Development Of Cost Effective Agglomerated Fluxes From Waste Flux Dust For Submerged Arc Welding

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Abstract: Submerged arc welding contributes to approximately 10% of the total welding. Approximately 10% -15% of the flux gets converted into very fine particles termed as flux dust before and after welding, due to transportation and handling. If welding is performed without removing these very fine particles from the flux, the gases generated during welding are not able to escape, thus it may result into surface pitting (pocking) and even porosity. On the other hand, if these fine particles are removed by sieving, the cost of welding will be increased significantly. And if this flux dust is dumped/ thrown, will create the pollution. Therefore to reduce the cost of welding and pollution, in the present work attempts have been made to develop the acidic and basic agglomerated fluxes by utilizing wasted flux dust. The investigation of the present study showed chemical composition and mechanical properties of the all weld metal prepared from the developed fluxes and the parent fluxes to be in the same range. The welded joints were also found to be radiographically sound. Therefore the developed fluxes prepared from the waste flux dust can be used without any compromise in mechanical properties and quality of the welded joint. It will reduce the cost of welding and pollution.

Keywords: Agglomerated fluxes, submerged arc welding, tensile properties, toughness

I.INTRODUCTION

Submerged arc welding process is characterized by higher metal deposition rate, deep weld penetration, and high speed welding of thin sheet steels at over 2.5 m/min and with minimum emission of welding fume or arc light. Deposition rates approaching 45kg/h have been minimal welding fume or arc light is emitted. Deposition rates approaching 45kg/h have been reported [1]. The molten weld and the arc zone are protected from atmospheric contamination by being “submerged” under a blanket of granular flux. This typical arrangement facilitates a slower cooling rate, which, in turn, improves both mechanical properties and metallurgical characteristics of weld bead [2].

Flux plays an important role in deciding the weld metal quality. Submerged arc welding fluxes are granular, fusible mineral compounds which blanket the arc and provide shielding, cleansing, and bead shape control [3]. Flux constitutes half of the total welding cost in submerged arc welding. They greatly influence process usability and weld metal mechanical properties [4]. It has been reported that agglomerated fluxes produce weld deposits of better ductility and impact strength as compared with fused fluxes [5]-[6]. These fluxes are hygroscopic in nature, therefore baking is essential for good weld metal integrity [7]. Data and Bandyopadhyay [8] has performed optimization to determine the amount of waste slag and flux mixture that can be used without sacrificing any negative effect on bead geometry, compared to conventional SAW process, which consumes fresh flux only. Prashad and Dwivedi [9] investigated the influence of submerged arc welding process parameters on microstructure, hardness and toughness of HSLA steel weld joints. No work so far has been performed to develop the flux by using flux dust.

The present study has been conducted to investigate the feasibility of developing one acidic and one basic agglomerated flux by utilizing wasted flux dust of the parent commercial available fluxes. The chemical composition and mechanical properties viz. tensile strength and toughness of the all weld metal joint using developed fluxes as well as parent commercial fluxes of the same type were compared. The radiographic examinations of all the welded joints were conducted to check weld metal integrity. It was found that the chemical composition and mechanical properties of the all weld metal prepared by using the developed fluxes are in the same range as that of parent fluxes. The welded joints were also found to be radiographically sound. Therefore the developed fluxes prepared from the waste flux dust can be used without any compromise in mechanical properties and

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quality of the welded joint. It will reduce the cost of welding and pollution.

II. EXPERIMENTAL PROCEDURE

In the present study two agglomerated cost effective fluxes were developed by using the flux dust of one acidic and one basic flux with addition of potassium silicate as binder and aluminum powder as deoxidizer. The solution of potassium silicate binder was added to the dry mixed powder of the flux dust and aluminum powder and it was wet mixed for 10 minutes and then passed through a 10 mesh screen to form small pallets. Potassium silicate was added as binder because of better arc stability [10]-[11]. The pallets of the flux were dried in air for 24 hours and then baked in the muffle furnace between 650-700^{0}C for nearly 3 hours [12]. After cooling these pallets were crushed and subsequently sieved. After sieving, fluxes were kept in air tight bags and baked again at 300^{0}C before welding.

The four butt weld joints were made with mild steel as base plate and backing strip. A constant voltage D.C submerged arc welding power source was used for forming the joints with base plates of mild steel plates having the dimension 275 x 125 x 25 mm^3 using 4 mm diameter wire electrode of grade C (AWS-5.17-80 EH-14). The plates were preset so that they remain approximately flat after the welding operation has been completed. DCEP polarity was used throughout the experimentation. The welding conditions like an open circuit voltage of 38V, current 550 amperes, electrode stick out 30mm and welding speed of 28cm/min were used and kept constant throughout the experimentation. The chemical composition of mild steel base plate and electrode wire is shown in Table I.

Table I Chemical composition of base plate and electrode Wire

Element (%)	C	Mn	Si	S	P	Ni	Cr
Base Plate	0.21	0.2	0.26	0.028	0.025	0.12	0.43
Electrode Wire	0.069	1.86	0.100	0.028	0.023	Nil	Nil

Four layer high weld pads were made for the basic developed agglomerated flux and parent flux as per AWS A5.23-90 standard with the same welding conditions. The chemical compositions of all weld metal were evaluated by using spectrometer. The welded assembly was subjected to radiographic examination to ascertain weld integrity prior to mechanical testing. Three all weld metal tensile test pieces were cut from each welded plate and machined to the standard dimensions. The tensile tests were carried out on a universal testing machine (Make FIE-India) on three test specimens for each type of developed and parent fluxes. Scanning electron microscopy of the fractured surfaces of tensile test specimens were carried out at 20kv, 10µm & 1500 X on microscope (Make JOEL Japan, JSM-6100). Charpy V notch impact test was carried out to evaluate the toughness of the welded joints at 0^{0}C. Charpy impact tests were performed on standard notched specimens obtained from the welded and main sections of the material. Five all weld metal impact test specimen of standard were cut from each welded joint of plates. These specimens were then fine polished by the surface grinder. Among the five values of the impact strength the lowest and the highest values were discarded and average of the three values was taken for the evaluations of impact strength of the groove welds. The charpy impact tests results obtained from the weld metal showed rather good repeatability. The same procedure was applied to the developed as well as parent fluxes to investigate the compatibility of the developed fluxes with the parent fluxes.

III. RESULTS AND DISCUSSION

The bead surface appearance of the developed fluxes were found to be excellent and free from any visual defects and it was comparable with the parent commercial flux. The slag was easily detachable form the welded joint for both of the developed fluxes.

As shown in Table-II, the compositions of all weld metal of the developed and parent fluxes are found to be in the same range. However, manganese content of the weld metal laid by using the developed acidic and basic fluxes is slightly lower than the weld metal laid by using the parent acidic and basic fluxes. The silicon content of the weld metal laid by using both of the developed fluxes is higher than the weld metal laid by using the parent fluxes.

The carbon equivalent was be computed from the following equation [13]

$$C_{\text{equivalent}} = C + \frac{Mn}{6} + \frac{Si}{24} + \frac{Ni}{40} + \frac{Cr}{5} + \frac{Mo}{4} + \frac{V}{4}$$

Where C, Mn, Si, Ni, Mo and V represent the metallic content, expressed as percentage.

Table II Chemical composition of all weld metal laid by developed and parent fluxes

Element (%)	C	Mn	Si	S	P	Ni	Cr	Carbon Equivalent
Parent Basic flux	0.041	1.5	0.35	0.018	0.016	Nil	0.09	0.31358
Developed Basic flux	0.05	1.35	0.47	0.013	0.018	0.0037	0.0345	0.30157
Parent acidic flux	0.058	1.6	0.49	0.018	0.018	Nil	0.08	0.3610
Developed acidic Flux	0.051	1.52	0.52	0.016	0.017	0.0142	0.048	0.3391

Additional potassium silicate binder, which was added for agglomeration of the flux dust, contains silicon di-oxide. The silicon di-oxide dissociate into oxygen and silicon due to heat during welding [14]. It causes the additional amount of oxygen and silicon content in the weld pool. The additional amount of oxygen results in oxidation of manganese and hence the less manganese content in the weld metal laid by using the developed fluxes as compared to the weld metal laid by using the parent fluxes. The additional amount of silicon results in increase of silicon content and hence the higher silicon content in the weld metal laid by using the developed fluxes as compared to the weld metal laid by using the parent fluxes. The radiographs of the welded joint which were prepared using developed fluxes were found to acceptable as per 9.252 of AWS D. 1.15-88 radiographic standard of dynamic loading.

The average values of tensile properties, yield strength, ultimate strength, elongation percentage, area reduction percentage and average impact strength of the developed fluxes as well as parent fluxes are shown in Table III. The tensile strength and average impact strength of all weld metal obtained by using the developed and parent fluxes are reported to be in the same range. However, the tensile strength and impact strength of all weld laid by using the parent acidic and basic fluxes are slightly higher than the tensile strength and impact strength of all weld laid by using the corresponding developed fluxes. It is attributed to slightly higher carbon equivalent of all weld metal laid by using parent fluxes than that of carbon equivalent of all weld metal using the developed fluxes.

Table III Tensile strength and Impact strength (toughness) and of all weld metals laid by using developed and parent fluxes

Flux	Yield strength (N/mm^2)	Ultimate strength (N/mm^2)	Elongation (%)	Area Reduction (%)	Impact strength / Toughness (joules)
Developed Basic flux	481	586	28	68	153.66
Parent Basic flux	495	584	22	66	156.33
Parent Acidic flux	510	625	25	52	74
Developed Acidic flux	500	617	29	65	69.96

The weld metal composition and mechanical properties viz. tensile strength and impact strength of the developed fluxes were also found satisfactory and comparable with parent fluxes available in market. The highest and lowest tensile strength were obtained for the weld metal with highest and lowest equivalent carbon respectively. Carbon equivalent for developed acidic flux is more than that of basic flux, resulting in higher value of tensile strength of these fluxes. The higher value of impact strength of basic flux can be attributed to lower oxygen content due to higher thermal stability of basic oxides. Scanning electron micrographs of the fractured tensile test specimens of the weld were laid out at same heat input using acidic and basic fluxes. All the micrographs of the developed as well as commercially fluxes showed the ductile mode of fracture.

IV.CONCLUSIONS

In the present study, detailed experimentation have been carried out to investigate the mechanical properties of submerged arc welded mild steel joints using developed as well as commercially available fluxes. The main conclusions are as follows:

1. The flux behavior of the developed basic and acidic fluxes was found to be satisfactory.

2. The weld bead appearance was observed to be excellent and free from any visual defects, having an easy detachability of slag and were comparable with the parent fluxes.

3. The welded joints prepared by using the developed fluxes were found to be radiographically sound.

4. The chemical composition of the all weld metal laid by using developed fluxes is comparable with that of weld metal laid by using the respective parent flux.

5. Tensile properties of the all weld metal laid using developed fluxes and parent fluxes of the same type are nearly same.

6. The impact strength of all weld metals obtained by using the basic fluxes are higher that of weld metals laid by acidic fluxes.

7. The flux dust can be reused after developing as agglomerated flux without compromising with the quality.

8. The cost of welding can be reduced thereby developing agglomerated fluxes from waste flux dust.

9. Further scope of research can be explored by utilizing another waste like slag and flux dust both to reduce the welding and production cost.

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