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A Study on Effect of Basicity Index in Submerged Arc Welding

Prof.N.Thenammai[1], Bharathipriya A[2]
[1]*Assistant professor Department of Metallurgical Engineering, Government college of Engineering Salem.11*
[2]*PG Scholar Department of Metallurgical Engineering, Government college of Engineering Salem.11*

Abstract- Among the arc welding processes, submerged arc welding (SAW) is preferred over other methods of welding because of its inherent qualities like easy control of process variables, high quality, deep penetration, smooth finish, capability to weld thicker sections and prevention of atmospheric contamination of weld pool. A layer of powdered flux generates a protecting gas shield as well as a slag to protect the weld region. The arc can be submerged below the flux layer & in general, is not noticeable throughout the welding process and to study the effect of flux constituents and basicity index on mechanical properties, hardness and microstructure of the weld metal.

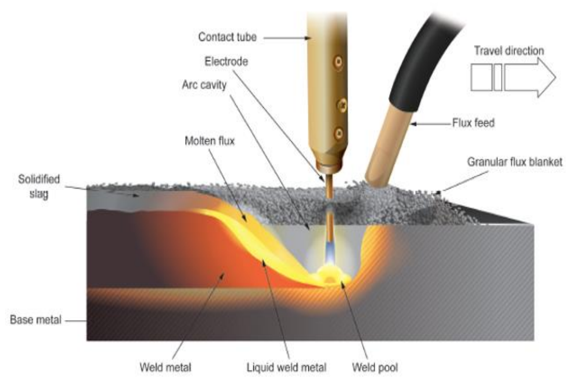
Keywords: Basicity Index, SAW,Flux, Composition

INTRODUCTION

SAW fluxes can influence the weld metal composition appreciably in the form of addition or loss of alloying elements through gas metal and slag metal reactions. Few hygroscopic fluxes are baked (at 250-300°C for 1-2 hours) to remove the moisture. The fused and agglomerated types of fluxes usually consist of different types of oxides and halides such as MnO, SiO2, CaO, MgO, Al2O3, TiO2, FeO, CaF and Sodium/Potassium Silicate. Halide fluxes are used for high quality weld joints of high strength steel to be used for critical applications while oxide fluxes are used for developing weld joints of non-critical applications. Some of oxides such as CaO, MgO, BaO, CaF2 , Na2O, KO, MnO etc. are basic in nature (donors of oxygen) and few others such as SiO2, TiO2 , Al2O are acidic (acceptors of oxygen). Depending upon relative amount of these acidic and basic fluxes, the basicity index of flux is decided. The basicity index of flux is calculated by the ratio of the sum of (wt. %) all basic oxides to all non-basic oxides.

WELDING PROCESS

Submerged Arc Welding (SAW) is a joining process that involves the formation of an electric arc between a continuously fed electrode and the workpiece to be welded. A blanket of powdered flux surrounds and covers the arc and, when molten, provides electrical conduction between the metal to be joined and the electrode. It also generates a protective gas shield and a slag, all of which protects the weld zone.



SAW EQUIPMENT

Arc formation between the wire electrode and workpiece happens as in the MIG welding process. But this process has an additional advantage of shielding by the granular flux making the SAW welding as spatter, fumes, and UV light free. The equipment has the following in its inventory.
Submerged arc welding can be used with DC or AC.

- Power source
- Welding torch/gun and cable assembly
- Flux hopper and its feeding
- Travel mechanism for automatic welding

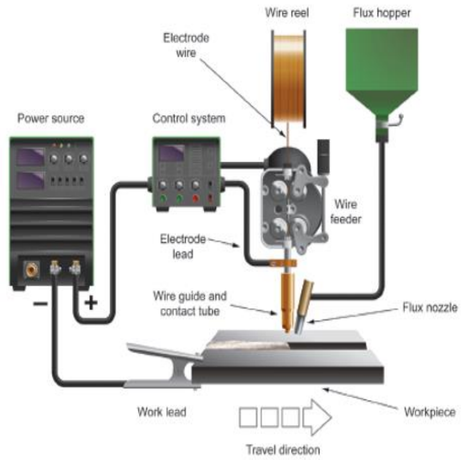


Figure1. General Arrangement of the SAW

FLUXES

Flux is a mixture of various minerals, chemicals, and alloying materials that primarily protect the molten weld metal from contamination by the oxygen and nitrogen and other contaminants in the atmosphere. The addition of certain chemicals and alloys also help to control arc stability and mechanical properties.

Basic fluxes for SAW are made from elements such as Calcium, magnesium, sodium, potassium and manganese oxides, calcium carbonate and calcium fluoride whilst silica, and alumina are the constituents of acid-based fluxes.

Submerged arc fluxes can be measured by their basicity index which is commonly used to describe the metallurgical behavior of a welding flux. The basicity index is a ratio between basic and acid compounds (oxides and fluorides) of which the flux is composed.

BASICITY INDEX

Basicity index of flux is a measure of the alkalinity or acidity of a flux used in metallurgical processes. There are several types of basicity indices commonly used, each providing insights into different aspects of the flux's behavior. Here are three types of basicity indices briefly explained:

1. Oxide Weight Ratio (OWR):

- This basicity index is calculated based on the weight percentages of specific oxides in the flux composition.
- OWR is expressed as the ratio of the weight percentage of basic oxides (typically CaO and MgO) to the weight percentage of acidic oxides (such as SiO2 and Al2O3).
- OWR = $(CaO + MgO) / (SiO_2 + Al_2O_3)$
- A higher OWR indicates a more basic flux, while a lower OWR suggests an acidic one.

2. Silica Ratio (SR):

- The silica ratio is another basicity index that focuses on the role of silica (SiO2) in the flux.
- It is calculated as the weight percentage of SiO2 divided by the sum of the weight percentages of CaO and MgO.
- SR = SiO2 / (CaO + MgO)
- A higher SR indicates a more acidic flux, while a lower SR suggests a basic flux.
- SR is particularly relevant in processes where silica is a critical component in slag formation and impurity removal.

3. Molten Oxide Activity (MOA):

- MOA is a basicity index that takes into account the activity coefficients of various oxides in the molten slag.
- It provides a more detailed assessment of the flux's behavior at high temperatures.
- MOA considers the activities of specific oxide components, and it can be calculated using thermodynamic models and experimental data.
- A higher MOA value indicates a more basic slag with higher reactivity.

These different types of basicity indices offer metallurgists and researchers a range of tools to assess and select fluxes suitable for specific metallurgical processes. The choice of which index to use depends on the process requirements and the specific oxides of interest in the flux composition.

Welding fluxes can be divided into three groups:

- Acid fluxes with a basicity index of <0.9
- Neutral fluxes with a basicity index of 0.9-1.2
- Basic fluxes with a basicity index of > 1.2

Basicity has significant influence on weld metal properties, particularly on toughness. Increasing basicity brings down the oxygen content and hence the inclusion level in the weld metal and thus increases the toughness.

The functions of the flux are as follows:

1. To clean the surface.
2. To prevent oxidation of the surface, when hot.
3. To lower surface tension or to allow normal action of metal surface tension.
4. To promote alloying of metal surface with the solder.
5. To promote wetting of the surface by the molten surface with the solder.
6. To create the “shielding gas cloud” during welding about the weldment.
7. To supply the additions of heat during welding operation.
8. To improve the quality of “high strength welds”.
9. To form the slag with metal impurities.
10. To stabilise the arc.
11. To retard the cooling of weld.

LITERATURE REVIEW

[1]. Schwemmer et al. (1979) discussed the effect of flux properties on weld bead dimensions. The arc stability has a profound effect on weld bead shape and penetration. The atoms of low ionization potential which improve arc plasma, conduction and reignition characteristic are often related to overall improvement in arc stability.

[2]. Patchett and Dancy et al., FeO addition to the flux has a more marked influence on arc stability, basicity. Arc stability depends upon availability of active oxygen at the cathode surface. Higher oxygen potential of gas over the flux improves arc stability and leads to deeper penetration.

[3]. Hazett et al., has found that when using single component compounds, CaO produces a more stable arc than SiO2 or MnO. It is reported that CaO improves the arc stability more than MnO.

[4]. Olson et al., Welding flux formulations have modified flux compositions to reduce this problem. Slag detachability has been related to both the physical and chemical properties of the flux. These properties include the differences between the thermal expansion coefficients of the slag and the metal, and the phase transformations in the slag during cooling.

[5]. Mills et al., The viscosities of various welding fluxes and oxides have been reported. Even the small concentration of impurities may degrade the performance of the flux.

[6]. Schwemmer et al. (1979) stated that FeO, CaO improves arc stability due to the presence of more easily ionized atoms however beyond a certain limit determined by other constituents it makes the viscosity of the slag too low. It also makes the flux more sensitive to moisture pick up, which causes porosity. MnO improves arc stability, due to increased oxygen potential in the arc cavity and as a result of change in oxide activity of slag. It favors high welding speed and deep penetration and decreases the sensitivity to rust and porosity. On the other hand, it decreases the current capacity.

[7]. Yang et al., investigated that bead width was not significantly affected by the type of power sources when acidic fluxes are used, however constant current source gives large bead width.

[8]. Kumar et al., When using basic fluxes. Various welding parameters such as heat input, welding speed, polarity, arc length, metal transfer etc seem to affect the weld width and reinforcement (Gurev and Stout, 1963). The B.I has no significant effect on bead width; however, reinforcement decreases with increase in basicity index.

[9]. Thodeti, et al., Weld bead width is the maximum width of the weld metal deposited on base plate. It increases flux consumption rate and affects chemistry of weld metal. Weld width and reinforcement are important physical properties of a weldment as they help in determining the strength of a welded joint.

[10]. Belton et al. (1963) has reported that as the amount of SiO2 decreases the width to depth of penetration ratio increases. Width to depth of penetration ratio is found to be slightly dependent on basicity.

[11]. Joublanc et al., shown that if the viscosity of the flux is too high, there could be depressions on the surface, and the edges of the weld bead would not be parallel. The reason for this is that the highly viscous flux impedes uniform solidification and does not allow the gases to escape.

[12]. Mcglone et al., With increase in mechanization and automation, the selection of flux and welding procedures must be more specific to ensure adequate weld bead quality is obtained.

[13]. Chandel et al., The behaviour of the flux is reported to be associated with basicity, viscosity, slag detachability, arc stability, weld penetration and bead shape. Most of the researchers have discussed the effect of process parameters on weld bead geometry

but the effect of flux composition has been discussed very little so this literature review will provide a base for the researchers in the field of SAW.

[14]. Pandey et al., Studies have also been carried out to find the influence of SAW parameters and flux basicity index on the weld chemistry and weld-metal carbon content.

[15]. Lucia et al., The effect of a post weld heat treatment (PWHT) on the microstructure and mechanical properties of the base metal, heat affected zone, and weld metal of a submerged arc welded pressure vessel steel was reported.

CONCLUSION

With the discussions on the above it is found that flux constituents have a major effect on flux behavior and bead shape geometry. The load carrying capacity of the welded joint does not only depend on microstructure but it is also affected by the physical behavior of the flux, and bead geometry. The main characteristics which are affected by flux constituents are arc stability, slag detachability, capillarity, viscosity and basicity index. These above characteristics of the flux also affect the bead geometry parameters like weld width, reinforcement, penetration and dilution. To make a strong joint in submerged arc welding the above characteristics of the flux should be considered and for this a scientific methodology is to be adopted for designing the fluxes. Research to determine the physical behaviors of welding flux that can be sensed to control consumable welding process behavior and to determine the physical property data necessary to model consumable welding process behavior is required.

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