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Effect of Flux in Submerged Arc Welding- A Review

Uma Gautam

Department of Mechanical Engineering, DTU (Research Scholar), New Delhi, India

***Abstract*— *Submerged arc fluxes play a very complex role during the welding process. Besides protecting the weld pool and influencing the bead geometry, fluxes also melt in a specific temperature range, refine the weld metal, as well as take part in slag metal reaction before finally being removed as slag. Welding flux constitutes nearly half of the cost in SAW process. Over the years, development of better welding flux compositions in terms of mechanical properties and productivity, which are economically cost effective too, has caught the eye of many researchers. In the present review paper, research work carried out by various researchers in the field of welding flux development has been reviewed.*

Keywords*—*flux, submerged arc welding, welding process.

I. INTRODUCTION

Role of fluxes in SAW is similar that of coating in stick electrodes of SMAW i.e. protection of weld pool from inactive shielding gases generated by thermal decomposition of coating material. 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, SiO_2, CaO, MgO, Al_2O_3, TiO_2, 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, CaF_2 , Na_2O, KO, MnO etc. are basic in nature (donors of oxygen) and few others such as SiO_2, TiO_2 , Al_2O 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.

II. LITERATURE REVIEW

1) **ir. J. H. PALM in 1972** investigated how Fluxes determine the Metallurgical Properties of Submerged Arc Welds and from metallurgical considerations and they concluded that the dissolved O-content (and not the total O-content) of the weld metal very likely is the decisive factor determining its impact properties, especially its transition temperature.
2) **B. M. PATCHETT in 1974,** effect of simple fluxes on heat transfer and arc stability has been investigated for both non consumable and consumable electrode arc processes using mild steel plate material. During the experiment Weld bead penetration and surface condition were used as the criteria to assess heat transfer and arc stability characteristics, and the performance of each flux was judged by comparison with a weld pass made with argon gas shielding. The results show that individual chemical compounds and their combinations have a measurable effect on heat transfer and on arc stability which is dependent on the physical and chemical properties of the compounds, the electrode polarity, and the physical nature of the electrode metal.
3) **B. G. RENWICK AND B. M. PATCHETT in 1976,** The influence of flux composition, wire diameter and current level on deposition rates, weld bead dimensions and flux consumption in submerged arc welding has been investigated and concluded that the Penetration and bead reinforcement increased with current and decreased as wire diameter increased at constant current, and were not affected by flux composition. Deposition rates, while increasing with current, decreased with wire diameter and were also unaffected by flux composition. Bead width and flux consumption initially increased with current, reached a maximum, and then tended to decrease.
4) **D. C. HILL AND C. L. CHOI in 1976,** presents the results of a study of halides as candidate materials for submerged arc welding of titanium alloys. The conclusions are following: a) Fluoride-base fluxes are required for the welding of titanium alloys. b) No oxide component is tolerable in these fluxes. c) Bead-on-plate screening for flux operability is not satisfactory. d) Fused fluxes offer superior atmospheric protection to blended fluxes. e) Fused CaF2 provides sufficient protection and fluxing for the groove welding of titanium alloys even with no auxiliary shielding. f) Auxiliary argon shielding

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results in somewhat reduced nitrogen contents, and yield stress, and therefore somewhat improved fracture toughness. g) Submerged arc welding produces intermediate quality strength toughness properties. h) Heat treating the welds at 535 C for 1 h in argon causes small decrease in strength and corresponding small increase in toughness.

5) **T. H. NORTH, H. B. BELL, A. NOWICKI AND I. CRAIC in 1978** , they investigated the influence of flux formulation on the oxygen content of submerged arc and concluded that Fused fluxes containing 45% CaF_2, 35% Al_20_3 and 20% CaO yield less oxygen in the weld deposit than do agglomerated fluxes with the same constituents, and Al additions to a 45% CaF_2, 35% Al_20_3/ 20% CaO flux lower the oxygen contents of weld deposits to below that of the electrode while the addition of up to 1.2% Al to the flux improves weld notch toughness
6) **T. W. EAGAR in 1978,** does the study on the Sources of Weld Metal Oxygen Contamination During Submerged Arc Welding and suggested that the oxygen level of submerged arc weld metal is controlled by SiO_2 decomposition in most acidic fluxes whereas the oxygen level of basic fluxes is controlled by the oxygen potential of the slag as determined by the FeO content of the slag.
7) **C. S. CHAI AND T. W. EAGAR in 1980,** studied the factors controlling weld metal chemistry during SAW & shown that the weld deposit chemistry is primarily dependent upon flux composition and also concluded that the oxygen potential of the flux is not a uniquely definable quantity nor can the weld metal mechanical properties be determined solely by the base plate, flux and electrode chemistries.
8) **POLAR, J. E. INDACOCHEA AND M. BLANDER in 1990,** closely controlled the flux(Si02-CaO-CaF2) in order to enhance the relative importance of the electrochemical Mechanism & observed that the welds produced with the high silica fluxes contain high-oxygen levels, and these are not affected by the change of polarity;
9) **N. BAILEY in 1991,** provide data showing how metal powder additions to submerged arc welds can be used safely to give increased productivity and hence reduce fabrication costs. the aim was to improve either productivity or toughness as alternative goals and result showed Metal powder additions increased efficiency, reduced weld passes and did not impair toughness.
10) **P. KANJILAL, T. K. PAL, AND S. K. MAJUMDAR in 2007,** The transfer of elements across the molten weld pool has been predicted by developing quadratic models in terms of flux ingredients with the application of statistical experiments for mixture design. The results show that some of the individual flux ingredients and their binary mixtures have a predominant effect on weld metal transfer of oxygen, manganese, silicon, and carbon contents. Analysis of experimental data also indicates that transfer of oxygen is affected by several properties of flux ingredients such as oxygen potential, thermodynamic stability, and viscosity. In the element transfer of silicon, both thermo chemical and electrochemical reaction mechanisms operate simultaneously. Transfer of manganese is principally related to the weld metal oxygen contents as well as electrochemical reaction in the molten weld pool. The transfer of carbon was generally governed by the oxidation reaction.
11) **HIROHISA TANABE & HIROYUKI HIRATA & KAZUHIRO OGAWA & MASAHIKO HAMADA in 2013**, investigates how the weld metal oxygen content varies with the arcing time by fixed welding (in which the welding torch is fixed), demonstrates the correlation between the flux property of slag viscosity and weld metal oxygen content, and proposes a model for determining the weld metal oxygen content using thermo dynamic and kinetic calculations and concluded that the oxygen content of submerged arc weld metal can be estimated by describing the deoxidization process by a linear reaction rate equation, estimating the weld metal oxygen content in the quasi-equilibrium state [O]e and the coefficient k, and determining the oxygen content of weld metal immediately after starting welding [O]i.
12) **AJAY KUMAR, HARI SINGH , SACHIN MAHESHWARI in 2015,** investigated the flow ability of developed agglomerated fluxes. The basic constituents of these fluxes are CaO, SiO_2 and $Al_2 O_3$. Minor additions of MgO, MnO, CaF , NiO and Fe-Cr are mixed in the basic constituents as to see the performance in terms of flow ability of these developed fluxes on weld metal and concluded that the flow ability of these fluxes was good and welding behaviour in terms of Arc initiation, Arc stability and weld appearance was also good.
13) **D.-W. Cho, D. V. KIRAN, AND S.-J. NA in 2015,** In this study, the constant heat input per unit length (2.5 kJ/mm) was maintained and flux consumption per unit length was analyzed for different welding conditions. The relationship among flux consumption per unit length, metal transfer mode, and resultant weld bead shapes was analyzed. it was found out that flux wall guided transfer plays an important role in forming the fusion zone in the low current tandem submerged arc welding processes. FWG metal transfer

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produces a wide bead width, but does not result in deep penetration.

14) **P. F. MENDEZ, G. GOETT, AND S. D. GUEST in 2015,** Metal transfer in submerged arc welding (SAW) has been captured in video at a rate of 10,000 frames per second by inserting a thin gauge steel tunnel along the welding path. Analysis of the videos show that at 500 A, a very chaotic, non axial globular metal transfer involving frequent explosions and bursts is present in both AC and DC polarities. Spectrometry of the arc in the weld cavity was performed, and no obvious signs of external gas entrainment were detected. The technique presented here opens the door for high speed video analysis of metal transfer and the design of complex waveforms in SAW.
15) **G. GÖTT, A. GERICKE, K.-M. HENKEL, AND D. UHRLANDT in 2016,** a combination of high speed and spatially resolved spectroscopy at 5000 fps was performed on a submerged arc welding process. This was achieved by inserting a thin gauge steel tunnel into the flux and aligning the diagnostics accordingly. Four processes were observed; both direct current electrode positive (DCEP) and direct current electrode negative (DCEN), as well as alternating current (AC) at 600 A and DCEP with a higher current at 1000 A. The observed processes showed only a slight change in chemical composition of main alloying elements in the solidified weld joint, while the oxygen content varied significantly in the droplet stage and weld joint between the processes. The high speed images indicated a correlation between droplet flux interaction and oxygen content. The spatially resolved spectra showed intense self reversed lines of Na, Ca, and Mn. Fe lines suggested that the arc was also dominated by metal vapour. Especially during the AC process, a fluctuating emission of Mn lines was observed, which correlated with the frequency of the shifting polarity.

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