Asian Journal of Chemistry Vol. 21, No. 10 (2009), S047-051

Slag Recycling in Submerged Arc Welding and its Influence on Chemistry of Weld Metal

KULWANT SINGH[1*], V. SAHNI[1], and S. PANDEY[2]
[1]*Department of Mechanical Engineering, SLIET, Longowal, Punjab, India*
**E-mail: engrkulwant@yahoo.co.in*

Slag generated during submerged arc welding has been recycled by replenishing it with suitable alloying elements and deoxidizers and by agglomeration process. This recycled slag in combination with EL-8 filler wire was used in these investigations. Desired chemistry of weld metal was obtained. It was further observed that the chemical composition of weld metal prepared using recycled slag is within the acceptable range of AWS (American Welding Society) specifications.

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

INTRODUCTION

The flux used for shielding in submerged arc welding is converted into slag during welding which is a waste and has to be disposed of. Weisman[1] has estimated that, in general, one kg of flux is consumed for every kg of weld metal deposited. Flux consumption increases with increase in arc voltage (Singh *et al*)[2]. About 2500 tonnes of slag was generated in India alone in year of 1982 (Visvanath)[3] which have risen to 10000 tonnes in the year of 2006 (Honavar)[4]. Such a large quantity of generated slag has to be disposed of. Presently slag generated during submerged arc welding is thrown away as a waste and needs land fill space for dumping. It is not possible to stop the generation slag as it is a bio-product of the process but could be reused. So an attempt has been made to recycle the slag. Slag has been processed in such a manner that allows it to be used as a flux and its effect on chemistry of weld metal has been investigated.

EXPERIMENTAL

Slag was crushed and meshed to the granular size typical of fresh flux. A weld pad as shown in Fig. 1 was prepared using this crushed slag in combination with EL-8 filler wire for chemical analysis of weld metal. Similar pad was also prepared using fresh flux. The welding parameters and other conditions were in accordance with ASME SFA 5.17. The chemical composition of filler wire and base metal is shown in Table 1.

[2]Department of Mechanical Engineering, IIT Delhi, India.

The chemical composition of weld pads prepared using pure crushed slag and fresh flux and recycled slag is recorded in Table 2.

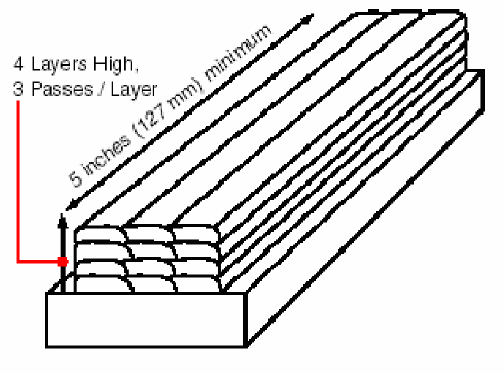

Fig. 1: Weld metal pad for chemical analysis (ASME SFA-5.17)

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	0.40	0.17	0.05	0.046

TABLE 2
CHEMICAL COMPOSITION (Wt.%) OF WELD METALS

	C	**Mn**	**Si**	**S**	**P**
AWS requirement	0.05-0.15	0.80-1.25	0.1-0.35	0.03 Max	0.030 Max
With pure slag	0.028	0.547	0.130	0.024	0.0272
With fresh flux	0.052	0.637	0.211	0.029	0.0337
With recycled flux	0.075	0.832	0.199	0.025	0.030

Processing of slag

The slag was crushed and subsequently milled in a ball mill to convert into powder form. Alloying elements and deoxidizers were added and mixed mechanically. Liquid potassium silicate was added as a binder to wet the powder. The wet mixture was agglomerated and passed through 10-mesh screen to convert into small pellets. These pellets were air dried for 24 hours and baked at 850°C for two hours in a muffle furnace. The baked mass was then crushed and sieved to the required particle to produce "recycled slag". This recycled slag was used as the flux in these investigations. The chemical composition of the weld pad was determined with a spectroscope and compared with AWS requirements.

These modifications were repeated until acceptable chemistry of weld metal was achieved. The trial runs and the corresponding weld metal compositions are shown in Table 3. The trial number 7 gave acceptable weld metal composition along with good bead appearance and free from visual defects.

RESULTS AND DISCUSSION

Transfer of Carbon

It is very difficult to predict the extent of carbon transfer during welding, but usually the weld metal has a lower carbon content than expected from nominal composition of electrode and the base plate, due to oxidation (Mitra *et al.* 1984)[5]. Oxidation of carbon may be represented by the reaction:

$$C + O = CO(g) \quad (1)$$

In the present study, percentage of Carbon in weld metal deposited with pure slag is 0.028% which is less than the filler wire used. It is due to oxidation of carbon as deoxidizers have already been exhausted from the slag. Addition of $CaCO_3$ (6.4% by weight) to the slag, carbon content of weld metal increased to 0.032 as in trial number 3, which further increases up to 0.075% with increase in percentage of $CaCO_3$ by weight as revealed from trial number 7 (Table 3).These observations indicate that carbon is picked up from $CaCO_3$. On dissociation $CaCO_3$ yields CO_2 which at high temperature further dissociate into CO & O. The CO_2 being unstable at high temperature dissociate into CO and O.

$$CO_2 \rightarrow CO + O \quad (2)$$

Oxygen reacts with the element having high affinity for it, whereas CO, which was present in the vicinity of the weld bead at relatively high temperature, dissociates into CO and CO_2.

$$2CO \rightarrow C + CO_2 \quad (3)$$

This free carbon is picked up by weld metal because of diffusion.

Transfer of Manganese

Manganese content of weld metal depends on the initial manganese content of filler wire, basicity index, amount of manganese and manganese oxide of the flux. Slag metal reaction involving an exchange of manganese, but no change in oxygen content of weld pool is;

$$2(MnO) + [Si] = 2[Mn] + (SiO_2) \quad (4)$$

Flux decomposition reaction of the following type increases manganese content in the weld metal along with oxygen.

$$(MnO) = [Mn] + [O] \quad (5)$$

From the Table 3, it can be seen that manganese content of weld metal increased with addition of ferro-manganese in the flux. It is further observed from trial number 5 and 7 that manganese content of weld metal increased with increase in basicity index.

Transfer of Silicon

The loss of silicon from the weld metal deposited with pure slag is expected due to oxidation;

$$[Si] + 2O = (SiO_2) \quad (6)$$

TABLE 3
WELD METAL COMPOSITION (Wt.%) FOR VARIOUS SLAG MODIFICATIONS

Trial No.	Additives	Weld metal composition (wt. %)				
		C	**Mn**	**Si**	**S**	**P**
1	With pure crushed slag	0.028	0.547	0.130	0.024	0.027
2	With fresh flux	0.052	0.637	0.211	0.029	0.0337
3	$CaCO_3$+SiO_2 = 6.4 % Fe-Mn+Fe-Ti = 2.0 %	0.032	0.421	0.113	0.027	0.0227
4	$CaCO_3$+SiO_2 = 11.2 % Fe-Mn +Fe-Ti = 3.0 %	0.087	0.428	0.142	0.029	0.0276
5	$CaCO_3$+SiO_2 = 11.2 % Fe-Mn+Fe-Ti = 5.0 %	0.070	0.557	0.140	0.025	0.0237
6	$CaCO_3$+SiO_2 = 12.0 % Fe-Mn+Fe-Ti = 7.0 % Fe-Si = 1.0 %	0.061	0.683	0.136	0.026	0.0271
7	$CaCO_3$+SiO_2 = 12.8 % Fe-Mn + Fe-Ti = 1.0 % Fe-Si = 2.0 %	0.075	0.832	0.199	0.025	0.030

However it is observed that silicon content of weld metal deposited with pure slag is 0.13% which is more than the filler wire used. It indicates that silicon has been transferred from slag to weld metal, which may be attributed to the dissociation of SiO_2 present in the slag.

Palm, H (1972)[6] has found that increase of SiO_2 always contributes to increase of Si and at the same time to a higher dissolved O content of the weld metal. As silica is added in the slag, silicon content of weld metal increased up to 0.142% (trial number 4). Further addition of SiO_2 in slag resulted in increased amount of.silicon up to (0.199%) The transfer of silicon takes place as per the following reaction;

$$(SiO_2) \rightarrow [Si] + 2[O] \quad (7)$$

Chai and Eagar (1981)[7] have derived the following relationship:

$$aSiO_2 = 73.6[wt\%Si][wt\%O] \quad (8)$$

From the above relationship it can be concluded that increased amount of silica in the slag, increases the activity of silica causing transfer of silicon from slag to weld metal.

Transfer of Sulphur

Table 3 depicts that sulphur content of weld metal deposited with pure slag is 0.024% whereas filler wire contains 0.02%. Addition of $CaCO_3$ and silica by (6.4%) in slag results an increased amount of sulphur in the weld metal. Further increase in the amount of $CaCO_3$ and silica in the slag leads to increased sulphur content up to 0.029% in weld metal (Trial 4). The transfer of sulphur to the weld metal can be explained as:

$$[S] + (O^{2-}) = (S^{2-}) + [O] \tag{9}$$

From above it is clear that sulphur content of weld metal depends on the number of oxygen ions, amount of sulphur in the slag and amount of oxygen present in the weld metal. As amount of silica in the slag increases, dissolved oxygen in weld metal also increases. Addition of $CaCO_3$ and SiO_2 to the slag leads to increased amount of sulphur in slag and oxygen in the weld metal, which led to increase in sulphur content of weld metal.

Conclusion

Submerged arc welding slag can be recycled. Recycled slag can produce weld metal having chemical composition within the acceptable range of American Welding Society (AWS) specifications.

REFERENCES

1. C. Weisman: in, AWS *Welding Handbook*, Vol.1, 7th Edition, Miami, USA.
2. Kulwant Singh, Sunil Pandey, R. Arulmani, *Australasian Welding Journal*, **51**, 2 (2006).
3. P.S. Viswanath, *Indian Welding Journal*, **15**,1 (1982).
4. D.S Honavar, *Technology Trends*, **9** (2006).
5. U. Mitra and T. W. Eagar, *Metallurgical Transactions A,* **15**, 1 (1984).
6. J. H. Palm, *Welding Journal*, **15**, 7(1972).
7. C.S. Chai, T. W. Eagar, *Metallurgical Transactions*, **12,** *B* (1981).