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ACTIVATED FLUX WELDING: A REVIEW

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Abstract - In the recent years more importance is given to increase productivity is every engineering activity. Welding is one of the important joining techniques and hence researches constantly work on impurity productivity of welding processes. One of the techniques employed to improve penetration of welding thereby improving its productivity is to use activated flux. In this article a clear review is done on the published articles with usage of activated flux in welding. Various researchers have reported significant improvement in penetration of up to 300 % with the usage of activated flux. Some of the common fluxes employed for welding are SiO_2, TiO_2, Cr_2O_3, MnO_2, Fe_2O_3, ZnO, Na_2CO_3, $NaHCO_3$, $CaCl_2$, MoO_3, $MgCO_3$, Al_2O_3 and borax etc., The review shows that activated flux welding can be successfully employed for joining compounds like stainless steel, Mild steel, Nickel based alloys, magnesium-based alloys and P91 steel.

Key Words: Activated flux, improving productivity, penetration, SiO_2, TiO_2.

1. INTRODUCTION

Welding is a technology for joining metals in manufacturing industries. Arc welding is undoubtedly one of the most common and important joining techniques used today. Gas Tungsten Arc welding (GTAW) and Gas Metal Arc welding (GMAW) is the most popular arc welding process. GMA welding involves a feed wire which moves through the gun constantly to create the spark to form a weld by melting it. GTA welding uses long rods to join two metals directly together. The main drawback of the Arc welding process include: (a) its relatively shallow penetration capability, particularly in single pass welding operations; (b) the high sensibility of the weld bead shape to variations of the chemical composition of the base metal; and (c) low productivity [1]. GTAW is widely used in industries which are also termed Tungsten inert Gas welding. GTAW is effective for a stable arc with different types of metals. There are some limitations of using GTA welding along with benefits like there is a limited thickness of metal up to which single pass GTA welding method can be used, welding speed is low in GTA welding and the decreased deposition rate [2]. MIG welding is an arc welding procedure in which a job is produced in coalescence by heating an arc between a metal electrode feed and workpiece. It is most commonly used in industries and termed as GMA welding procedure [3, 4]. This can be suitable for ferrous as well as non-ferrous materials. It produces electrical arcs with a power supply between consumable electrodes and workpiece in the MIG welding procedure. Various kinds of shielding gases used in MIG welding are Argon, Carbon-dioxide, Helium, and different composition were taken based on the material composition. MIG welding efficiency and productivity depend on the number of welding parameters such as welding voltage, welding current, gas flow rate, welding speed, nozzle distance, electrode angle, shielding gas types, etc [5].

1.1 Activated Flux Welding

Higher efficiency and deep weld penetration can be achieved by the addition of oxygen. The activated flux TIG (A-TIG) welding method is a method in which a small amount of dioxide or fluoride is smeared on the surface of the plate before welding or some oxygen or carbon dioxide is mixed into the inert shielding gas [6]. Inorganic material is mixed with a volatile medium to form activated flux. Fluxes become conducting when it is in a molten state. In activated Tungsten Inert Gas welding, although the depth of penetration can be increased, there was an issue with overall efficiency. In evolved advanced A-TIG method, double shielding gas was used. The pure inert gas is used inside while on the outer side as shielding one, oxide or carbon dioxide is mixed with inert gas in order to protect the tungsten electrode from oxidization [7]. Although activated flux welding is an effective welding method to obtain deep penetration, the cost for preparation of a double shielding torch and two types of gas increases and restricts its applicable fields. A simplified activated flux welding method using only a simple nozzle cap was tried by some researchers. The nozzle cap was designed to aspirate oxygen from the atmosphere into the molten pool [8]. Various properties of the weld were analyzed with the help of different apparatus like image analyzer or stereo graphic analyzer [9]. The quality of welding can be determined by means of the depth of penetration. The Quality of welding also depends upon the thickness of the material. It is impossible to apply the flux evenly on the weld surface when it is in a powdered form. Hence, the powder is converted to paste form by mixing it with methanol or other substance which encompasses a tendency to vaporize quickly leaving the evenly distributed oxide flux on the surface as represented in fig.1 [10].

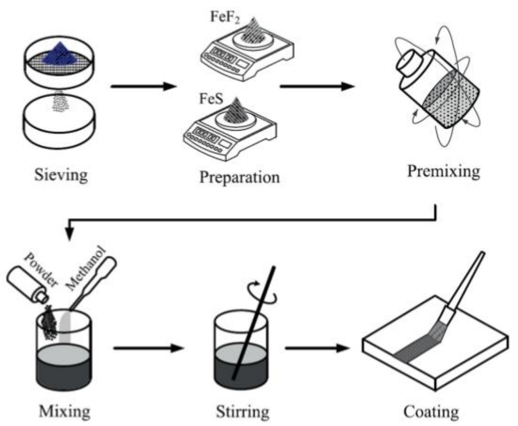

Fig-1: Method of applying flux

2. LITERATURE REVIEW

Fan et al. (2009) [11] studied the weld bead penetration of magnesium alloy with activated flux coated electrode. Welding plasma of magnesium alloy is studied by emission spectrum diagnostic technique. An acquisition system of plasma spectrum is introduced and the effect of flux on arc plasma is analyzed through the comparison of the plasma spectra of TIG welding with normal wire and flux coated wire. The mechanism that leads to increased penetration of the weld bead in flux coated wire weld is analyzed. The increase of the weld bead penetration favours the arc constriction mechanism since the activated flux is imported into the welding arc directly by filler wire. Two fluxes TiO_2 and composite flux AFM01 are used to examine the effect of the fluxes on weld penetration of magnesium alloy. The composite flux named as AFM01 is self-made and consists of various metal oxides and chlorides. The use of electrode with the above flux resulted in obvious increase in penetration compared to the normal wire. In certain cases the welding penetration was improved up to 200%. At the same time, the composite flux coated wire also caused marginal increase in weld width. The TiO_2 flux coated wire has a little effect in increase depth penetration and width. Vasudevan muthukumaran et al. (2012) [12] discussed the flux formulation for enhancing penetration of austenitic stainless steel. The Penetration Enhancing Activating Flux (PEAF) formulation which is preferably obtained as paste was used along with Tungsten Inert Gas (TIG) welding or alternatively termed as Gas Tungsten Arc Welding (GTAW). it has been observed that 87.7% SiO_2, 12.3% TiO_2 and 0% Cr_2O_3 have better depth of penetration and bead width and the penetration was improved by 300 % in comparison with conventional TIG. Dhandha & Badheka et al. (2015) [13] to results of the study demonstrated that the mechanism responsible for growth in depth of penetration and also decrease in weld bead thickness has been achieved by arc constriction. The improvement in weld penetration and decrease in bead thickness were observed using MnO_2, Fe_2O_3, ZnO, Cr_2O_3 fluxes, among these fluxes higher penetration was found in ZnO flux with an aspect ratio of penetration to weld bead width of 0.95. Vidyarthy & Dwivedi et al. (2016) [14] discussed identifying the cause for an increase in weld penetration by the A-TIG process. It is proposed that oxides and halides are the most remarkable influencers on penetration due to the vaporization of flux which constricts the arc and the flux applied on the surface will reverse the direction of surface tension resulting in a reverse marangoni mechanism. The improvement in penetration was observed due to arc constriction and reverse marangoni mechanism for most of the steels. Anup Kulkarni et al. (2018) [15] the investigates activated flux TIG welding of dissimilar steel combination of 8 mm thick plates of Modified 9Cr-1Mo (P91) steel and 2.25Cr-1Mo (P22) steel. The effect of different fluxes namely- SiO_2, TiO_2, Cr_2O_3, MoO_3 and CuO on the weld bead geometry was investigated. A TiO_2 flux has a higher aspect ratio compared to other fluxes. Ramkumar et al. (2018) [16] discussed that the microstructure attributes and structural integrity of Ti-6Al-4V welds of 5 mm depth were embraced using triggered flux (SiO_2) using ATIG welding procedure utilizing oxide surfactant. The significant inferences which reported in the analysis were: there's an increase in Length of penetration in welding present (100–240A) and also decrease in bead thickness on the usage of chromium surfactant and the tensile strength was significantly improved with A-TIG. Liu et al. (2019) [17] Findings demonstrated that the AZ31B magnesium alloy and 6061 aluminium alloy were welded by the longitudinal magnetic field hybrid cold metal transfer (CMT) welding process. Three magnetic pole structures were designed and the distributions of the magnetic fields were simulated. The results show that the platform-shaped magnetic pole structure can improve the longitudinal direction of a magnetic field in the weld zone, which was suitable to redistribute the welding heat source and decrease welding spatters. The Al/Mg interface can be divided into three zones, mixed zone ($Mg_{17}Al_{12}$ + α-Mg), Mg-rich zone ($Mg_{17}Al_{12}$), and Al-rich zone (Mg_2Al_3). The applied magnetic oscillation obviously reduced the thickness of the Mg_2Al_3 layer and dispersed the distribution of strengthening phases Mg_2Si that can prevent crack propagation. The micro-hardness value at the interface layer was increased and the shear strength of the Al/Mg joints reached a maximum of 1411N with magnetic oscillation that was higher than the normal welding process of 1072N. The increasing shear strength of welded joints was mainly due to the reduction of weld pores, the suppression of brittle phases, and the distribution of strengthening phases. Nilakantha sahu et al. (2021) [18]discussed various composition of metal oxides with different weight percentages which are used in metals like stainless steel 316L and alloy 800 in TIG welding. It's observed that the large improvement in depth of penetration will be obtained by using multi component flux. Flux A (35% TiO_2, 40% SiO_2, 15% NiO, 10% CuO) and Flux B (35% TiO_2, 40% SiO_2, 15% ZnO, 10% MoO_3) visualise the shape of weld bead, corrosive behaviour and depth of penetration of the weld. The resulted flux of full penetration was only observed using Flux B. Anand Baghel et al. (2021) [19] demonstrated the 5 types of activated fluxes which were examined at the AISI 1018 during MIG welding. Among the five fluxes namely $Al_2(SO_4)_3$, NaOH, Na_2CO_3, $NaHCO_3$ and borax, the better penetration of the weld was seen on borax. Anand baghel et al. (2021) [20] This article discussed with the effect of chloride and oxide fluxes viz. calcium chloride ($CaCl_2$) and ferric oxide (Fe_2O_3) on microstructural and mechanical properties of TIG welded joints of dissimilar SS304 and SS202 steels. Results reflected that use of oxide and chloride fluxes significantly affects the weld bead geometry, bead dimensions and penetration. The usage of oxide flux resulted in the complete penetration and approximately linear root of weld with good fusion of both the base metals. Fusion zone showed columnar dendritic cast grain structure while coarse grain structure was obtained in heat-affected zone. Pratishtha Sharma et al. (2021) [21] Described flux assisted-tungsten inert gas (FA-TIG) welding of bimetallic P92 martensitic steel-304H austenitic stainless steel (ASS) was carried out using SiO_2–TiO_2 binary flux. Seven binary fluxes were prepared by varying the proportions of flux powders (SiO_2 and TiO_2) and the effect of flux composition on weld bead cross-section was studied. The experimental results indicated that binary flux (flux B) with composition 90% SiO_2 + 10% TiO_2 yields better penetration and reduced bead width.

3. USES OF ACTIVATED FLUX IN ARC WELDING PROCESSES

The uses of activated flux for different welding processes were tried by researchers. Some of the articles related with usage of activated flux for TIG and MIG /MAG welding processes are discussed as below.

3.1 Activated TIG Welding Process

TIG welding process also known as GTAW process, is the most popular method used in manufacturing industries for thinner materials to obtain high-quality welds. A Major disadvantage of this process is that there were limitations in penetration during single pass, poor tolerance to many material compositions and more consumption of time [22]. Recently attention has been paid to a new variant welding known as E.O. Paton Electric welding institute in 1960 [23]. More recently various activating fluxes like SiO_2, TiO_2, Cr_2O_3, HgO have become commercially available from several sources and are available in the form of powder or paste (mixture of flux powder and appropriate solvent) which is applied on the faying surfaces to be welded with the help of a brush. These fluxes are used for welding materials i.e. C-Mn steel, Cr-Mo steels, stainless steels and nickel-based alloys, Aluminium and Titanium in industries for various applications [24]. Due to the application of flux, A-TIG process should be improved in weld penetration significantly [25]. The higher penetration in A-TIG welding process can be obtained with the help of some mechanisms including reverse Marangoni Effect, Arc constriction due to their negative ions and the insulating surface of flux, gravity force and Electromagnetic or Lorentz force and friction factor. But, the most proposed mechanism for deeper penetration is reverse marangoni and arc constriction [26, 27]. In the reverse marangoni effect, the surface tension gradient changes negative to positive that results the convection to turn in opposite direction and flow towards centre from edge which leads to increase in penetration. The change in magnitude and direction of surface tension gradient is due to surface active elements such as O_2 and S [28]. During conventional TIG welding, convection currents move in a centrifugal direction and the surface tension gradient is negative. Hence conventional TIG welding results in a shallow and low depth of penetration. But in A-TIG welding, when flux material is added, the directions of convection currents are inversed to a centripetal direction and the surface tension gradient becomes positive resulting in deep penetration as shown in fig.2. An anode spot is formed on the joint surface due to the flux powder which attracts electrons from the electrode that acts as a cathode. Due to the formation of anions at the edge of the arc, the density of current tends to increase at the centre of the anode. Hence, the arc is focused sharply on the weld joint, leading to deeper penetration as shown in fig.3 [29]. The activated flux TIG welding process is utilized for various types of ferrous and non-ferrous metals [30]. The effect of Cu_2O, NiO, Cr_2O_3, SiO_2 and TiO_2were investigated on SUS 304 using the GTAW process. The oxygen content increases the depth to width proportion when it is in the range of 70-300 ppm and also changes the surface tension gradient which results in increased penetration [25]. The increase in penetration was observed due to the reverse marangoni effect in a single component and multi-component oxide fluxes in case of Inconel 718 alloy steel. The single-component fluxes used in the initial experiment for the activating flux with TIG (A-TIG) welding technique were SiO_2, NiO, MoO_3, $Cr2O_3$, TiO_2, MnO_2, ZnO, and MoS_2. Four fluxes were chosen to make six new mixtures utilising 50% of each original flux due to the increased DWR of weld beads. A-TIG weldments coated with 50/50 SiO_2 and MoO_3 flux and a 75 degree electrode tip angle offered enhanced welding performance [31].

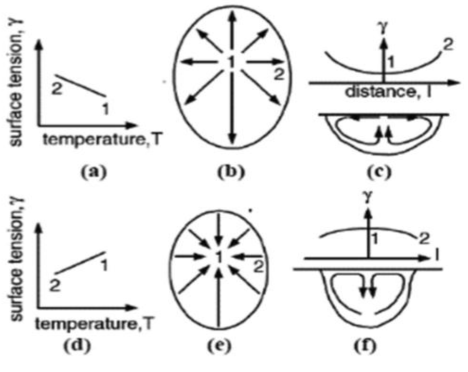

Fig-2: Reversed marangoni effect

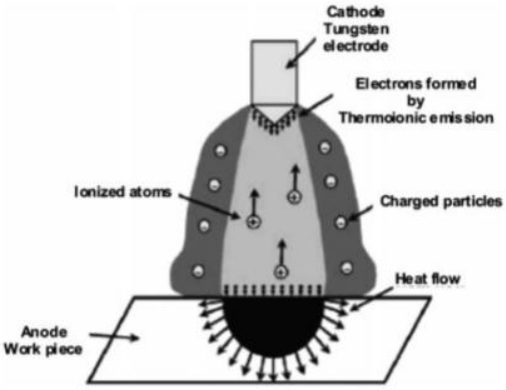

Fig-3: Arc constriction effect

3.2 ACTIVATED MIG WELDING PROCESS

Most of the research has been carried out on A- TIG method, but limited research articles only reported the usage of activated fluxes in the case of the activated GMAW process. Activating flux helped GMAW to improve the weld region and penetration and additionally enhance the tensile strength of their GMAW joint whereas the distortion of their weldments was decreased by the flux helped GMAW. $MgCO_3$, SiO_2, Fe_2O_3 these oxide fluxes are used in AISI 1020 steel. It's resulted that an $MgCO_3$ flux produced the most noticeable effect and better tensile strength and hardness [32]. While compared with two other fluxes such as SiO_2 and Cr_2O_3 in the activated MIG welding of stainless steel. In addition, they performed optimization of parameters such as welding speed, current, arc voltage on the weld quality and hardness of weldment [33]. Using three various fluxes TiO_2, Al_2O_3 and Fe_2O_3 in the activated MIG welding of Mild steel. In addition, process parameters such as welding speed, current, arc voltage on the weld quality and hardness of weldment and tensile and hardness tests were conducted to analyze the mechanical properties of flux coated welds with conventional MIG welding process without flux. It is resulted that TiO_2 coated MIG weld has shown better results compared to aluminium oxide and iron oxide [34]. Influence of flux coating on the penetration depth, micro-hardness, tensile strength and metallurgical traits. The experimental design is developed for three factors of current, travel speed and flow rate with three levels. Further, with the aid of radiography, it is concluded that the defect-free welds and tensile tests have also shown better quality using the activated flux technique [35].

4. CONCLUSIONS

A comprehensive on the usage of activated flux to improve penetration of fusion welding was done. A variety of activated fluxes like SiO_2, TiO_2, Cr_2O_3, MnO_2, Fe_2O_3, ZnO, Na_2CO_3, $NaHCO_3$, $CaCl_2$, MoO_3, $MgCO_3$, Al_2O_3 and borax etc., were tried by various researchers SiO_2 and TiO_2, seems to be the most common activated flux which comes across more frequently in research articles.

The usage of activated flux improved penetration of welding while performing welding on stainless steel, Mild steel, Nickel based alloys, magnesium based alloys and P91 steel. Eventhough a standard activated flux for a particular application is not getting arrived. It is clearly evident that activated fluxes can be effectively used for productivity improvement in welding.

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