EFFECT OF FLUX ASSISTED TUNGSTEN INERT GAS WELDING (ACTIVATED TIG) ON WELD BEAD MORPHOLOGY OF AUSTENITIC STAINLESS STEEL 304

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ABSTRACT: Gas Tungsten arc Welding (GTAW) is fundamental in those applications where it is important to control the weld bead shape and metallurgical characteristics. This process is, however, of low productivity, particularly in the welding of large components. Activated Tungsten Inert Gas (A-TIG) welding improves welding pool penetration significantly, achieved usually by applying a thin layer of active flux composition on the surface of metal substrate.

Austenitic Stainless Steel 304 is used extensively in day to day life applications. A novel variant of autogenous TIG welding process (A-TIG) was applied on SS 304 in which oxide, fluoride, chloride of metal powders PbO, NaF, $ZnCl_2$ were used as fluxes to produce a bead on plate welds to achieve desired depth of penetration at lowest het input possible.

The purpose of present work is to investigate the effect of oxide, fluoride, chloride fluxes on weld bead morphology namely, width(w), depth of penetration(d) and aspect ratio(d/w) and the best optimal results were evaluated.

KEYWORDS: A-TIG Welding, Autogenous, Fluxes, Weld Morphology, Stainless Steel.

1. INTRODUCTION:

1.1. TIG welding:

Gas Tungsten Arc Welding (GTAW), also known as Tungsten Inert Gas(TIG) welding, is an arc welding process that uses a non-consumable tungsten electrode to produce the weld. The weld area is protected from atmospheric contamination by an inert shielding gas (argon and helium), and a filler metal is normally used, though some welds, known as autogenous welds, do not require it. A constant-current welding produces energy i.e.,conducted cross the arc.

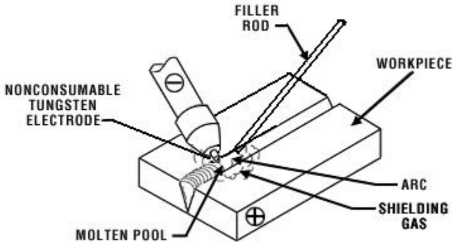


Fig 1.1. TIG Welding Process

1.1.1. Applications:

While the aerospace industry is one of the primary users of gas tungsten arc welding, the process is used in a number of other areas. Many industries use GTAW for welding thin workpieces, especially non-ferrous metals. It is used extensively in the manufacture of space vehicles, and is also frequently employed to weld small-diameter, thin-wall tubing such as those used in the bicycle industry. In addition, GTAW is often used to make root or first pass welds for piping of various sizes. In maintenance and repair work, the process is commonly used to repair tools and dies, especially components made of aluminium and magnesium.

1.2. Activated Flux TIG Welding:

The major limitation of TIG Welding of stainless steels is the limited thickness of materials which can be welded in a single pass and thus resulting in low productivity. Therefore, improvement in weld penetration is desired in stainless steel welds produced by TIG welding. A variant of the TIG welding process called A-TIG is known to overcome the limitations. This process involves a thin coating of the activated flux on the joint before welding. The attributes for improvement in penetration by using activated flux are constriction of the arc as well as reversal of Maragoni flow in the molten weld pool.

The flux in the form of powders is made into a paste by mixing with acetone and the paste is applied on the surface to be welded by means of a brush. The acetone evaporates within seconds leaving a layer of flux on the surface. The activated flux gets vaporized during welding and constricts the arc by capturing electrons in the outer regions of the arc. Thus restricting current flow to the central region of the arc and will increase the current density in the plasma and at the anode resulting in deep weld pool and narrow arc. Due to an increase in the dissolved oxygen content, the coefficient of surface tension changes from negative to a positive value. This results in the reversal of Maragoni flow and creates a narrow and deep weld pool.

1.2.1. Maragoni effect:

In the absence of a surface-active agent, the warmer liquid metal of lower surface tension near the centre of the pool surface is pulled outward by the cooler liquid metal of higher surface tension at the pool edge.

1.2.2. Reverse Maragoni effect:

In the presence of asurface-active agent, on the other hand, the cooler liquid metal of lower surface tension at the edge of the pool surface is pulled inward by the warmer liquid metal of higher surface tension near the centre of the pool surface. A-TIG Welding works on the principle of Reverse Maragoni effect.

2. LITERATURE REVIEW:

Kamal H.Dhandha,Vishvesh J,Badheka..etal[1] GTAW process is less productive when applied to large components. A novel variant of autogenous TIG welding process was applied on 6 mm thick P91 steel in which oxide powders CaO, Fe_2O_3, TiO_2, ZnO, MnO_2 and CrO_3 were used to produce a bead on plate welds. The experimental results indicated that the increase in depth of penetration is significant with the use of Fe_2O_3, ZnO, MnO_2 and CrO_3. in case of ZnO, MnO_2 and CrO_3 are 0.95, 0.85 and 0.83 respectively and in case of normal TIG, it was 0.29. There is increase in aspect ratio with the flux ZnO by 320% as compared to conventional TIG welding process.

Kuang-Hung Tseng[2] Five kinds of oxide fluxes MnO_2, TiO_2, MoO_3, SiO_2 and Al_2O_3 were used to investigate the effect of activated TIG process on weld morphology, angular distortion of type 316L Stainless Steels. An autogenous TIG welding was applied to 6 mm thick stainless steel plates. The oxide fluxes used were packed in powdered form. The experiment results indicated that SiO_2 flux facilitated root pass joint penetration, but Al_2O_3 flux led to the deterioration in the weld depth and bead width compared with conventional TIG welding process.Activated TIG welding can increase the joint penetration and weld depth to width ratio, thereby reducing angular distortion of the weldment.

E.Ahmadi, A.R.Ebrahimi,R.Azari Khosroshahi[3] In this study, performance of A-TIG welding on 304L austenitic stainless steel plates has been presented. Two oxide fluxes, TiO_2 and SiO_2 were used.The experimental results indicated that A-TIG welding could increase the weld penetration and depth to width ratio. It was also found that A-TIG welding could increase the delta-ferrite content of weld metals. The weld metal presented an austenite and delta-ferrite structure and it is different from that of base metal.

Ravi Duhan and Suraj Choudary[4] The use of activating flux effects the different properties of the joint produced by the welding. In the present work, Fe_2O_3, $MgCl_2$, MnO_2, and ZnO were used as activating flux to investigate the effect of activated TIG process on hardness of grade 304 stainless steels. The results show that MnO_2 flux can only led to increase in the hardness in weld zone except the other flux used.

S.W.Shyu,H.Y.Huang,K.H.Tseng and C.P.Chou[5] A novel variant of autogenous TIG welding process, oxide powders (Al_2O_3, Cr_2O_3, TiO_2, SiO_2 and CaO) was applied on a type 304 stainless steel through thin layer. The experimental results indicated that the increase in the penetration is significant with the use of Cr_2O_3, TiO_2, and SiO_2.

3.METHODOLOGY AND EXPERIMENTATION:

3.1. Base Metal

304 Stainless Steel is selected as base metal for present investigation.

Table 3.1: Composition of 304 Stainless Steel

S.No.	Constituent	Composition(%)
1	Iron(Fe)	71.3
2	Chromium(Cr)	18.94
3	Nickel(Ni)	8.35
4	Manganese(Mn)	1.30
5	Lead(Pb)	0.11

After confirming the metal composition, the metal plates were cut to the size of 50 mm*40 mm*5 mm.

3.2. Flux Preparation:

In the present study, following six type of fluxes were used.

1.PbO

2.$ZnCl_2$

3.NaF

4.($PbO+ZnCl_2$)

5.($ZnCl_2$+NaF)

6.(NaF+PbO)

These flux powders were weighed and 5 gm of each of the above fluxes were mixed with 15 ml of acetone to form a flux paste.

3.3. Welding:

The specimen plates are mechanically cleaned to make it a clean bright metal. Further, the plates are cleaned with acetone to remove any surface residues and oil. The flux paste was prepared simultaneously. The flux paste is applied on the top surface of the test plate prior to welding.

Fig 3.3. Flux Coating over Steel Plates

The welds were made with a fixed stand-off distance(also known as arc length, L) of 2-3 mm from the tip of the tungsten to the workpiece. The arc is moved along the centre line of the test specimen and welds were carried out in the flat position on a single plate which was coated with the flux. During A-TIG welding a part or all of the fluxes is molten and vaporized. Welding parameters, i.e., current and travel speed were controlled during the welding process.

The following welding conditions are maintained the same throughout the study.

Table 3.2: Welding Parameters

S.No.	Parameter	Value
1	Shielding Gas	Argon
2	Gas Flow rate	10L/min
3	Current	110A
4	Voltage	30V
5	Traverse Speed	140mm/min
6	Arc length	2-3 mm

3.3.1. Post Welding:

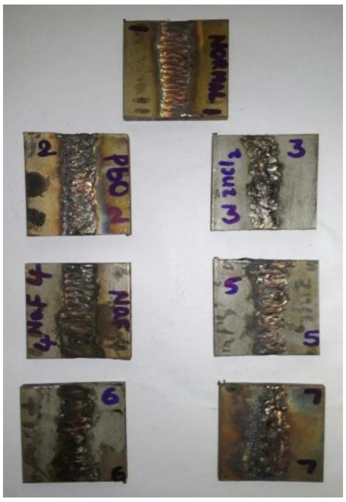


Fig 3.3.1. Steel Plates After Welding

The welded plates were cut in the centre of them using ‘Grinding wheel cutter’ to get the required cross-section (area of interest).

3.4.Metellographic specimen preparation:

The cross-section (area of interest) of the welded samples were polished mechanically using emery papers of grades 1/0, 2/0, 3/0, and 4/0 in the same sequence (in the order of increasing smoothness). During the process, the samples were made flat but maintaining the microstructural integrity of the specimen. Further the samples were polished using disc-polishing machine (in metallurgy lab) with alumina as abrasive. This polishing is only to remove minute surface irregularities. Then the samples were cleaned thoroughly under running water to prevent alumina from deposition on the surface.

3.4.1. Etching:

The purpose of etching is to optically enhance microstructural features such as grain size and phase features. Etching sensitively alters these microstructural features based on composition, stress, or crystal structure. The most common technique for etching is selective chemical etching and numerous formulations have been used over the years. Chemical etching selectively attacks specific microstructural features. It generally consists of a mixture of acids or bases with oxidizing or reducing agents.

In the present study, the etchant used is

Ferric chloride solution + Hydrochloric acid (by equal proportion)

The etchant was applied uniformly on the surface using cotton swabs. After allowing the etchant for three minutes, the surface is cleaned with water and acetone subsequently. The etchant reacts with the metal selectively and projects the weld bead bright and clear macroscopically.

4. RESULTS AND DISCUSSION:

Studies in the area of activated flux TIG welding shows that following mechanisms plays a major role in increase in depth of penetration as follows:

- Maragoni Effect.
- Effect of Arc Constriction due to negative ions.
- Effect of Arc Constriction due to insulating surface of flux.
- Buoyancy or gravity force.
- Electromagnetic or Larentz force.
- Impinging or friction factor.

Out of the above mentioned mechanisms, it was found that ‘Arc Constriction ‘ plays a major role in increase in depth of penetration during present investigation.

4.1. Effect of Fluxes:

Post-etching, the depth of weld (d) and bead width (w) can be obtained from the macrostructures. For different fluxes, they are as follows.

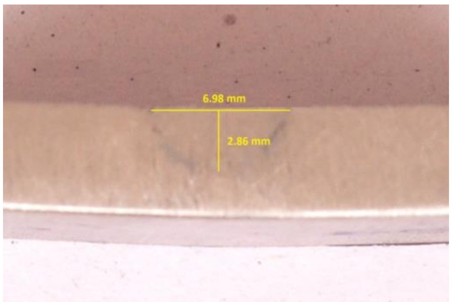


Fig 1. Normal TIG

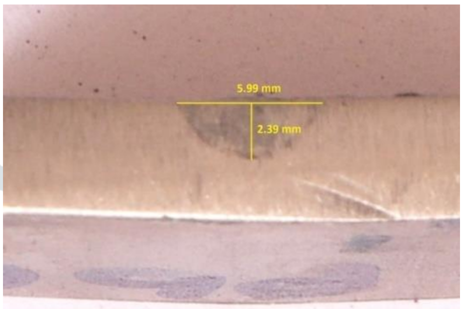


Fig 2. PbO

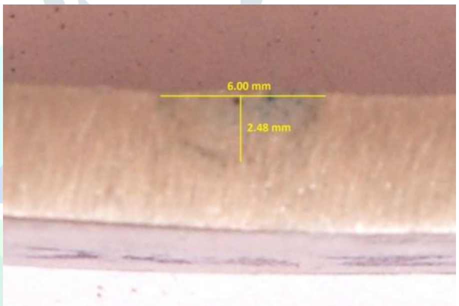


Fig 3. $ZnCl_2$

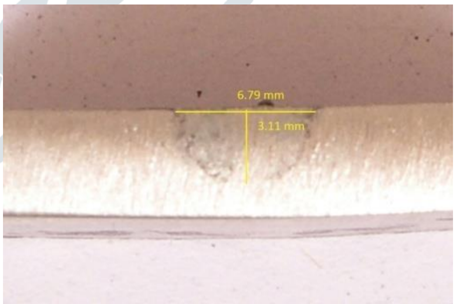


Fig 4. NaF

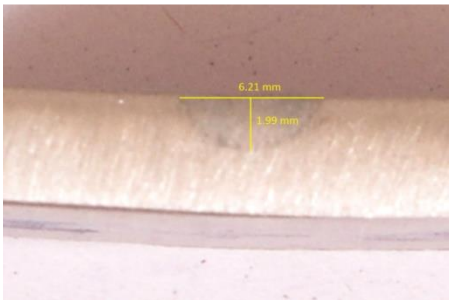


Fig 5. (Pbo+$ZnCl_2$)

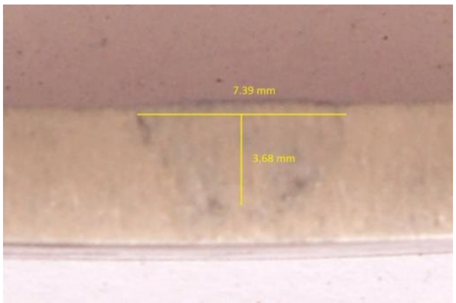


Fig 6. ($ZnCl_2$+NaF)

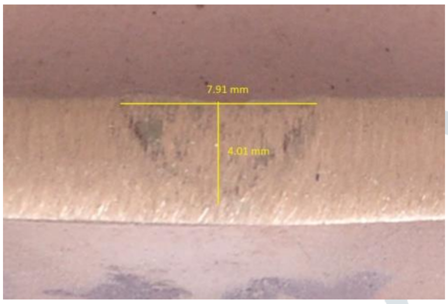
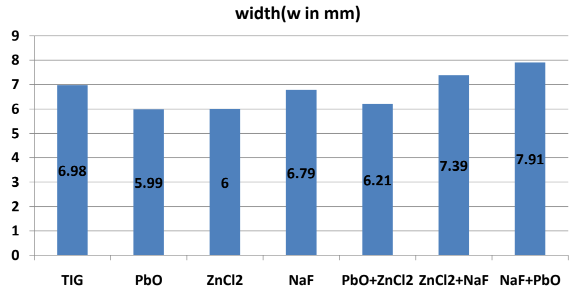


Fig 7. (NaF+PbO)

As weld bead is clearly visible, the depth of the weld and the bead width are determined manually.

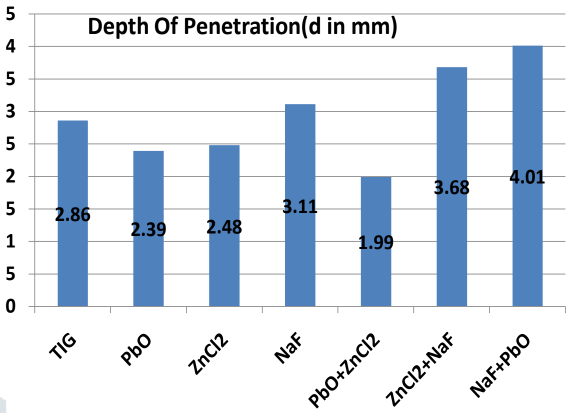
4.1.1. Effect of flux on bead width:



Graph 4.1.1.

There were significant variations with bead widths. The width with the flux $ZnCl_2$ was lower among all and it was 6mm.

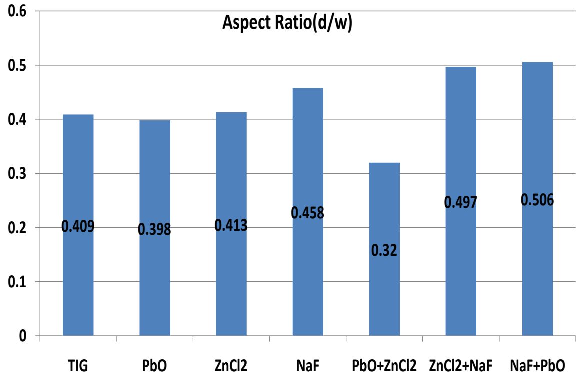
4.1.2. Effect of flux on depth:



Graph 4.1.2.

There were significant variations with bead depths of welds. Maximum depth of penetration was obtained with the flux, (NaF+PbO) and it was 4.01mm.

4.1.3. Effect of flux on aspect-ratio:



Graph 4.1.3.

Maximum Aspect-ratio was obtained with the flux, (NaF+PbO) and it was 0.506.

In conventional TIG welding, the flow of molten metal takes place from centre to edges because surface tension at the centre of the weld pool is lower than at the edges. This results in less depth and more width of the weld pool. But when fluxes are added, the reversal of Maragoni effect occurs and due to arc constriction, more increase in weld depth and considerably less decrease in bead width are obtained. Deeper and narrower weld pool is obtained in A-TIG welding process compared with the conventional one.

CONCLUSION:

- The addition of an activating flux led to an increase in the penetration depth of the weld pool.
- The Mechanisms that led to the increased weld penetration are reverse Maragoni effect and Arc Constriction.
- Maximum depth of Penetration was obtained with the use of flux (NaF+PbO) and it is 4.01 mm.
- Later, possible maximum depth of Penetration was obtained with the use of flux ($ZnCl_2$+NaF) and NaF and their values are 3.68mm and 3.11mm respectively.
- Maximum Aspect Ratio was secured with the use of flux (NaF+PbO) and it is 0.506.

FUTURE SCOPE:

The present study was done on the single plate. Best and Optimal results were obtained from it. This study can be carried out upon the welded joints and depth of penetration of weld beads and their aspect ratios can be increased.

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