Effect of slag reclaiming on weld microstructure In Submerged Arc Welding process

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ABSTRACT

Slag formed during SAW process has been collected and processed for using further in subsequent runs of Submerged Arc Welding of mild steel material. The mixture of fused flux (slag) and fresh flux has been used as an alternative of fresh flux. The percentage (by volume) of slag in the mixture of fused flux and fresh flux has been termed as slag-mix%. The aim is to observe whether any noticeable adverse effect occurs on weld microstructure while consuming increasing percentage of slag-mix in SAW process. The present investigation leads to the idea that reconsumption of slag in SAW process does not impose any alarming adverse effect on parameters of the desired weld quality in terms of weld micro structure.

Keywords: SAW, slag-mix

INTRODUCTION

It is known that in Submerged Arc Welding, a portion of the granular flux gets melted and this melted flux i.e. fused slag is not used further. The slag is discarded and fresh flux is used in each run. The possibility of use of fused slag in certain proportion, mixed with fresh flux, may prove to be a challenging area of research. Literature survey indicates rare efforts in this regard. Therefore there exists the scope of intensive research in this particular area of Submerged Arc Welding. It becomes necessary in this context to study the effect of use of fused (recycled) slag, mixed with fresh flux, on bead geometry and weld quality.

Research related to slag reconsumption in conventional SAW process has been carried out by Moi, S. C. et al. (2001) Their study introduced the concept of using slag-mix% as a process variable. The percentage of slag, in the mixture of fused flux and fresh flux, has been denoted as slag-mix%. The main effects of using slag-mix and interactive effects of process parameters (including slag-mix%) on features of bead geometry and HAZ, in terms of bead height, depth of penetration, bead width and HAZ width have been evaluated through Analysis of Variance (ANOVA) method. Motivated by their concept, Sing, K. et al. (2006) recycled fused slag by replenishing it with suitable alloying elements and deoxidizers and by agglomeration. They carried out experiments with this modified recycled flux. They observed favorable results. Datta, S. et al. (2008) developed mathematical models of process behavior during SA welding with reclaimed slag. Their study revealed an optimal (maximum) slag-mix% for producing favorable bead geometry of SA weldment.

Bead-on-plate weld have been made on mild steel material, using fused slag-mixed with fresh flux-in order to investigate the effect of use of slag-mix on microstructures of submerged arc weld. One of the motives in the present work is to move towards the idea of 'Zero Waste Concept', such that fused slag could be reused instead of being discarded and disposed off as waste. The objective of identifying most favorable combination of the parameters including slag-mix% is also taken into consideration in the plan of the present work.

EXPERIMENTATION

In this set of experiments, fused slag has been mixed with fresh flux at different proportions, and this mixture of fused flux and fresh flux has been used to do bead-on-plate welding of mild steel plates. The percentage of fused slag in the mixture of fresh flux and fused slag is

Table 1. Experimental runs for bead-on-plate welding

Observation Number	Sample No.	Slag-mix %
1	O	0 (Fresh Flux)
2	A	10
3	B	20
4	C	40
5	D	60
6	E	80
7	F	100

referred to here as slag-mix%. The slag-mix% has been varied from 0 to 100 with a total of seven levels (Table 1).

The parameters voltage (OCV) (36 V), wire feed rate (0.79 cm/s), traverse speed (0.24 cm/s), electrode stick-out (20 mm), flux basicity index (1.6) and electrode diameter (3.16 mm) have been kept invariable in all the above experimental runs.

Collected slag has been crushed manually and passed through proper sieves to control its grain size approximately equal to that of fresh flux. Copper coated electrode wire of diameter 3.14 mm (AWS A/S 5.17:EH14) has been used during the experiments. Bead-on-plate welding has been performed on mild steel plates with flux (AWS A5.17/SFA 5.17) with grain size 0.2 to 1.6 mm with basicity index 1.6 ($Al^2O^3+MnO^2$ 35%, CaO+MgO 25% and SiO^2+TiO^2 20% and CaF^2 15%). The experiments have been performed on Submerged Arc Welding Machine-INDARC AUTOWELD MAJOR (Maker: IOL Ltd., India). The specimens have been prepared for metallographic test. Microstructures have been investigated in Optical Trinocular Metallurgical Microscope (Make: Leica, GERMANY,

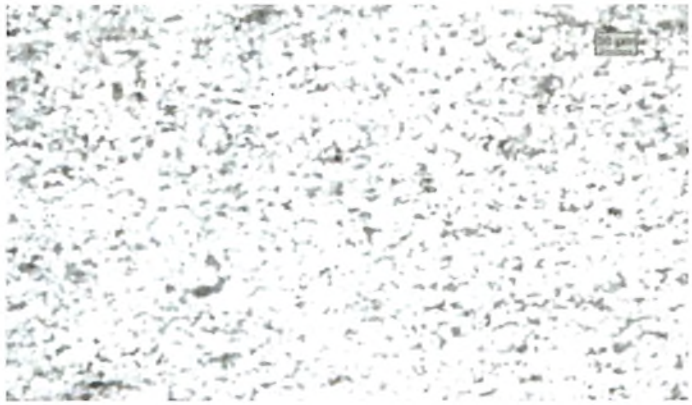

Figure 1. Base metal microstructure

Figure 2. (Sample O) Weld prepared in SAW process without slag-mix

Figure 3. (Sample A) Weld prepared in SAW process with 10% slag-mix

Model No. DMLM, S6D & DFC320 and Q win Software).

RESULTS AND DISCUSSIONS

The base metal microstructure as observed under microscope is shown in Figure 1. Among the several observations made under the microscope, only one typical base metal microstructure is presented here. It reveals the existence of equi-axed ferrite (white in color) and pearlite (black in color). The amount of pearlite is found to be much less, which is consistent with the results of chemical analysis of base metal indicating a low percentage of carbon (0.2%).

In general, the weld metal microstructures (consisting ferrite and pearlite), shown in Figures 3-9, have been found to be richer in pearlite as compared to that found in base metal (Figure 1) The carbon content in the weld metals expected to be influenced by the carbon percentage in the electrode material, apart from the carbon percentage of the base metal. This is obvious, because, the weld metal is formed due to melting of both the parent (base) metal and the electrode. Pearlite-rich microstructures for the weld metals may also result from slag-metal reactions during welding. Weld metal is likely to have higher value of hardness, as compared to the base metal because of pearlite-rich microstructure.

The weld microstructures, however, are somewhat different with respect to distributions of pearlite and ferrite, their amounts, grain sizes etc., depending upon the welding conditions adopted. This is evident from the Figures 2-8.

The weld metal microstructure is controlled mainly by the cooling cycle. At lower energy input (i.e. with low level of current) the time for solidification is less.

Figure 4. (Sample B) Weld prepared in SAW process with 20% slag-mix

Figure 5. (Sample C) Weld prepared in SAW process with 40% slag-mix

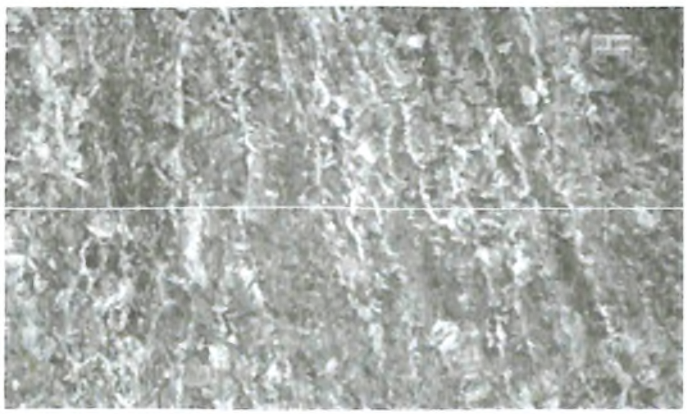

Figure 6. (Sample D) Weld prepared in SAW process with 60% slag-mix

This rapid cooling promotes smaller grains. With higher energy input, the time required for solidification decreases, and, therefore, cooling rate slows down-which yields coarser grains. Courser grains in the microstructure generally indicate lower hardness and low tensile strength.

Following is the comparison made on weld and HAZ microstructures obtained in SAW processes with and without slag-mix.

Figure 2 shows the microstructure of the weld metal obtained in conventional SAW process (SAW with 0% slag-mix, Sample O). This consists of columnar crystals with dendrite growth (grain boundary ferrite). Figure 3 shows the microstructure of the weld metal obtained in SAW process with 10% slag-mix, Sample A). Compared to sample O, It is richer in ferrite (grain boundary ferrite) with columnar grains and less dendritic growth.

Figure 4 depicts the microstructure of the weld metal obtained in SAW process with 20% slag-mix, Sample B). Columnar crystals with fine dendrites have been found. Microstructure consists of grain boundary ferrite with small percentages of acicular ferrite. Figure 5 shows the microstructure of the weld metal obtained in SAW process with 40% slag-mix, Sample C). Formation of acicular ferrite has been observed. Presence of grain boundary ferrite is less. Figure 6 is corresponding to the microstructure of the weld metal obtained in SAW process with 60% slag-mix, Sample D). The microstructure is rich in pearlite (as compared to sample O). Hardness value is expected to be more compared to the weld produced in conventional SAW process (sample O). Formation of thin layers of grain boundary ferrite has been observed. Figure 7 shows the microstructure of the weld metal obtained in SAW process with 80% slag-mix, Sample E). It consists of acicular ferrite (AF) small feathery laths with low aspect ratio. Dendritic growth in grain boundary ferrite has not found. Figure 8 is related to the microstructure of the weld metal obtained in SAW process with 100% slag-mix, Sample F). It is found that the microstructure contains very fine dendritic growth over vary thin layers of grain boundary ferrite. Ferrite content is much less compared to that found in sample O, indicating higher expected value of hardness.

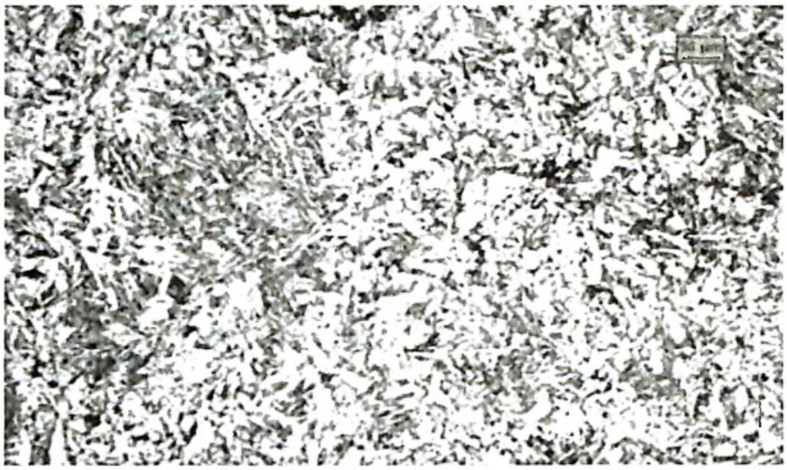

Figure 7. (Sample E) Weld prepared in SAW process with 80% slag-mix

Figure 8. (Sample F) Weld prepared in SAW process with 100% slag-mix

It is found that use of slag-mix does not adversely affect weld microstructure. The microstructure obtained in SAW process using slag-mix is almost consistent with that obtained in conventional SAW process. Some structural differences have been observed with increase in slag-mix% used, which could be explained through in-depth study of weld heating and cooling phenomenon, slag-metal reaction, as well as weld chemistry. But the micro structural studies made in this work and the above analysis of the results indicates that use of slag-mix would not impose any harmful effect on weld microstructure.

CONCLUSION

Microstructures of the weld metal obtained in SAW process (using varying slag-mix) has been found consistent with that produced during conventional SAW process. Use of slag-mix does not produce any alarming effect on weld microstructures. Therefore, SAW slag could be reclaimed again. Additionally, it is always important and useful to reduce waste and to move towards 'Waste to Wealth', or finally approaching towards 'Zero Waste Concept'.

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