Waste to Wealth: Reuse of Slag as a Flux in Submerged Arc Welding

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In the present work an attempt has been made to use slag waste as a flux in submerged arc welding. Slag generated during submerged arc welding has been recycled by mixing varying percentages of crushed slag with fresh flux to use in subsequent runs. The influence of using flux-slag mixture on weld chemistry has been investigated. The results indicate that the use of such a mixture in submerged arc welding does not adversely affect the chemistry of weld metal. In addition, slag detachability and bead appearance both were found satisfactory. Arc stability observed during welding was also satisfactory.

Key Words: Submerged arc welding, Slag, Flux, Recycling, Chemistry, Weld metal.

INTRODUCTION

Since the development of the submerged arc welding process (SAW) there have been attempts by technologists and researchers to increase its productivity and to decrease the welding cost. Flux contributes a major part towards welding cost in submerged arc welding process. Weisman[1] has estimated that, in general, one kg of flux is consumed for every kg of weld metal deposited. About 2500 tonnes of flux was consumed in India alone in year of 1982 (Visvanath)[2] which have risen to 10000 tonnes in the year of 2006. Such a large quantity of flux, after welding, becomes slag waste and has to be disposed-of. Attempts have been made by researchers to use slag mixed with fresh flux for shielding. Eagar *et al.*[3] investigated that the reuse of fused slag is economical in submerged arc welding of titanium. Beck and Jackson[4] found that if it is processed properly and according to the code requirements, recycled slag can be reliably used as an alternative to fresh flux. They further claimed a saving upto 50% of the total cost of purchased flux by recycling the slag.

Motivated by their concept, Singh *et al.*[5] found that recycled slag can produce acceptable bead geometry. As a continuation of the study, Singh *et al.* [6] further observed that recycled slag can produce sound welds.

Some researchers have also been explored the possibility of using a mixture of fresh flux and fused slag. Experiments carried-out by Livshits *et al.*[7] have

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shown the possibilities of using pulverized slag crust mixed with iron filings for hard-facing applications. They further claimed that this process is efficient and economical. Datta *et al.*[8] found that the use of fused slag does not affect the weld metal and HAZ microstructure harmfully. Datta *et al.*[8] also obtained favourable bead geometry using 20% slag mix.

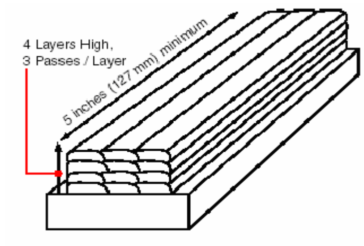

Fig. 1. Weld metal pad for chemical analysis (ASME-SFA 5.17)

Research related to slag recycling and subsequently reuse in submerged arc welding is not rich. Very few weld researchers so for have been attracted to this field, but the scope of work and its significance is vast and bright. It is felt that there exist enough prospects to elaborate the research in this particular direction. If it can be experimentally proved successfully that the use of slag is possible instead of fresh flux, without producing any harmful/adverse effect on weld quality then this technique can be adopted in practical field resulting 'waste to wealth'. Because its time to employ 'zero waste concept'.

Motivated by this concept, the present work has been aimed with an objective to carry out investigations using slag mix for shielding in submerged arc welding. The motive of this work is to check the application feasibility of recycled slag in the form of a mixture consisting fresh flux and fused slag. The influence of using slag mix on weld chemistry has been investigated. Fused slag was crushed and sieved to grain size of original fresh flux and mixed mechanically with fresh flux in different proportions.

EXPERIMENTATION

The slag generated by conventional submerged arc welding was collected. This slag was crushed and meshed to the granular size of the original flux and then mixed with the fresh flux in varying proportions (0%, 20%, 40%, 60, 80% and 100%). Slag mix in combination with EL-8 filler wire was used in these investigations. Weld pads as shown in Fig. 1 were prepared for chemical analysis of the weld metal. The welding parameters and other conditions were in accordance with ASME-SFA 5.17.

A constant potential transformer-rectifier type power source having current capacity of 600 amperes at 100% duty cycle and open circuit voltage ranging 12-48 volts was used. Fully mechanized submerged arc welding system of carriage type was employed to conduct the experiments. DCEP polarity was used throughout the experimentation. The chemical composition of uppermost layer was determined by a spectroscope and is recorded in Table-2. For surface finish and bead appearance, beads on plate were deposited. Surface condition was checked by dye penetration test and visual examination. Slag detachability was noted during cleaning. Arc stability was indicated by the pointer of voltmeter fitted on the equipment

RESULTS AND DISCUSSION

Chemistry of weld metal

The chemical composition of base material and electrode used is shown in Table-1. The chemical compositions of weld metal deposited using various proportions of slag-mix have been recorded in Table-2. American Welding Society (AWS) specifications have also been given in Table-2 for comparison.

Table 1: Chemical composition of electrode and base metal

	Carbon	Manganese	Silicon	Sulfur	Phosphorous
Electrode	0.069	0.48	0.02	0.02	0.0184
Base plate	0.165	0.4	0.17	0.05	0.046

Table 2: Chemical composition of weld metal

Sample	C %	Mn %	Si %	S %	P %
AWS Requirement	0.015- 0.15	0.80 - 1.25	0.1- 0.35	0.03 Max	0.03 Max
Weld metal with 0% slag mix	0.052	0.637	0.211	0.029	0.033
Weld metal with 20% slag mix	0.031	0.602	0.184	0.026	0.033
Weld metal with 40% slag mix	0.035	0.633	0.200	0.027	0.032
Weld metal with 60% slag mix	0.030	0.624	0.184	0.021	0.028
Weld metal with 80% slag mix	0.030	0.592	0.152	0.026	0.027
Weld metal with 100% slag	0.028	0.547	0.130	0.024	0.027

Chemical analysis indicates that carbon contents decreased from 0.052 to 0.031% with addition of 20% slag in fresh flux (trial number-2). Addition of fused slag decreases the amount of deoxidizers in the flux. Weld metal get oxidized due to reduced amount of deoxidizers, hence loss of carbon from weld metal. Further addition of fused slag does not have a significant effect on loss or gain of carbon by weld metal.

Transfer of manganese (Mn) from flux to the weld pool or removal of Mn from weld pool to the slag is determined not only by the amount of Mn in the flux which produces MnO, but also by the reaction of Mn with silicate anions which form $MnSiO_3$ which is more readily absorbed by the slag than by the metal. It appears from Table-2 that welding conditions for the present study have fovoured the formation of $MnSiO_3$ preferentially over the formation of MnO, resulting in decreased Mn and Si content of the weld.

The table also indicates decrease in the levels of P and S in the weld metal deposited with slag-mixes as compared to the weld metal prepared using fresh flux. This suggests that the use of slag mix as flux may be beneficial in this respect.

Surface appearance

Smooth beads with good surface finish were obtained. Top surface of the bead was shining with light blue in colour, may be due to oxidation. No undercuts, slag entrapments and pockmarks were observed. However scattered porosity was revealed by dye penetration test.

Conclusion

Slag mixed with fresh flux up to 60% can produce sound weld. The use of slag - flux mixture reduces sulphur and phosphorous in weld metal which is beneficial regarding toughness of the weld. Carbon contents of weld metal decrease with addition of slag in fresh flux.

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