Study the Influence of Heat Input on the Shape Factors and HAZ width during Submerged Arc welding

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ABSTRACT

Welding process variables play a significant role in determining the quality of a weld joint. The joint quality can be defined in terms of properties such as weld- bead geometry, mechanical properties and distortion. In this paper, an experimental study was conducted to investigate the influence of welding parameters in submerged arc welding (SAW) process particularly welding current (I) and traverse speed (T_s) on weld shape factors and heat affected zone (HAZ). These responses have different meaning in joint properties. Penetration shape factor (PSF) defines the deposition and distortion of weldment whereas reinforcement form factor (RFF) means the excess of the deposited material. Width of HAZ indirectly defines the mechanical properties of the weld. It was found that an increase in current PSF has a significant effect and RFF has a little effect. And traverse speed shows a mixed trend over PSF and little change in RFF. Welding current and traverse speed have a positive effect on HAZ.

Keywords: Submerged Arc Welding, Penetration Shape Factor, Reinforcement Form Factor, Width of HAZ.

1.0 INTRODUCTION

Submerged arc welding (SAW) is used extensively in industry to fabricate pressure vessels, pipelines, marine vessels, and wind turbine towers because it offers several advantages such as ease of automation, low operator skill requirements, high deposition rate, deep penetration, high quality welds, excellent surface finish, ability to weld thick plates and minimum welding fumes [1]. The quality of a weld joint is directly influenced by the welding heat input i.e. related to current, voltage and traverse speed during welding and the joint quality can be defined in terms of properties like weld-bead geometry, mechanical properties and distortion [2, 3].

The effect of the welding heat input on weld bead geometry is important because it can be applied in automatic and semiautomatic control of arc welding processes where optimal selection of heat input is required for high productivity and cost effectiveness. As such, several studies have been conducted to understand the relationships between arc welding process parameters and weld bead geometry. Gunaraj and Murugan [4] investigated that response surface methodology (RSM) is a powerful technique to develop mathematical models to correlate parameters namely the open-circuit voltage, wire feed-rate, welding speed and nozzle- to-plate distance to some responses namely, the penetration, reinforcement, width and percentage dilution of the weld bead in SAW of pipes. In another paper the authors developed a mathematical model for predicting important weld bead dimensions and shape relationships within the optimal range of process control variables for SAW of pipes [5]. The bead cross –sectional area affects the total shrinkage and, consequently, the residual stress and distortion [6]. Chandel et al. [7] investigated the effect of welding process parameters on welding efficiencies for SAW and gas metal arc welding (GMAW) using bead-on-plate welds of ASTM A36 steel and reported that electrode melting efficiency increased with an increase in current and electrode extension, but with a decrease in arc voltage and electrode diameter.

Weld bead geometry is the first indication of the weld bead quality. Controlling bead geometry is important for minimizing cracking susceptibility of weldments. Lee et al. [8] found for bead-on-plate welds of ASTM A36 steel produced using a single wire SAW process, that welding current had a strong influence on the size of the heat-affected zone, with the size decreasing with increasing welding current. Different researcher used several optimization methods for finding the optimal welding condition for quality welding. Tarng, Y. S. et al. applied grey-based Taguchi methods for optimization of Submerged Arc Welding process parameters in hardfacing with multiple performance characteristics [9]. Serdar Karaog lu et al. [10] focuses on the sensitivity analysis of parameters and fine tuning requirements of the parameters for optimum weld bead geometry.

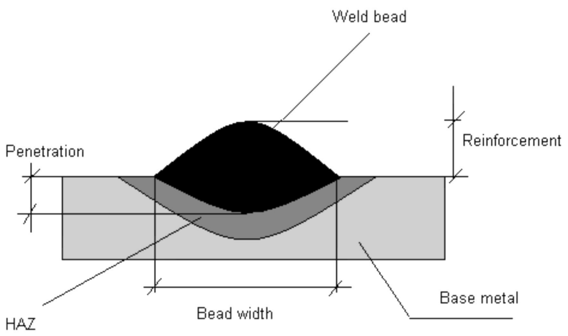

Fig. 1 : Schematic of weld bead geometry

Weld bead geometry includes the weld bead width (W), the weld bead height (H), or the weld bead reinforcement (R), and the depth of penetration (P) as shown in **Fig. 1**. These parameters, PSF (W/P), RFF (W/R) and width of HAZ are sensitive to the welding input parameters, namely, welding current, voltage and traverse speed etc. Therefore, in this work an attempt is made to study effect of welding current and traverse speed on bead geometry parameters, PSF, RFF and width of HAZ.

2.0 WELDING PROCEDURE

The bead-on-plate welding technique was used to perform the experiments on a submerged arc welding machine (Make: ADOR WELDING LIMITED, INDIA; Model- MAESTRO 1200 (F)). A 10mm thick mild steel (AISI 1015) plate was used for this study. The chemical composition (wt %) of base plate and electrode wire was shown in **Table 1**. Electrode wire of 3.15 mm diameter (AWS A/S 5.17: EL 8) coated with copper has been used. A fused type silicon product with grain size 0.2 to 1.6 mm with basicity index 1.6 flux (AUTOMELT A55) was used for welding having chemical composition of, SiO_2+TiO_2=30%, CaO+ MgO =10%, Al_2O_3 + MnO= 45%, CaF_2= 15%.

After welding test plates were visually inspected for detection of any defect or irregularity of weldment and then cut by hydraulic power saw across the welding. Transverse section of the welded joint was polished by using standard metallographic procedure and finally polished specimens were etched with mixture of 2% natal solution. Parameters associated with bead geometry and HAZ in terms of bead width, reinforcement (bead height), depth of penetration and depth of HAZ have been measured by optical trinocular metallurgical microscope (Make: Leica, Germany). In this present investigation an attempt is made to see the effect of current and traverse speed because these two parameters have significant effect on bead geometry [11]. Data related to bead geometry and HAZ width at different welding input parameters have been furnished in **Table 2** and **3**.

3.0 RESULTS AND DISCUSSION

Welding process parameters control the heat input of the welding process which affects the melting rate of the base metal. Therefore, any change in the process variables will change the amount and the shape of the melted pool which consequently alter the bead geometry. **Fig. 2** shows some macrographs of weld bead at different welding heat inputs varying from (11.9- 17.96) kJ/cm^2. Macrographs of the weld bead reveal that with the increase of heat inputs shape of the weld pool increasing.

Table 1 : Chemical composition (wt%) of base plate and electrode wire.

Element	Carbon	Manganese	Silicon	Sulphur	Phosphorus	$Carbon_{equ}$
Base plate	0.163	0.419	0.150	0.013	0.019	0.24
Electrode wire	0.04	0.4	0.05			

Table 2 : Experimental values of bead geometry parameters and HAZ width at different welding current.

Expt. No.	Current (I) Amp	Penetration (P) mm	Reinforce-ment (R) mm	Bead width (W)	PSF (W/P)	RFF (W/R)	HAZ width (D) mm
1	450	4	1.86	11.46	2.865	6.16129	1.733
2	550	4.8	2.45	12	2.5	4.897959	1.77
3	625	6	3.04	12.6	2.1	4.144737	1.8
4	650	6.32	4.45	13.29	2.102848	2.986517	2.1

Table 3 : Experimental values of bead geometry parameters and HAZ width at different traverse speed.

Expt. No.	Traverse Speed (Ts) cm/mt	Penetration (P) mm	Reinforce-ment (R) mm	Bead width (W)	PSF (W/P)	RFF (W/R)	HAZ width (D) mm
1	75	4	1.86	12	3	6.4516	1.733
2	90	3.2	1.8	11.2	3.5	6.2222	1.366
3	115	3.1	1.7	10.25	3.306452	6.0294	1.3
4	120	2.8	1.5	9.1	3.25	6.0666	1.04

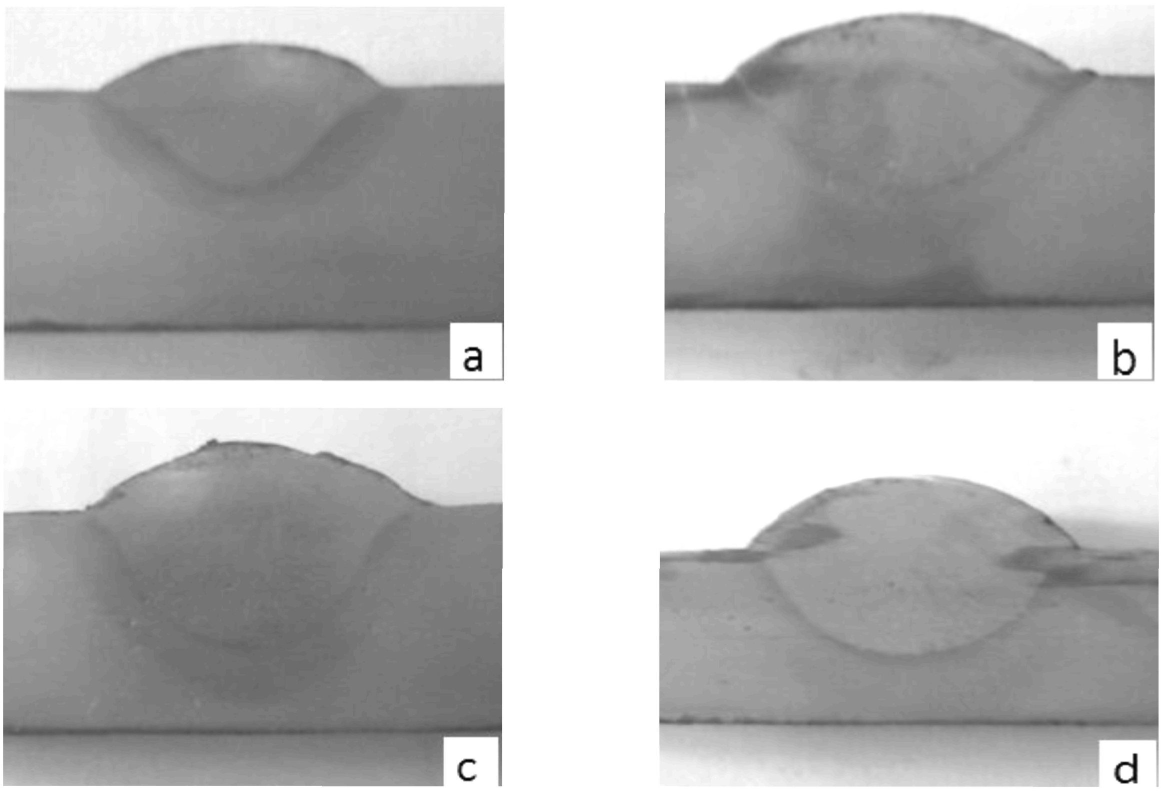

Fig.2 : Macrographs at different heat inputs,
a= 11.97 kJ/cm², b= 14.63 kJ/cm², c= 16.625 kJ/cm², d= 17.96 kJ/cm².

3.1 Effect of welding process parameters on PSF

The measured PSF values with bead geometry parameters are plotted against the welding current and traverse speed as shown in **Fig. 3** and **Fig. 4** respectively. Penetration and bead width increases with the welding current which is consistent with previous studies [5, 11]. As current increases the temperature and the heat content of the droplets increases which results more heat being transferred to the base material. Therefore, P, R and W increases with other variables remains constant [4, 12]. PSF decreases significantly with current up to 625 amp after that it becomes steady. The rate of increase of P is higher than the rate of increase in W, so that W/P decreases.

From **Fig. 3** it is clear that R and W decrease with the traverse speed increases. As because of the decrease in T_s the power per unit length of weld bead is also decreased. Also at higher traverse speed, the electrode travels faster and covers more distance per unit time. However PSF increases with traverse speed up to a limit of 90cm/mt, further increasing of traverse speed PSF shows a negative trend. This is due to the fact that initially the rate of decrease of P is higher than the rate of decrease of W but after 90 cm/mt the rate of decrease of W increased with respect to P.

3.2 Effect of welding process parameters on RFF

Fig. 4 and **Fig. 5** show the plot between the RFF with R and W against I and T_s respectively. It is apparent from the **Fig. 5** that R and W increases with respect to welding current and the reasons have been already discussed earlier. RFF decreases with the increase of current because the rate of increase of R is higher than the rate of increase of W.

From the **Fig.6** it is clear that the effect of traverse speed is significant for W only. On the other hand no such effect has been observed in case of R and W/R.

3.3 Effect of welding process parameters on HAZ width

Fig. 7 and **Fig. 8** reveal the plot of width of HAZ vs welding current and traverse speed respectively. Current has positive

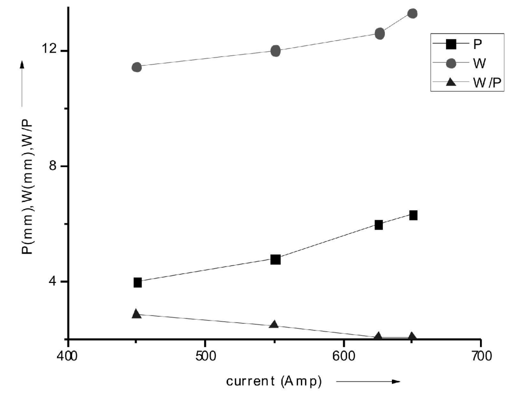

Fig.3 : Effect of current on PSF.

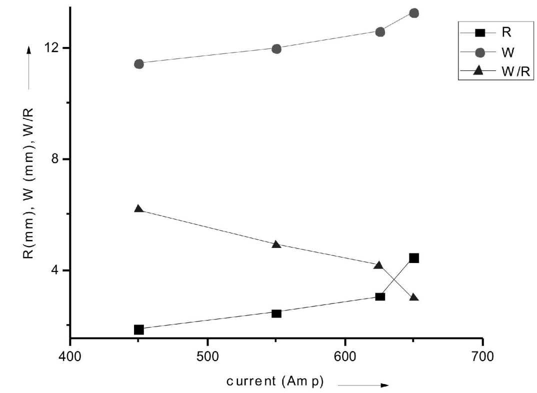

Fig.5 : Effect of current on RFF.

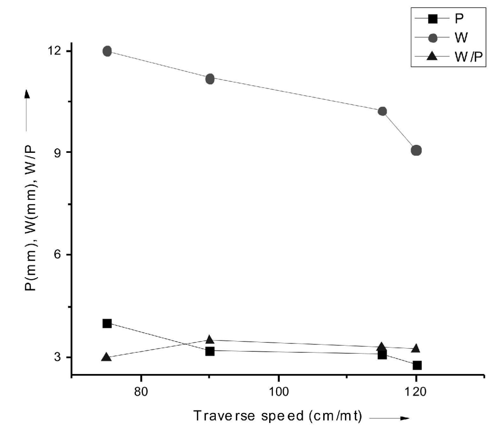

Fig.4 : Effect of Traverse speed on PSF.

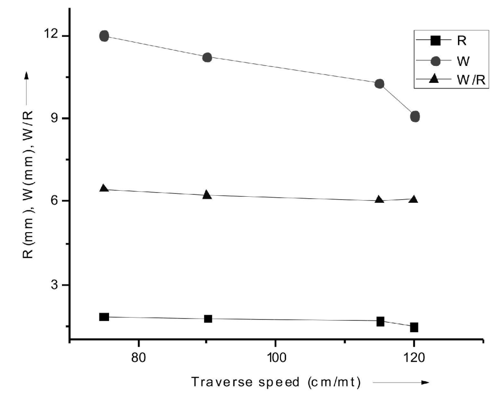

Fig.6 : Effect of Traverse speed on RFF.

effect on width of HAZ whereas traverse speed has negative effect. It is observed from the figures that the width of HAZ increases with the welding heat input or arc energy. This is because an increase in heat input results in a decrease in cooling rate. Also increased heat input generally results in a larger weld pool size and fused area [5, 6].

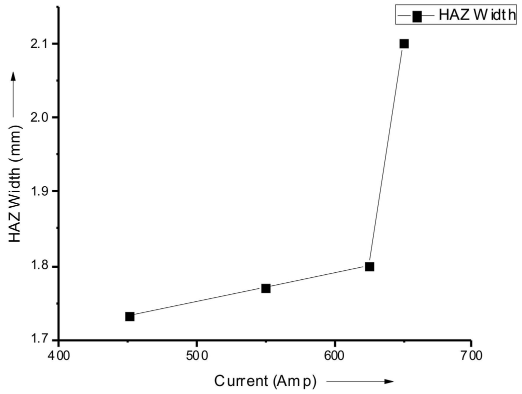

Fig.7 : Effect of current on width of HAZ.

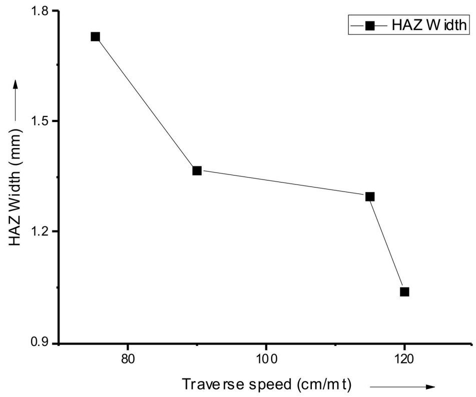

Fig.8 : Effect of Traverse speed on width of HAZ.

4.0 CONCLUSION

The effect of welding current and traverse speed on weld bead geometry, PSF, RFF and width of HAZ was investigated. The major findings obtained are concluded below:

- Macrographs reveal that weld pool size increases with increasing of weld heat input.
- Penetration, reinforcement, bead width and width of HAZ increased with increasing of welding current.
- Bead geometry parameters and width of HAZ decreased with increasing of traverse speed.
- SPF decreases with welding current and showing mixed trend with traverse speed. Whereas RFF decreased with current but not showing so much effect with traverse speed.

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