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Effect of Different Fluxes on DOP and Bead Width in TIG Welding: A Literature Review

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Abstract: *The flux assisted GTAW or A-TIG process developed at the Paton welding institute. In this paper studied effect on depth of penetration and bead width by using different types of fluxes. Here we are including fluxes like Fe_3O_3, MnO_2, CrO_3, CaO, TiO_2, MoO_3 and SiO_2. There are many forces affecting on high depth of penetration and narrow bead width, which are; Marangoni force, Lorentz or Electromagnetic force, Buoyancy force and Aerodynamic drag force. High depth of penetration and narrower bead width achieved using A-TIG welding. Here studied that DOP, bead width and D/W (aspect) ratio enhancing fluxes are the Co_3O_4, CuO and Cr_2O_3. It is conclude that sulfur and oxygen are main constituents of base metal for increasing DOP and D/W (aspect) ratio. Electric current has a positive effect on weld penetration and D/W (aspect) ratio.*

Keywords: *A-TIG welding, Bead width, Depth of Penetration, Flux, Marangoni effect.*

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I. Introduction

Gas tungsten arc (GTA) or tungsten inert gas (TIG) welding process is one of the most common permanent metal joining processes used for welding of stainless steels, titanium alloys, aluminum alloy sand other non-ferrous metals because of its good quality weld and low cost equipment. It is popular to weld thin sections and can be used for various welding positions such as horizontal, vertical and overhead and also popular to produce a smooth hand clean weld. Although the process attributes several advantages, low weld penetration renders it less appropriate for industrial use. To overcome the limitation of low penetration in a single pass, groove design and Multi pass is required to weld thick sections which decrease productivity of the process and increase cost of production. Tungsten inert gas (TIG) welding performance can be improved with an inorganic powder named 'activating flux', which is laid on the metal before welding [12] One of the most notable techniques is the use of activating flux in TIG welding process. 90–95% application of activating fluxes has been reported in A-TIG process. The A-TIG welding totally eliminates filler wire addition, reduces edge preparation time [13] and enhances the penetrating power in the weld pool. Hence, single pass weld with higher welding speed can be achieved.

1.1 Mechanism of TIG welding

It is also called as tungsten inert gas welding. It is an arc welding process where coalescence is produced by heating the work-piece with an electric arc struck between tungsten electrode and work-piece. To avoid atmosphere contamination of the molten weld pool, a shielding gas is used. If required, a filler metal may be added. In this process non consumable tungsten electrode is used. First of all current supply and shielding gas switch on. Afterwards with base metal the tungsten electrode strike for producing arc, when tungsten end and base metal between gap is maintained at a 2-3 mm then sufficient arc will be produce. Then provided shielding gas protect the weld part to atmosphere to resist oxidation of weld.

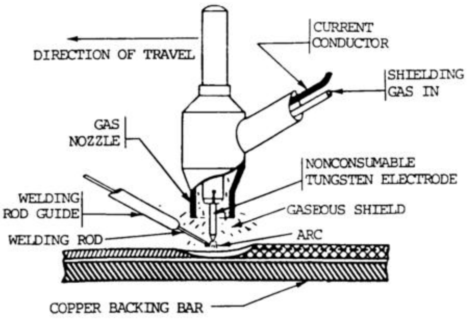

Fig. 1. TIG Welding mechanism

1.2 Procedure for A-TIG application

Mix the oxide powder with acetone in a 1:1 weight ratio,to produce a paint-like consistency. The ratio of flux pow-der to carrier solvent is not critical, it must be mixed to a consistency that can be "painted on" .The flux mixture will thicken over time as the acetone evaporates. Add more acetone as needed to return the mixture to the proper consistency. Using the small paint brush, apply oxide powder to the center of the plate. The layer should be sufficiently thick so that the flux appears. The layer should be slightly wider than the anticipated width of the weld bead. Flux should sufficiently be adhered to the surface to combine A-TIG to be used in all position. During welding, arc length has to be maintained as per welding procedure specification. After welding, any unconsumed flux can be removed with ease. Flux that has been consumed by the arc creates a tenacious layer. A residual slag typically remains on the top surface to the weld pool can be removed by grinding or aggressive wire brushing **[1]**

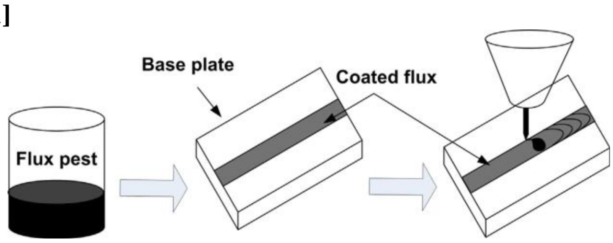

Fig. 2. A-TIG Welding mechanism

II. Literature Review

Visvesh J Badheka et al; they have study and observed depth of weld penetration and bead width using A-TIG welding. They had taken fluxes as a CaO, Fe_2o3, Tio_2, ZnO, MnO_2 and CrO_3. From their observation they concluded that increasing in penetration and the decrease in bead width are significant with the use of the activating fluxes Fe_2O_3, ZnO, MnO_2 and CrO_3 and maximum depth to width ratio (aspect ratio) they achieved using ZnO, MnO_3 and CrO_3 are 0.95, 0.85 and 0.83 respectively. In case of normal TIG they secured 0.29. They have conduct this experiment with 200A weld current, 160A creater current, 100 mm/min travel speed pure argon shielding gas experiment were carried out by them on 6mm P91 plates. They concluded that arc constriction plays major role in depth of penetration. [1]

R kumar et al; from their review they had concluded that During TIG welding the surface tension gradient is negative and the convection movements are centrifugal and it leads to shallow penetration. The addition of activated flux induce an inversion of the convection currents changing the sign of the surface tension gradient, resulting convection movements changed to centripetal. Hence, the penetration depth increases. They have studied that TIG welding with SiO2 and MoO3 fluxes achieves an increase in weld depth and a decrease in bead width respectively. The SiO2 flux can facilitate root pass joint penetration. Without activating flux weld depth achieved is very less and bead width is unnecessarily high. [2]

Hung Tseng et al; investigated the influence of oxide-based flux powder and carrier solvent composition on the surface appearance, geometric shape, angular distortion, and ferrite content of austenitic stainless steel tungsten inert gas (TIG) welds. The flux powders comprising oxide, fluoride, and sulfide mixed with methanol or ethanol achieved good spread ability. For the investigated currents of 125 to 225 A, the maximum penetration of stainless steel activated TIG weld was obtained when the coating density was between 0.92 and 1.86 mg/cm2. The results show that higher current levels have lower ferrite content of austenitic stainless steel weld metal than lower current levels. [3]

Cheng Hsien Kuo et al; found that the surface appearance of TIG welds produced with oxide flux formed residual slag. TIG welding with SiO2 powder can increase joint penetration and weld depth-to-width ratio and therefore the angular distortion of the dissimilar weldmelt can be reduced. Furthermore, the defects susceptibility of the as welded can also be reduced. [4]

Paulo et al; concluded that without activating flux weld depth achieved is very less and bead width is unnecessarily high. Best result is achieved in case of silicon dioxide, and highest penetration. CaO and Al oxide is not advisable to use because they are giving same or near result as conventional TIG welding. [5]

Hsien Kuo Cheng et al; investigated their study the Performance of Dissimilar A-TIG Welds. The experimental results indicated that the SiO2, Fe2O3 and Cr2O3 fluxes can increase joint penetration in both of the stainless steel and the mild steel. The CaO flux only can increase the joint penetration of the mild steel. The reversed Marangoni convection are considered to the main factors for increasing penetration of A-TIG on dissimilar welds in this study. Furthermore, TIG welding with SiO2 powder can significantly reduce the angular distortion and increase the tensile strength of the dissimilar weldment. [6]

R. Ebrahimi et al; the addition of an activating flux led to an increase in the penetration depth and a decrease of the width. Simulations showed the Marangoni effect combined with Lorentz forces in TIG and A-TIG welding processes. The results of experiments agreed with the simulation conducted for TIG welding. A-TIG weldment exhibited mechanical properties (including strength, ductility, and hardness) better than those of TIG welding without flux. [7]

Heiple et al; revealed that surface active elements in the molten pool change the temperature coefficient of surface tension from negative to positive, thereby reversing the Marangoni convection direction from outward to inward. As the direction of the fluid flow in the molten pool becomes inward, the joint penetration increases dramatically. [8]

Kuang-Hung et al; revealed that Cr2O3 flux assisted TIG welding can create a high depth-to width ratio weld. Since the A-TIG welding can reduce the heat input per unit length in welds and the residual stress of the weldment can be reduced. TIG welding with Cr2O3 flux can increase the retained ferrite content of stainless steel 316L weld metal and in consequence, the hot cracking susceptibility is reduced. [9]

Jay J vora et al; they carried out investigation on mechanism and weld morphology of activated TIG welded bead on plate weldments of reduces activation ferrite/martensite steel using different six oxide fluces and they are Al_2O_3, Co_3O_4, CuO, HgO, MoO_3 and NiO. Their experimental results Indicates that enhanced penetration has been achieved with use of fluxes Co_3O_4, CuO, HgO and MoO_3 from this Co_3O_4 and CuO gave through penetration due to combined effect of reverse marangoni and arc constriction. Their experiment shows that weld depth obtain with TIG welding was found to be 3.6mm whereas with the use of oxide fluxes Co_3O_4, CuO, HgO and MoO_3 are 7.8, 8.1, 5.5 and 5.2 respectively was obtained. Their Experimental results indicating that enhanced depth width ratio values of 0.95, 0.88, 0.53 and 0.51 were obtained with fluxes Co_3O_4, CuO, HgO and MoO_3 respectively compared to TIG welding. Arc constriction mechanism present only in Co_3O_4 and CuO in A-TIG welding. This phenomenon completely absent in other fluxes. [10]

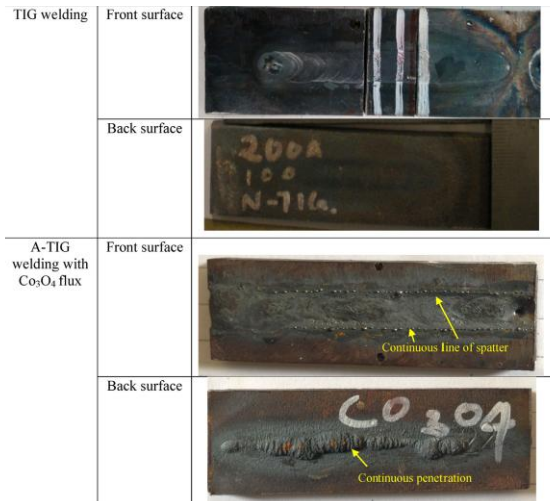

Fig. 3. Surface appearance of welded plates. [10]

III. Effect OF TIG & A-TIG ON Weld Quality

3.1 Effect of flux on arc voltage

Arc voltage is directly proportional to Arc length. In automatic mode arc length set to be constant. It is found that the arc voltage increases when TIG employed with flux. Change in arc voltage is due to effect of oxides. Welding are containing lot of free electrons activated flux decompose at are temperature and generate positive ions, Result in attraction of decompose flux additives attract electrons causing welding arc to constrict. Constriction of arc increases temperature at a mode.

3.2 Marangoni effect

With the TIG welding the flow was predominate drifted towards the edges from the center. The Conventional fluid flow for any fluid system is always from regions with higher surface tension towards lower and the surface tension is gravity dependent on the temperature as weld center has the higher temperature compared to edges the surface tension is lower at edges compared to center. Thus fluid in molten state was drifted from center to the edges. This was reason for the characteristic weld shape with having wider and shallower bead in TIG welding. This widely referred as Marangoni effect. [10]

3.3 Reverse Marangoni effect

Direction of this fluid flow in weld pool is changed by surface active elements Sulphur and oxygen. Due to this elements dependency of surface tension on temperature is decreases and reversed fluid flow happens. During A-TIG welding processes with oxides fluxes there are lot of oxygen molecules freely available in the solidifying weld pool which influences the fluid flow from edges to the center. Thus deeper and narrower bead shape is obtained. Higher Depth Width ratio indicates strong reversed Marangoni effect. [10]

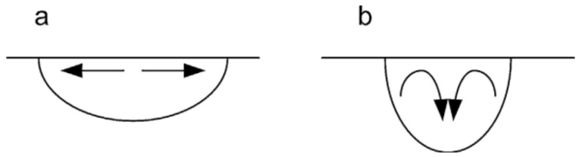

Fig. 4. Marangoni convection in (a) Conventional TIG and (b) A-TIG welding process [14]

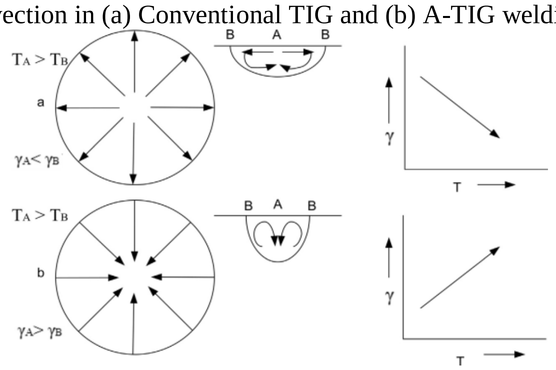

Fig. 5. (a) Negative surface tension temperature coefficient; (b) positive surface tension temperature coefficient [14]

3.4 Effect of flux on depth of penetration/weld depth

There is a significant variation in the penetration of the welds. Weld depth obtained was the least amongst all for the weld beads done without flux. The greater penetration of A-TIG welding is caused by constriction of the electric arc. Arc constriction effect of flux is related to the evaporation of the flux and its preferential ionization. This could increase the anode cur-rent density and the arc force acting on the welding pool [16] . Marangoni effect reveals that the surface tension at the higher temperature region is lower than that at the lower temperature [17] .Weld pool centre is having high temperature so the surface tension near the centre is low as compare to outer region. So fluid flow width of bead is higher and penetration is less. Sur-face active elements such as oxygen and sulfur can change the direction of the fluid flow in weld pool [18] .Weld penetration depth dramatically increases in the presence of some individual oxides, such as Fe2O_3, TiO_2, ZnO, MnO_2 and CrO_3. Reversal of Marangoni effect took place because of free oxygen available in the weld pool due to decomposition of oxide fluxes. This led to more surface tension at the weld pool than that near the edges. Therefore more weld depth was obtained [17]. However, the CaO has no effect on A-TIG penetration whereas TiO_2 shows full penetration in discontinuous length.

3.5 Effect of flux on bead width

There were significant variations in the bead widths of the welds. The widths with flux become narrower than those with-out it. When Fe2O3, ZnO, MnO2and CrO3flux was used, the surface tension at the center of the weld pool became higher than that near the edges

3.6 Forces acting in A-TIG welding

Marangoni forces: this force “On certain curious Motions at the Surfaces of Wine and other Alcoholic Liquors”. Subsequently Carlo Marangoni did his doctoral work on this force and explained that ‘fluid always flows from low surface tension region to high surface tension region’. Due to Marangoni force in weld pool, fluid flow in the centrally out-ward direction and thus transfer a maximum of its heat to the wall of the weld pool rather than bottom. This action leads it to the high width and low depth of penetration during TIG welding [14]

Electromagnetic or Lorentz force: Electromagnetic force is caused by the interaction of the induced magnetic field and that of the current passes through a conductor. The welding current induces a magnetic field around the conductor. Resulting Lorentz force acts toward the weld pool center in the direction of current flow. [14]

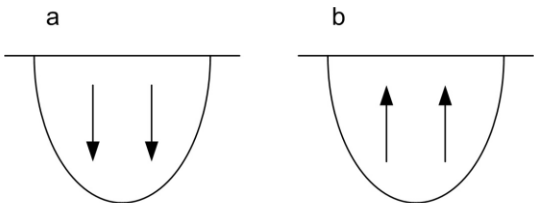

Fig. 6. (a) Electromagnetic or Lorentz force and (b) Buoyancy force in molten weld pool [14]

Buoyancy force: it is caused by the density difference of the molten metal in the weld pool. Molten metal density decreases with the temperature increase. Due to buoyancy force, the fluid tends to flow from high density to low density. During A-TIG welding, it always acts toward the surface of the weld pool. However, buoyancy forces are generally less effective as com-pared to other forces during TIG welding of plate up to a thickness of 10 mm. [14]
Aerodynamic drag: it produced by the action of the arc plasma flowing over the surface of weld pool which induce an outward flow along the surface of the weld pool showing. [14]

IV. Gape Identification

There are significant research done on welding current, welding voltage, shielding gas flow rate and fluid flow rate in molten weldment. Research also has been done for the DOP, bead width and D/W (aspect) ratio. Following points were not covered by reference researchers in A-TIG welding.

- Significant research has been done on the plates or on the standard specimen of like mild steel, stainless steel etc. no one has study effects of parameters on pipe welding.
- Effect of process parameters studied on D/W ratio, DOP and Bead Width but still that parameters effect did not studied for toughness, hardness, tensile strength, compressive strength.
- Different optimization techniques were not covered in given reference of research.
- They have not studied and compared their experimental results with FEA analysis of A-TIG welding process.
- They have not studied the post heating effect and pre heating effect on the DOP, bead width and D/W (aspect) ratio by A-TIG welding.
- They have not studied the effect of different input parameters on its output in different thickness of plate.

V. Conclusion

- Every flux has its own property and every flux can’t give good penetration. Flux effectiveness is depending on the chemical and physical property of the base material.
- Some researchers have identified that sulfur and oxygen are domain constituents of base material which increase the depth of penetration as well as d/w (aspect) ratio.
- In TIG welding without activating flux we can’t achieve good penetration and also the weld bead width will be unnecessary high. While in with using activating flux d/w (aspect) ratio is high, DOP is sufficient or more then the thickness of weldment and bead width is narrower.
- The Cr_2O_3, CuO and Co_3O_4 fluxes are highly effective and gives more depth of penetration as compare to other fluxes in A-TIG welding.
- Researchers have conclude that CuO and Co_3O_4 are the fluxes which are highly affected on DOP and bead width due to the arc constriction parameter.
- There is no significant change in microstructure and micro-hardness values of the TIG and A-TIG weldment were observed. Weld portion has mix coarse and fine martensitic structures.
- It is also conclude that Arc length and the welding speed have a negative effect on the penetration depth in A-TIG welding, while current has positive effect on the same.
- Electrode tip geometry has little effect on the weld pool geometry.

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