Effect of Activating Flux (Metal Oxide) on the Weld Bead
Nomenclature of Tungsten Inert Gas Welding Process – A Review

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Abstract. Welding is inevitable process in the industry. So, many developments are being carried out in existing welding methods and new welding techniques have been developed. Likewise, Tungsten Inert Gas (TIG) welding process is broadly used in manufacturing firms owing to its capability to produce high quality welds at an affordable cost. The Study of recent advancement in TIG welding is necessary to the welding community. Hence, this review paper dealt the recent evolution in the TIG welding which is Activated flux TIG (ATIG).

1. Introduction
Welding is the process of amalgamating two/more homogeneous and heterogeneous metals with the help of either heat or heat and pressure. Currently, most of the structural fabrication contains welded joints and those welds were made by using proper welding technique. In the industries, suitable welding process has been selected based on the metals to be welded and the quality of the weld needed. The history of welding starts several decades back. During the 19th century, the blacksmiths pounded heated metals until they get welded which was the first and foremost metal joining reported by many authors [1-3].

The remarkable breakthroughs in the welding had occurred in the period of 20th century. The French engineers Edmond Fouche and Charles Picard developed oxyacetylene process which was used in industries in the year 1903. Similarly, Auguste [4] founded arc welding method in 1881 but it was not widely used until the development of coated electrodes. Strohmenger & Oscar Kjellberg invented coated electrodes in the early 20th century and it was commercialized in the year 1929. During the 20th century, many welding processes, consumables and shielding methods were developed. The major welding processes called TIG welding and metal inert gas welding were developed by the year 1930 and 1948 respectively and still many industries are using these processes as their major welding techniques in spite of the vast availability of welding methods.

In TIG welding process, Non-consumable welding electrode is used which is the major advantage in this process. But this TIG welding is not suitable for welding of thick plates because without filler metal it is tough to bridge the gap between the plates to be welded. Hence, a new TIG welding method
called Activated flux Tungsten Inert Gas (ATIG) has been developed. In this ATIG welding process the thicker plates can be welded without the use of filler metal which could be the effect of activating flux. To reveal the recent advancement in ATIG welding process, a detailed literature review has been made and reported in this paper.

2. Advantages and limitations of fusion and non-fusion welding processes

Generally, the welding methods are grouped into fusion welding and non-fusion welding category and each welding process has their own advantages and limitations. In case of non-fusion welding techniques, the absence of molten pool, filler metal, slag and shielding gas etc., are the common advantages but the limitations are based on their process types. Some of the non-fusion welding processes and their limitations are as follows: Friction welding process is suitable to join cylindrical parts. Adhesive bonding method the metallurgical bond does not take place between the parent metals. Friction stir welding technique the tools are not readily available to join high strength materials and cost of the tool also high. Explosive welding technique the skilled labors are required and the storing of explosives is an inevitable problem to the industries. Diffusion welding method the consumption of time to produce weld is more. High energy rate welding techniques the cost of the instrument is high and the process needs skilled labors.

Due to the unavoidable limitations in the non-fusion welding processes, the fusion welding technique comes to be the most promising structural fabrication technique among the fabricators. This is because of the absence of aforementioned unavoidable non-fusion welding process hindrances and its astonishing advantages. Especially, Fusion welding processes are able to produce high-quality welds at an affordable cost, more flexible, suitable for any weld configuration and welding positions etc., However, it has some limitations like high heat input, weld distortion, coarse grain formation, spatter, slag inclusion, precipitation etc., [5]. If those limitations of the fusion welding process are eliminated, then it is fruitful to enjoy all the advantages of fusion welding technique.

3. Activating flux in the fusion welding techniques

Enhancement in the depth of penetration of weld has long been hunted for most of the arc welding processes. Even though the welding parameters (such as current, torch speed, welding gap, torch angle etc..) have more influence on the weld penetration, they cannot be varied widely because improper welding parameters promote the formation of weld defects which could cause weld failure. Many research works are going on to boost the ability of fusion welding techniques to produce more weld penetration in a single pass welding without the occurrence of weld defects.

One of the optimistic methods to enhance the penetration in the fusion welding process is the practice of activating flux. Kuo M et al. [6] investigated the effect of metal oxide flux in the laser beam welding and revealed that the use of metal oxide flux can increase the weld penetration appreciably. Huang H et al. [7] examined the effect of various activating fluxes on the welding arc and weld penetration characteristics in the Gas Metal Arc Welding (GMAW) technique with the help of advanced camera. The author found that the welding plasma extends into the root opening due to the existence of oxide flux and thus results in higher penetration. Zhang R et al. [8] studied the use of activating fluxes SiO2, TiO2 and Cr2O3 in the electron beam welding and reported the significant improvement in the weld penetration. Further, they stated that the alteration in surface tension gradient in the weld pool is the principle reason for the improvement of depth of penetration. Skariya P et al. [9] examined the effect of activating flux in the TIG welding and reported the marangoni effect is the reason for penetration enhancement in the weld.

Huang H-Y et al. [10] examined the effect of metal oxide flux (activating flux) in the plasma arc welding and gas tungsten arc welding processes and divulged that the practice of activating flux in both the welding techniques has a positive impact on the weld penetration. The Gas Tungsten Arc Welding (GTAW) is the most widely used joining technique in the manufacturing industries because of its capability to produce high quality welds at an affordable cost. However, GTAW has confines like less productivity and limited weld penetration. Hence, many investigators [11-13] studied the use of activating flux in the GTAW and reported the noteworthy enhancement in the depth of penetration and various joint properties. Skariya P et al. [14] conducted a detailed study in the Activated flux
Tungsten Inert Gas (ATIG) welding of 15CDV6 steel and concluded that metallurgical aspects of fabricated weld bead is superior than the conventional TIG welding process weld bead.

4. ATIG welding process

Recently, the ATIG welding has received attention from the manufacturers due to its ability to weld thicker sections in a single pass welding, high production efficiency, simple edge preparation and non-requirement of filler metal. The United States of America navy welding center has been using the ATIG welding technique magnificently to fabricate the navy vessels and flying machines for the past few years [15]. In this ATIG welding, the fine particles of oxide flux(s) called as activating flux(s) in the form of paste like consistency is applied on the area of metal to be welded before welding. This applied activating flux contributes for the enhancement of weld penetration. Many researchers [16-19] investigated the participation of activating flux in ATIG weld penetration and found that the mechanisms of plasma arc constriction and reversed marangoni effect are the predominant reasons.

![Figure 1. The graphical representation of molten fluid flow pattern a) GTAW b) ATIG](image)

In the plasma arc constriction mechanism, the applied activating flux perishes at plasma column and creates massive positive ions. These ions absorb the free electrons present in the plasma column and create arc column constriction. Owing to the confined plasma arc, more melting of base metal take place which results in deeper penetration [20], [21]. In the reversed marangoni effect mechanism, the decay of activating flux provides the oxygen element to the molten weld pool. This produced oxygen element modifies the molten fluid flow pattern by modifying the surface tension to the middle of the weld pool from the molten pool edges which causes intense penetration. Figure 1 depicts the molten fluid flow pattern of GTAW and ATIG welding methods which gives a clear idea about the reason for an enhancement of weld penetration in ATIG welding.

Tseng K-H et al. [22] studied the influence of five different fluxes namely SiO2, TiO2, MoO3, MnO2, and Al2O3 on the mechanical and metallurgical characteristics of AISI 316 L stainless steel weld fabricated using ATIG process. The authors identified that all the investigated activating flux had shown significant enhancement in the weld penetration. Similarly, Nayee SG et al. [23] studied the different activating fluxes in the heterogeneous joining of stainless steel and carbon steel using ATIG welding method and stated that the use of metal oxide flux enhances the depth of weld penetration and lowers the weld distortion.

Huang H-Y et al. [7] described that the performance of metal oxide activating flux is significantly affected by ATIG welding process parameters. The author additionally stated optimizing the welding process parameters is vital to attain superior weld properties of the ATIG joint. Magudeeswaran G et
al. [24] explored the effect of ATIG welding parameters on S32205 duplex stainless steel weld joints and identified that optimized welding parameters are essential to fabricate defect free weld joints. Vidyarthi RS et al. [25] premeditated the effect of different welding parameters such as current, torch speed and flux layer density on the weld morphology of ferritic stainless steel. They have reported that all the investigated parameters had a significant effect on weld penetration, weld bead width and depth to width ratio but flux layer density has no effect on the fusion zone characteristics. Vasudevan M et al. [26] and Chandrasekar G et al. [27] revealed that the weld bead width and weld penetration of ATIG weldment are more subjective by the welding process parameters. Further, both researchers indicated that the optimization of ATIG parameters is essential to produce defect free weld. Similarly, in the fusion welding techniques, welding Heat Input (HI) has a noteworthy effect on various physical properties of the weld joints [28, 29]. Kim JS et al. [30] conveyed that the HI of the welding process must be under control during welding of nickel based alloys to retard precipitation of Chromium carbide at the grain boundaries. Agilan M et al. [31] examined the welding of nickel alloy Inconel 718 and reported that the HI affects the depth to width ratio and the microstructure of heat affected zone and weld fusion zone. Devendranath Ramkumar K et al. [32] and Chandrasekar G et al. [33] conveyed that the controlled HI is necessary to produce a weld with good mechanical and metallurgical properties. Patel D et al. [34] compared the effect of welding process parameters on conventional TIG and ATIG welded joints and revealed that the welding process parameters having some effect on weld morphology so optimizing the parameter is essential to produce sound ATIG welds.

5. Conclusion

It is found from the detailed review that the fusion welding techniques are best suitable for industrial production. The ATIG welding process can produce less width and high depth weld beads with the use of low welding heat input. However, selection of proper activating flux for the individual metal is required in order to enjoy the full benefits of ATIG process.

6. References

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