Analysis of the influence of the heat input and bead volume on HAZ Hardness for Submerged Arc Welding Process of Mild steel plates

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ABSTRACT

In Submerged Arc Welding process involves critical set of variables which are needed to control. An attempt has been made in this paper to find out- the influence of the heat input and bead volume on HAZ Hardness for Submerged Arc Welding Process of Mild steel plates. Mild steel plates are welded by changing input variables (current, voltage, trolley speed, i.e. heat input) and Rockwell hardness no. has been observed on welded portion and at the zone adjacent to the welded portion. A detailed analysis of the microstructure changes is carried out to understand the HAZ softening phenomenon.

Key wards: SAW, Microstructure, HAZ, Hardness

INTRODUCTION

Submerged arc welding (SAW) is a high quality, high deposition rate welding process commonly used to join plates of higher thickness in load bearing components. This joining process important critically for fabricating structures, bridges, ships, boilers, etc. This method of arc welding provides a purer and cleaner high volume weldment that has relatively a higher material deposition rate compared to the traditional welding methods. In a country like India, in the context of infrastructural development, the SAW process has much more useful applications in welding of critical components and equipment. Use of this technology has huge economic and social implications in the national perspective. A common issue in the application of SAW process raises a concern about the uncertainties involved with the heat affected zone (HAZ) in and around the weldment. The most concerned query is about HAZ softening that imparts some uncertainties in the welded quality. It increases the probability of fatigue failures at the weakest zones caused by the heating and cooling cycle of the weld zone. It is observed that a refine microstructure of the HAZ, imparts largely the intended properties of the welded joint [1]. In order to bring out an appropriate combination of SAW parameters and a methodology to control such parameters an in depth investigations and characterizations of HAZ softening zone are necessary to enrich this submerged arc welding technology.

In Submerged Arc welding process, major process control parameters are current, arc voltage and travel speed. They all affect the bead shape, depth of penetration and chemical composition of the deposited weld metal. Another very critical issue in the understanding of the joint performance obtained from SAW process rests on the analysis of heat affected zone. It is difficult for the operator to observe the weld pool during the process. So, better control comes from SAW process parameter settings than dependence on the operator's expertise. It is shown by the researchers [1] that the HAZ has various regions those influence the ability of the joint to provide crack resistance and uniform strength in both the direction of the weld. An estimation of bead width and depth of penetration obtained from infrared thermal imaging technique (IRTI technique) is also found to influence the quality of SAW process [2]. Very little information is available in the literature on the aspects of HAZ softening during SAW process. A three dimensional analysis to predict the zones of microstructure of SAW process is indicated in [3]. A model to predict HAZ in case of SAW is addressed by [1] attempts to predict HAZ in case of SAW. A combined effect of chemical composition of flux and welding parameters on the mechanical properties of SAW process is shown to

Table 1 : variation of output parameters w.r.t input parameters

Sl.No.	Job No.	Voltage (V)	Current (A)	Travel Speed (cm/min)	Penetration (mm)	Reinforcement Height(mm)	Weld Width(mm)
1	A1	25	350	17	6.7	2.38	17.96
2	A2	35	450	17	3.72	2.34	21.9
3	A3	25	350	17	6.69	3.16	21
4	A4	35	450	17	8.26	2.76	30.92
5	B1	25	350	30	5.28	1	13.94
6	B2	35	350	30	4.58	1.78	20.12
7	B3	25	450	30	6.60	2.25	15.90
8	B4	35	450	30	7.78	1.94	22.66

be of utmost significance [4-5]. It is apparent from these references [1-5] that SAW process has drawn much of attention, in recent time, for characterization of its various aspects. It is also very clear that a systematic study to bring out a correlation based performance characterization through identification of control parameters in conjunction with quality assessment is missing. An identification of the contribution of each of its process control parameters on the quality or performance of a SAW joint, possess a challenge to the researchers in this area and demands a very systematic study of the problem.

Experimental Procedure

The experiment was conducted with the MEMCO semiautomatic welding equipment with constant voltage rectifier. Flux used is ADOR Auto melt Gr II AWS/SFA 5.17(Granular flux), Electrode selected is ADOR 3.15 diameter copper coated wire, Test Piece is 400 x 75 x 6 mm square butt joint, Weld position is flat with electrode positive and positioned perpendicular to the plate.

The experiments were conducted as per the design matrix at random to avoid errors due to noise factors. The job 400x25x6 mm (3 pieces) was firmly fixed to a base plate by means of tack welding and then the welding was carried. The welding parameters were noted during actual welding to determine the fluctuations if any. The slag was removed and the job was allowed to cool down. The job was cut at three sections and the average values of the penetration, reinforcement height and width were taken using vernier caliper of least count 0.02mm.

Weld Bead Profile

The output variable was decided based on the guidelines in the reference material. The bead parameters were considered for measuring the response output.

Three output parameters considered are (shown in fig-1):

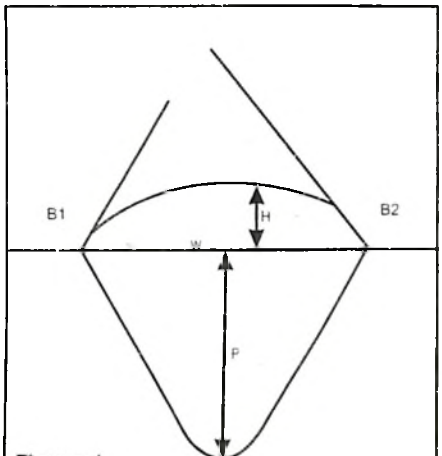


Figure-1

P - Penetration (mm)
H - Reinforcement height (mm)
W - Width (mm)

Experimental Results

Table 2 : Hardness variation along the bead axis for heat input 22 kJ/mm

Sl.No.	Distance from the top Surface along the bead axis mm	Rockwell hardness values R_b
1	0	20.0
2	2	20.0
3	4	18.0
4	6	16.5

Table 3 Hardness variation along 2mm left offset line of the bead axis for heat input 22 kJ/mm

Sl.No.	Distance from the top Surface along line 2mm left offset to the bead axis mm	Rockwell hardness values R_b
1	0	22.5
2	2	21.0
3	4	19.5
4	6	17.5

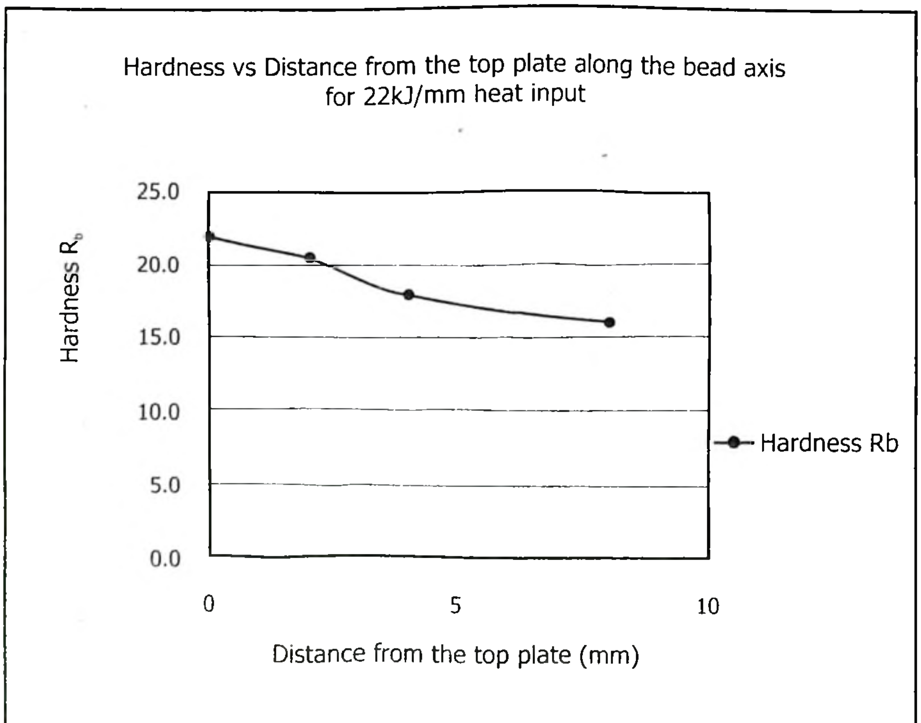
Table 4 Hardness variation along 2mm left offset line of the bead axis for heat input 22 kJ/mm

Sl.No.	Distance from the top Surface along line 2mm left offset to the bead axis mm	Rockwell hardness values R_b
1	0	22.0
2	2	20.5
3	4	18.0
4	6	16.0

Table 5: Hardness variation along the line 8mm lower to the top surface for heat input 22 kJ/mm

Sl.No.	Distance from the bead axis along the line 8mm lower to the top surface	Rockwell hardnes values R_b	Remerk
1	4 mm left to bead axis	21.0	
2	2 mm left to bead axis	17.5	
3	at the bead axis	16.5	Heat Affected zone
4	2 mm right to bead axis	16.0	Heat Affected zone
5	4 mm right to bead axis	16.0	Heat Affected zone
6	6 mm right to bead axis	19.0	
7	8 mm right to bead axis	19.0	

Fig. 2 Hardness variation along the bead axis for heat input 22 kJ/mm



From the fig.2,[table-2] it is evident that the hardness values decreases due to the HAZ softening effect of the submerged arc welding process. In the top portion of the plate where actually bead is formed, the hardness in the Rockwell Scale B is around a value of 20.0. In the parent material zones where there is no Heat affect, the rock well hardness value is observed above 20.0. But in the lower part of the bead axis the hardness values decreases to 16.0. This ensures the formation of the larger grain size due the heating and cooling effect of SAW process. The similar phenomenon can also be observed along the line 2 mm right offset to the bead axis as depicted in the fig. 3,[table-3]. The grid size is 2mm X 2mm as because narrower grid will lead to erroneous hardness values due to the prior indentation of the specimen for hardness testing in the vicinity of the specified zone.

Fig.3 [table-3] confirms the HAZ softening along the line parallel to the bead axis in 2mm left offset position. The initial value of the Hardness is 22.5 (R_b) where it comes down to even 17.5 at the bottom most part of the 10 mm thickness plates. The entire HAZ softened zone can be observed if plot the hardness values along the line parallel to the top plate at 8mm down position from the top surface.

In the fig.4[table-4] the similar phenomenon can be observed as indicated in the fig.3. The area of lower hardness confirms the HAZ softening effect due to the heating and cooling cycle in SAW process. It is known that for thicker plate welding process has narrow heat affected zone. But even in the case of SAW with thicker plate joining operation a significant HAZ softened zone can be identified for 22 kJ/mm heat input cases. It has been observed from the table 5 that heat affected softening is visible around the bead axis in 8mm below the top surface of the plate for the heat input of 22.0 kJ/mm.

It is quite evident from the figure that the grain structure at the heat affected zone of the welding sample experienced a noticeable grain growth due to the heating and cooling effect of the welding process. The alignment of the grain formation confirms the directional component of the grain growth for the sub merged arc welding process of 22 kJ/mm heat input.

CONCLUSION

Existence of prominent grain growth provides the confirmatory evidence of the HAZ softening phenomenon. In the welded portion, grain refinement occurs in most of the region due to the heating and cooling cycle of SAW method. Predominant direction of the grain growth is clearly observed from the photograph of the microstructure. This grain formation is distinctly revealed in the magnification (50,100) for the heat input of 22 kj/mm. Hall Petch equation states the strength of the metal is to vary reciprocally with size of subgrain.The similar phenomenon is also revealed in case of hardness. In context of this equation one can say that hardness of the grain growth portion will also manifest lower values related to higher grain sizes. In the grain growth portion of the welded region longer grains have been found depicting the chances of dislocation, slip, low yield strength and low hardness values measured in Rockwell scale B.

Fig.3 Hardness variation along 2mm left offset line of the bead axis for heat input 22 kJ/mm

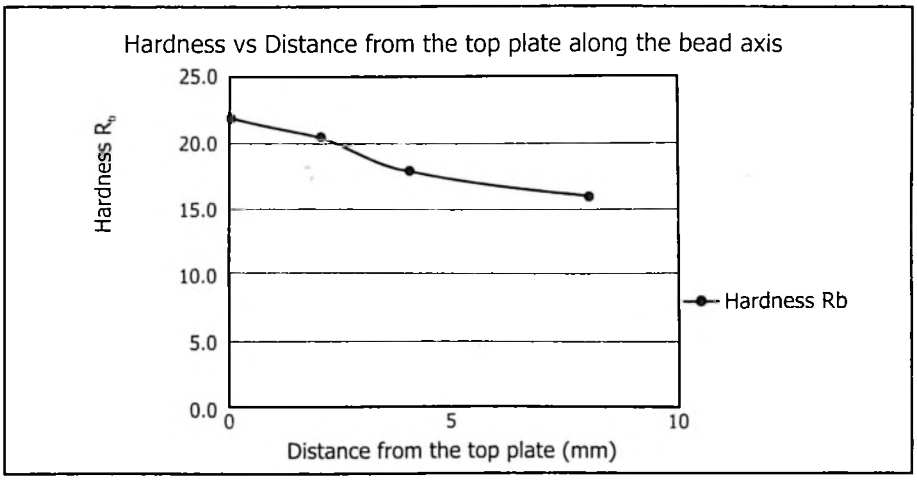
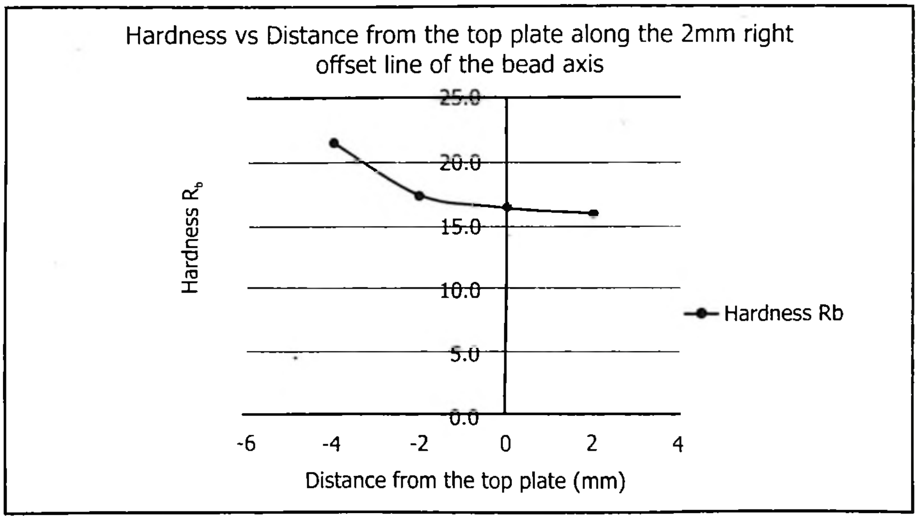


Fig. 4 : Hardness variation along 2mm right offset line of the bead axis for heat input 22 kJ/mm



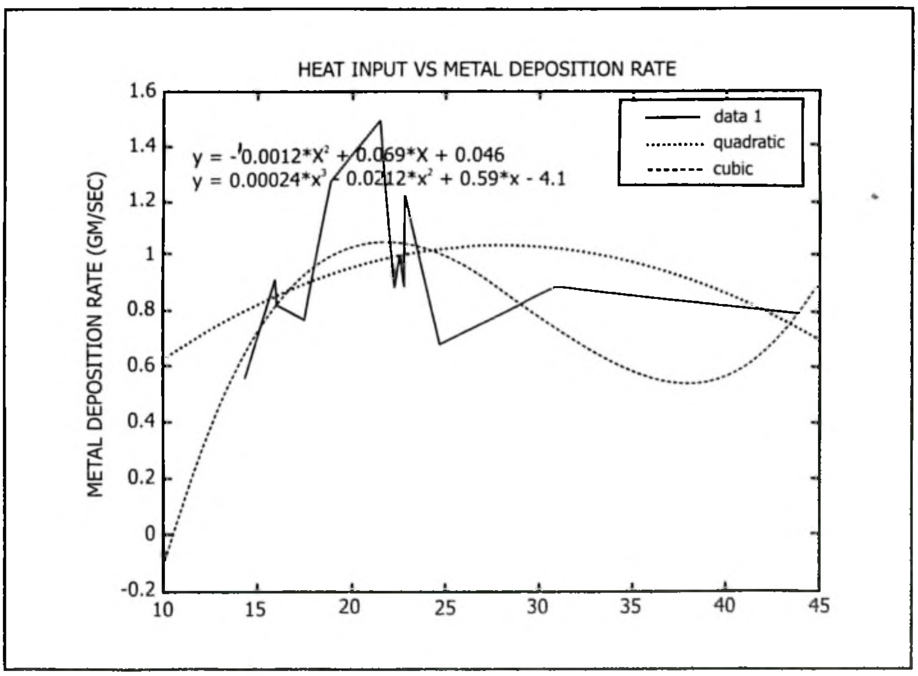


Fig. 5
Graph showing the relationship between Heat input vs Metal deposition rate for SAW process for joining 10 mm thickness AISI 1018 steel plates

Fig-6 : Microstructure at the welded zone of 100 Magnification for 22 kJ/mm Heat Input

Few points are prominent in this microstructure, these are caused due to grain growth and these are the softening portion of welded zone.

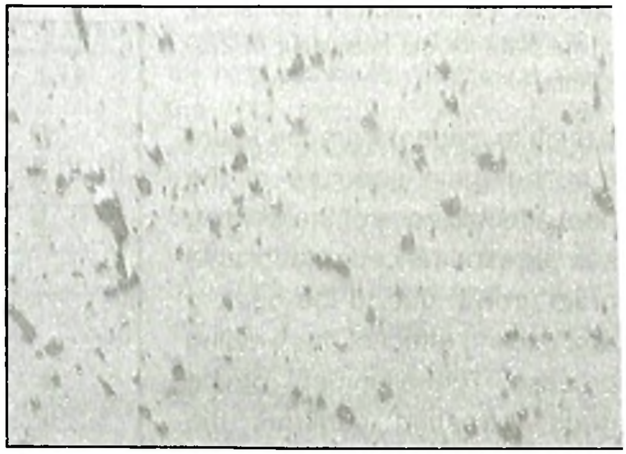


Fig-7 : Microstructure at the non welded zone of 100 Magnification for 22 kJ/mm Heat Input

Here more softening portion

Fig-8 Microstructure at the welded zone of 400 Magnification for 22 kJ/mm Heat Input

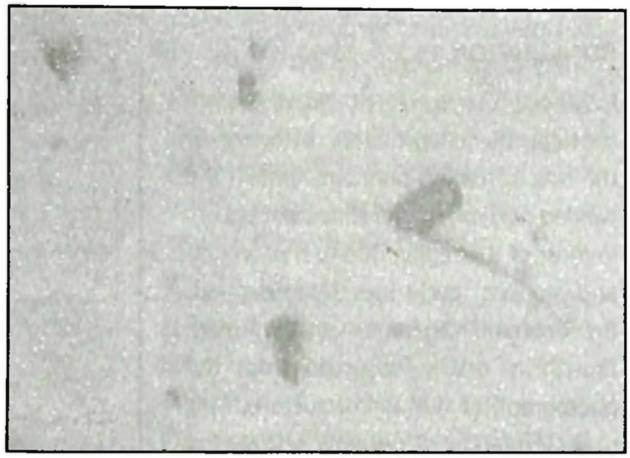


Fig-9 : Microstructure at the non-welded zone of 400 Magnification for 22 kJ/mm Heat Input

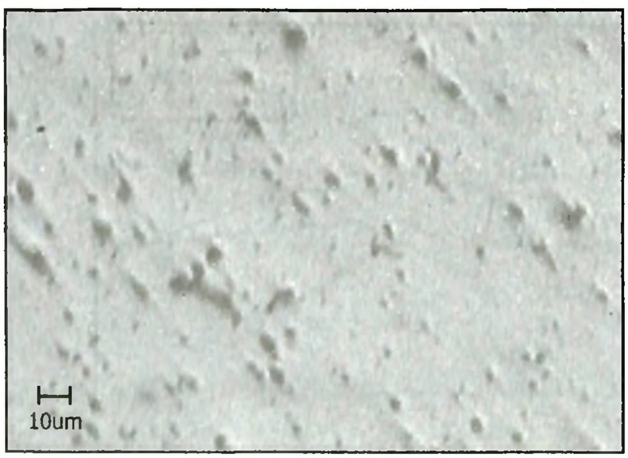


Fig-10 : Microstructure at the welded zone of 50 Magnification for 22 kJ/mm Heat Input.

The alignment of the grain formation confirms the directional component of the grain growth for the sub merged arc welding process of 22 kJ/mm heat input.

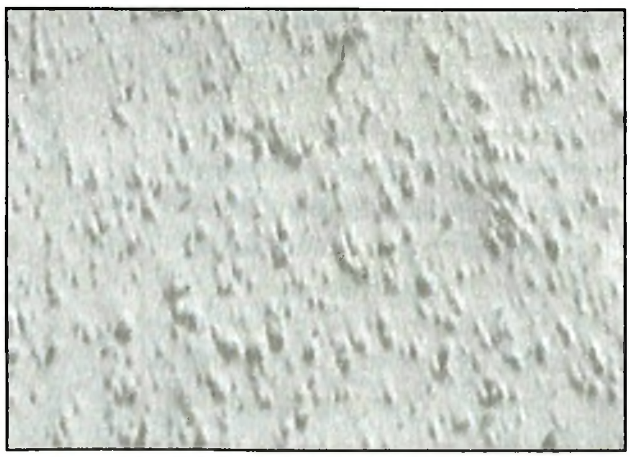


Fig-11 : Microstructure at the non-welded zone of 50 Magnification for 22 kJ/mm Heat Input

View of the 10 micron distance as per the calibration slides of 50 magnifications. Here more softening portion (non welded zone) w.r.t welded portion

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