488996715
2	270.49	35.00	25.00	15.5215	1.91449	3.37952	0.48863587
3	292.37	35.00	25.00	16.1321	2.18607	3.39279	0.48490087
4	123.61	35.00	24.00	12.209	0.952347	3.09785	0.437022482
5	100.00	28.00	22.46	9.88143	1.41457	4.04843	0.402914779
6	100.00	28.00	22.41	9.93653	1.43028	4.04353	0.402878306

Out of these, the one can be selected on the basis of maximum value of desirability function, as obtained through design expert DX 6.0.8 software. Therefore the optimal input parameters for obtaining optimal weld bead geometry are:

Current (I) = 261.32 Amp

Voltage (V) = 35 Volts

Speed = 25 m/h

The optimal suggested for obtaining optimal bead geometry is shown inFig.4. From the 3-D graph (Fig.4), it can be clearly seen that the desirability increases with the increase in voltage at the minimum value of current, but at maximum current value of 400 Amp, The value of desirability function decreases with the increase in voltage. The maximum value of desirability function can be seen on the 3-D graph (Fig.4) at max. voltage is 35 V and intermediate value of current.

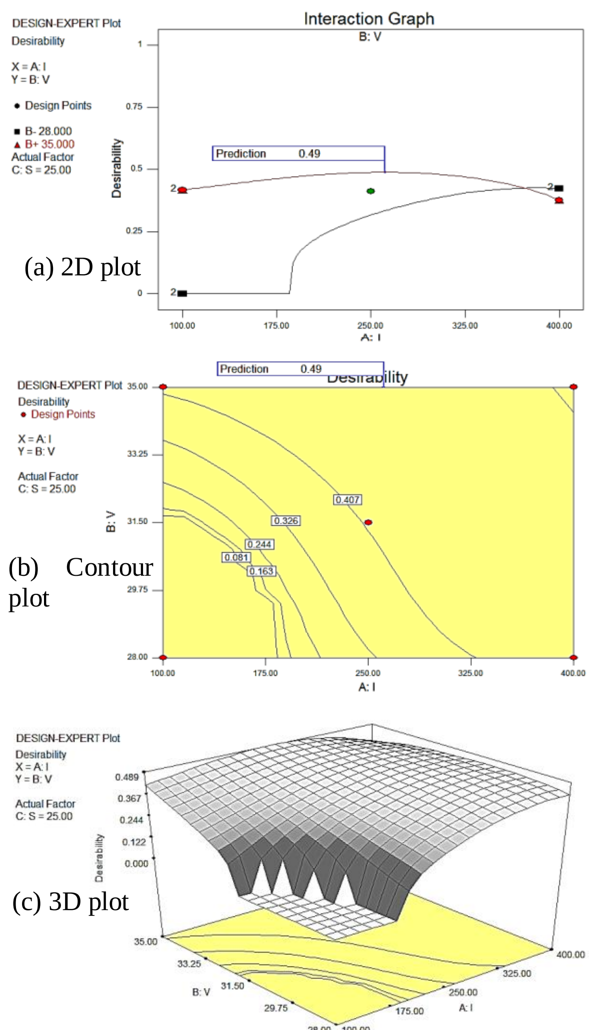

Fig.4: Effect of current (A) and voltage (B) on desirability.

7. CONCLUSION

- In the present study, Significant model obtained for weld bead geometryconsidering current, voltage and transverse speed as the input parameters.The SAW input parameters play a significant role in governing the weld bead geometry of SS 316L.
- Weld width increases more with the increase in current and voltage but the effect of increase in current is more

predominant.

- Penetration also increases with the increase in current whereas no considerable variation in penetration could be observed with the variation in voltage.
- Reinforcement increases simultaneously with the increment in current and decreases suddenly at the highest value similarly reinforcement decreases much during voltage compared to current.

8. REFERENCES

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