A Review on Activated Gas Tungsten Arc Welding (A-GTAW)

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ABSTRACT: In the present work an attempt has been made to review the effect of activating flux when used with normal GTAW process, to understand the mechanisms involved behind the working of the flux, to understand the effect of different oxide fluxes on GTA welding parameters and mechanical properties of the weld. Gas Tungsten arc welding is an arc welding process that uses an arc established between a non-consumable tungsten electrode and the work-piece for joining of two similar or dissimilar metals with the application of heat or pressure or both with or without the use of filler metal. It produces high quality weld with ease and there is precise control of welding parameters but it gives shallow weld penetration, lower productivity and hence it is mainly used for welding work-pieces with thickness less than 2.5 mm in a single pass. The use of activated flux in conventional GTAW process is one of the most significant advancements for overcoming the shortcomings of GTA welding, which helps in increasing the depth of penetration and depth to width ratio of the weld pool, thereby increasing the productivity of the process and also it helps in achieving better mechanical properties.

***Index Terms*—Activated flux, A-GTAW, depth of penetration, depth to width ratio.** *(Keywords)*

I. INTRODUCTION

Gas–tungsten arc welding (GTAW), also called tungsten inert gas welding (TIG), is a process that melts and joins metals by heating them with an arc established between a non-consumable tungsten electrode and the work piece under a shielding gas. GTAW is used in modern industry, especially for stainless steel, titanium alloys and other materials for high quality weld. Its applications include welding of sheet, plate, tube, and castings for use in aerospace, power generation, shipbuilding, and other industries. GTAW process has many advantages like high quality, easy and precise control of welding parameters, etc. And at the same time, there are many disadvantages associated with this process, such as shallow weld penetration and lower productivity.

As a result, GTAW is mainly used for welding the work-piece with thickness less than 2.5 mm in a single pass. One of the most notable advancement in this welding process is the use of activating flux. Activated GTAW process that increases the penetration was first proposed by Paton Electric Welding Institute in the 1960s [1-4]. Activating flux is a mixture of inorganic material suspended in a volatile medium. A thin layer of the flux is brushed on to the surface of the joint to be welded prior to welding followed by application of welding arc for melting the base metal. [5]. Application of these fluxes results in many desirable effects on the welding like increasing the depth of penetration, increasing the depth to width ratio the of the weld pool.

II. LITERATURE SURVEY

Activated GTAW process that increases the penetration was first proposed by Paton Electric Welding Institute in the 1960s. [6] The commonly used fluxes are TiO_2, SiO_2, Cr_2O_3, ZrO_2 halide fluxes. These fluxes can be prepared by using different kind of component oxides packed in the powdered form with about 30-60 μm particle size. To produce a paint-like consistency, these powders are mixed with acetone, methanol, ethanol etc. The coating density of the flux should be about 5-6 mg/cm². A thin layer of the flux is brushed on to the surface of the joint to be welded prior to welding followed by application of welding arc for melting the base metal. [6-7]

Application of these fluxes results in a) increasing the arc voltage compared with conventional GTAW process under identical conditions of arc length, welding current which in turn burns the arc hotter and increases the joint penetration and weld depth-to-width ratio, which helps in reducing the angular distortion of the weldment b) increasing the constriction of the arc which increases the current density at the anode and the arc force action on the weld pool. [8-10]The arc constriction also facilitates the development of weld of high depth to width ratio. Increase in depth of the penetration in turn increases the rate of lateral heat flow from the weld pool to the base metal. Increased rate of heat flow from the weld pool causes grain refinement owing to the high cooling rate and low solidification time. High depth to width ratio, effect imparted to the weld pool by activated fluxes is found similar to the high energy density process. Activated flux assisted GTA welding processes have been developed for joining of titanium and steel for nuclear and aerospace applications. The commercial fluxes tend to produce a surface slag residue which is required to be removed.

How to Apply the Flux?

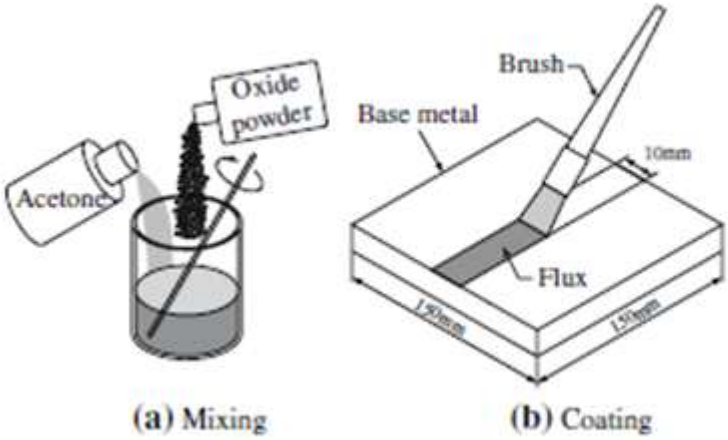

Figure 1: Schematic diagram of GTA welding with activating flux

A-GTAW is a kind of welding with a thin layer of fine flux covered on the surface of the base material. Prior to welding, flux mixed with acetone is applied on the surface of the work piece to be welded. The acetone evaporates within seconds leaving a layer of flux on the surface. During A-GTAW, a part or all of the fluxes is molten and vaporized. As a result, greatly increased penetration weld with good mechanical property can be obtained. [11-12]

Proposed Mechanisms of A-GTA Welding Process:

According to literature there are two proposed mechanisms associated with the working of Activated flux in GTAW process. Both of them are explained below.

1. <u>Reverse of Marangoni Effect</u>

The ability of flux to wet the surface of the molten pool affects on the composition which in turn modifyies the surface tension. Change in fluid flow is related to Thermal Coefficient of Surface Tension (TCST) of the molten pool:

- If the TCST is negative, the cooler peripheral regions of pool will be having a higher surface tension than the centre of the weld pool and the flow of the molten metal will be directed outwards creating a wide shallow weld pool.

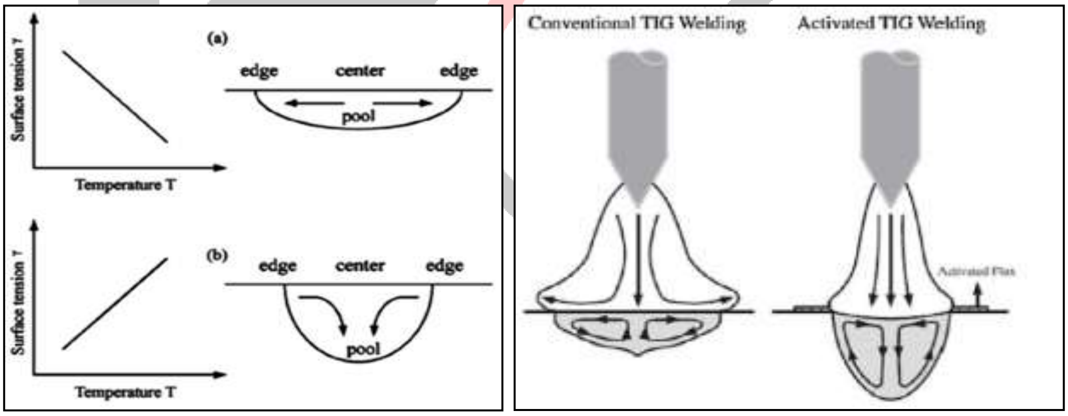

Figure 2: Marangoni convection mode in the weld pool a) conventional GTAW and b) A-GTAW

- Heiple and Roper proposed that surface active elements such as oxygen, sulfur and selenium could change the temperature coefficient of the surface tension for iron alloys from negative to positive and further influence the direction of the fluid flow in the weld pool.

So for materials having a positive gradient, the flow of the molten metal will be reversed to the centre of the weld pool and in the centre the molten metal flows down. This creates a narrower deeper weld pool for precisely the same welding conditions. For stainless steels, sulphur can change the TCST and hence alter the penetration depth of the resulting weld. Other elements such as calcium or aluminum, also affect penetration, though these elements probably tie up the elements affecting TCST, such as sulphur, rather than having a primary affect themselves. It is believed that the activating flux had a similar effect on the weld pool. [13-20]

2. Arc constriction:

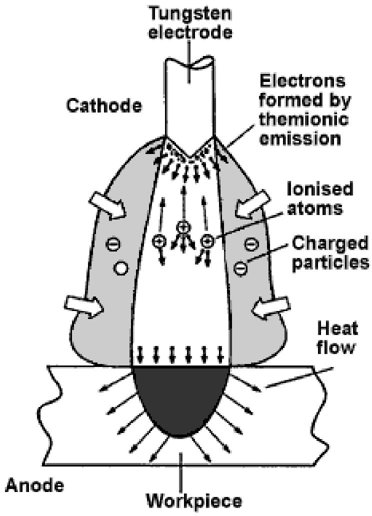

Figure 3: Arc Constriction

As the conductivity of the flux is much lower than that of the metal vapors, and the melting and boiling points of the flux is higher than that of the weld metal, the metal evaporation would be generated only in the central regions of the welding arc, where the temperature is higher than that of the dissociation temperature of the flux compounds, which leads to a reduction in the conductivity area of the anode spot [21-22.]

Advantages

Advantages of the A-GTAW process compared with conventional GTAW are as follows:

- There is increase in productivity due to greater depth of penetration, i.e., up to 8 mm in stainless steel as compared to 3mm for conventional GTAW. The increase in productivity is derived through a reduction in welding time and/or a reduction in the number of welding passes.
- There is reduction in distortion, i.e., the use of a square edge closed butt joint preparation reduces weld shrinkage as compared to a conventional multipass V butt joint.
- Problems of inconsistent weld penetration associated with cast-to-cast material variations can be eliminated e.g., deep penetration welds can be made in low sulphur stainless steel (~0.002%), which would otherwise show a shallow, wide weld bead in conventional GTAW welding.
- Better mechanical properties
- Filler wire consumable is not required
- Edge preparation is not required.
- Welding power consumption is less compared to conventional GTAW
- Back gouging and grinding can be eliminated.

Disadvantages

Despite the productivity benefits of A- GTAW, industry to date has been slow in exploiting this process owing to the following reasons:

- The use of the flux is seen as an additional cost and its application an additional operation. [23]
- The commercial fluxes tend to produce an inferior surface finish compared to conventional TIG welding in mechanized welding operations but in manual welding operations, the surface roughness is similar.

There is a light slag residue on the surface of the weld after welding and to remove it often rigorous wire brushing is required.

Er Bhawandeep Singh, Er Avtar Simgh (2015); studied the effect of different kinds of oxide powder fluxes such as Cr_2O_3 , $MgCO_3$, 1:1 mixture of both these powder, MgO, CaO, Al_2O_3 mild steel. They found that activating flux aided GTAW increased the weld penetration, tending to reduce the width of the weld bead. Also with the application of flux on mild steel its hardness gets reduced depth to width ratio increases. The Cr_2O_3 flux produced most noticeable effect. [5]

S.W. Shyu, H.Y. Huang, K.H. Tseng, and C.P. Chou (2007); investigated the effects of oxide fluxes on weld morphology, arc voltage, mechanical properties, angular distortion and hot cracking susceptibility as compared to conventional GTAW, when applied to the of welding of 5 mm thick austenitic stainless steel plates.Al_2O_3, Cr_2O_3, TiO_2, SiO_2 and CaO were applied on a type 304 stainless steel for this purpose. They found that by using Cr_2O_3, TiO_2, and SiO_2 significant increase in penetration is obtained and also A-GTAW can increase the retained delta-ferrite content of stainless steel 304 weld, which consequently reduces the hot-cracking susceptibility of as-welded structure.[1]

E. Ahmadi, A. R. Ebrahimi and R. Azari Khosroshahi (2013); studied the performance of AGTAW on 304L austenitic stainless steel plates .They used two oxide fluxes, TiO_2 and SiO_2 to investigate the effect of A-GTAW process on weld morphology, microstructure and mechanical properties of weldments. They found that A-GTAW could increase the weld penetration and depth-to-width ratio of the weld pool and A-GTAW could increase the delta-ferrite content of weld metals and improve the mechanical properties.[24]

M. Zuber, V. Chaudhri, V. K. Suri, and S. B. Patil (2014); investigated the effect of SiO_2 on welding distortion, ferrite number, hardness value and depth of penetration on welding of austenitic stainless steel 304L plates having thickness of 8 mm. They found that there was an increase in depth of penetration and weld aspect ratio which resulted in lower angular distortion. They obtained a ferrite content of 14% by weight in the weld joint obtained; this increase in the ferrite content was attributed to the flux which helped in rapid cooling of the weld joint.[25]

Prof. A.B. Sambherao (2013); investigated the effect of TiO_2, Fe_2O_3, SiO_2 and Al_2O_3 fluxes on the surface appearance, weld morphology and retained δ-ferrite content obtained with the GTAW process when applied to the welding of 6mm thick (AISI 316L) austenitic stainless steel plates. He observed that the flux seemed to constrict the arc which helped in increasing the current density at the anode spot, there by resulting in higher weld depth. He found out that a significant increase in penetration (around 300 %) was obtained in welds done with a TiO_2 activating flux. This effect is due to the reversal of Marangoni convection and the arc constriction produced by the flux. Al_2O_3 produced only a small increase in weld depth; therefore he proposed that the fluid flow appears to be in the outward direction when Al_2O_3 flux is added. As Fe_2O_3 is unstable, when Fe_2O_3 mixed with TiO_2 flux was used, the oxygen content in the weld pool increased to a larger extent. This reversed the Marangoni convection very sharply; even more increase in the weld depth was obtained compared to when only TiO_2 flux was used. He recommended that combination of fluxes such as mixture of TiO_2 and Fe_2O_3 flux should be used to achieve desirable properties of the weld.[26]

Akash.B.Patel and Prof.Satyam.P.Patel (2014); firstly studied the effect of each GTAW parameters on the weld's joint strength and then they determined the optimal parameters using the Taguchi method with L9 (9) orthogonal array. SiO_2 and TiO_2 fluxes were used to investigate the effect of activating flux on the weld mechanical properties of 321austenitic stainless steel. They observed that the activating flux aided GTA welding increased the weld penetration, thereby reducing the width of the weld bead. The SiO_2 flux produced the most significant effect. Also, the welded joint presented better tensile strength and hardness.[27]

Tseng et al (2010); investigated the effect of oxide powdered fluxes on weld morphology, angular distortion, and hardness of a 6mm thick type 316stainless steel plate. They observed that the SiO_2 flux is more preferable over Al_2O_3. Additionally they also concluded that to obtain high quality welds and stable weld arc, the activated GTAW process requires large diameter electrodes to support a given level of the weld current.[28]

Sakthivel et al (2011); compared the effect of AGTAW with conventional GTAW on welding of 316L(N) .They compared the creep rupture behavior of 316L(N) base metal, and weld joints made by A-GTAW and conventional GTAW at 923 K over a stress range of 160–280 MPa. They found an enhancement in creep rupture strength of weld joint fabricated by A-GTAW process over conventional GTAW process.[29]

Badheka et al(2013); studied the effect of oxide fluxes such as TiO_2, ZnO and MnO_2 on welding parameters like welding current, welding speed, joint gap and electrode diameter on a 6 mm thick dissimilar weld made between carbon steel to stainless steel. They observed that (1) the highest depth/width (D/W) ratio was observed under TiO_2 and ZnO fluxes compared to conventional GTAW process, (2) Lowest angular distortion was observed under TiO_2 flux compared to conventional GTAW process and (3) Mechanical properties, Joint Efficiency of Activated flux welds are higher compared to conventional GTA welding process.[30]

III. Summary:

As per the theory discussed in the literature review, we can summarize the following points:

1. The use of activated flux leads to an increase in the weld penetration and depth to width ratio of the weld as compared to conventional GTAW process.
2. Out of all the oxide fluxes used SiO_2 and TiO_2 showed the most noticeable results in increasing the depth of penetration of the weld pool as compared to conventional GTA welding.
3. An increase in the delta ferrite content of the weld is obtained which can be attributed to the flux which assisted in rapid cooling of the weld pool.
4. Improved mechanical properties were obtained in the weldment as compared to conventional GTAW process.

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