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RECENT DEVELOPMENTS IN GAS TUNGSTEN ARC WELDING (GTAW)

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Abstract - The global Gas Tungsten Arc Welding (GTAW) machine market, valued at approximately $870 million in 2025, is projected to experience robust growth, driven by a Compound Annual Growth Rate (CAGR) of 5.7% from 2025 to 2033. This expansion is fueled by several key factors. The increasing demand for high-precision welding in industries like aerospace, where lightweight and high-strength materials are crucial, is a significant driver. Advancements in technology, leading to more efficient and automated GTAW machines, are also positively impacting market expansion. America and Europe likely maintaining strong positions due to established industries and technological advancements. However, the Asia-Pacific region is expected to experience significant growth, propelled by rapid industrialization and increasing manufacturing activities in countries like China and India.

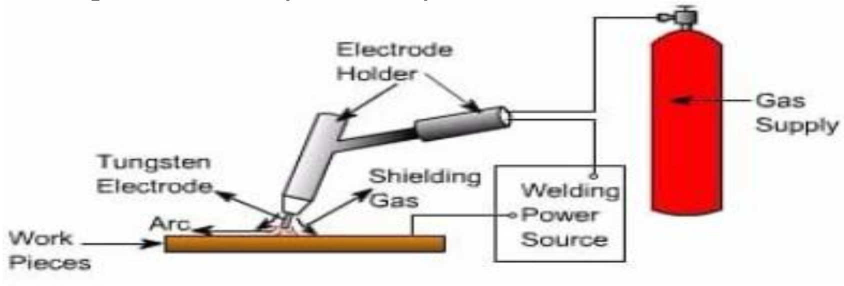
A few benefits of this welding method include improved tensile strength, finer grain hardness, excellent weld quality and appearance ,micro structure improvement, and metallurgical properties over the source metal. To shed light on those sectors that have not yet realised their full potential, the primary objective of this research is to assess current advances in the TIG welding business. Thus, based on tests, parameters, and the kinds of materials used for welding, numerous TIG welding tales are compiled and investigated in this study article. The bulk of the mentioned studies state that the main parameter among them rate and angle of weld utilising modern techniques have not been used up to that point.

Tungsten Inert Gas (TIG) welding, also known as gas tungsten arc welding (GTAW), is a type of arc welding process that utilizes an inert gas shield and a non-consumable electrode. The electrodes may include a mixture of 1 to 2% thoria (thorium oxide) along with the tungsten core, or they may consist of tungsten alloyed with 0.15 to 0.40% zirconia (zirconium oxide). This method is suitable for welding both ferrous and non-ferrous metals. Advantages of this process include a reduced heat-affected zone, the ability to join dissimilar metals, the lack of slag, and a high concentration of heat, particularly when compared to other welding methods. The parameters for TIG welding are crucial factors that influence the quality, productivity, and cost of the welding proce

Keywords: Aspect Ratio, Non-Consumable Tungsten Electrode, Optimization, Process Parameters, Shielding Gas, Tungsten Inert Gas, Weld Bead, Welding ,thorium oxide.

1. INTRODUCTION

Welding is a process of metallurgical fusion in which the surfaces of the two components to be joined are heated to a temperature exceeding their melting point before being allowed to cool and solidify, thus forming a permanent bond. The welding temperature ranges from 1800ºF to 3600ºF. This process involves melting the workpieces at their interface, and after solidification, a durable joint is formed. Optionally, filler material can be added to create a pool of molten material that solidifies over time, resulting in a strong connection between the materials. There are numerous methods and sources utilized in the welding process, such as a gas flame, electric arc, laser, electron beam, friction, and ultrasound. This process can take place in various settings, including open air, underwater, and even in space. Welding is categorized into several types: gas welding which includes Oxyacetylene gas welding; arc welding which encompasses SMAW, GMAW, GTAW, and SAW; and energy beam welding which consists of laser beam welding and electron beam welding, among others. Welding technology plays a critical role in all phases of production and manufacturing. To achieve consistently high-quality welds, arc welding relies on skilled personnel to prevent distortion.



Schematic of TIG welding.

The majority of companies employ gas tungsten arc welding (GTAW), a high-quality welding technique. Higher welding speeds and higher deposition rates are the process's limitations, though. The GTAW method is altered so that filler metal is heated before entering the weld pool in order to get around this restriction. Resistance heating is used to accomplish this heating. The availability of arc energy to melt the base metal is guaranteed by hot wire GTAW (HW-GTAW). As a result, the rate of deposition increases, and welding rates also rise significantly. Welding is a crucial method of material joining that is especially useful for structural component applications. This essay examines how the hot wire technique is used during traditional

When it became necessary to weld magnesium, the TIG welding process—an arc welding technique—was created in the late 1930s.When a high-quality weld, stability in a variety of welding applications, and a nice weld joint look are needed, TIG welding is utilized. By heating metals with an arc created between non-consumable tungsten electrodes and the work piece while a shielding gas is present, TIG welding melts and connects metals.

2. LITERATURE REVIEW

The impact of RSW parameters on the microstructure and load-bearing capability of DP 600 steel has been the subject of several investigations. Kumar et al., (2016) examined the mechanical characteristics and microstructure of SS 304. Low, medium, and high heat combination TIG welding was employed for this purpose. In comparison to joints manufactured using medium or high heat, joints created using low heat showed higher ultimate stress. The primary conclusion of this study was that copper may be used in addition to SS 304 when TIG welding copper and SS 304 together. Muthupandi et al., (2015) hypothesised that precipitating brittle intermetallic phases like (sigma) or (chi) would occur when using larger heat inputs. However, when large amounts of heat are applied, Furthermore, the use of low heat input and rapid cooling rates compromises toughness and corrosion resistance. To solve the instability problem with the open-looped control system for the consumable DE-GMAW, Shi et al. (2014) proposed a closed loop control system architecture. Using a fuzzy controller, a welding process that is stable and reduced splatter and increased efficiency. Eboo claims that the laser beam improved the depth-to-width ratio of the final weld appearance, reduced arc column resistance, and stabilized the welding current and arc voltage. Thus, a key technique for attaining high speed welding is laserMIG/MAG hybrid welding. Metzbower et al. (2012) investigated the effects of pass-by-pass gas tungsten arc welding on the hardness of mild steel.

The structural integrity of operationally welded structures within the heat-affected zone may be gravely threatened by high magnitude residual stresses on the scale of the material's yield strength. In their 2018 study, Miao et al. and Zhang et al. suggested adding an additional non-consumable electrode to the consumable procedure. According to the explanation, the conventional consumable electrode configuration might be expanded to include two non-consumable electrodes. They created a variation of the approach injected arcs from both sides of the weldment to increase the depth of weld penetration. Both electrodes were powered by a current bypass that was powered by the same power source. The rate of metal deposition is given a lot of weight when combining thicker plates with metal. Kanemaru

An increase in joint toughness was seen when comparing the hardness of the weld joint to that of the test sample that was MIG-welded. Increased weld metal deposition in confined spaces and improved control over the heat-affected zone are the outcomes of using several heat sources during the welding process. [Vasudevan et al. In order to address the issue of insufficient depth penetration of TIG welding joints an dits impact on the weldability of 304LNand The mechanical characteristics, microstructure, and weld bead geometry of 316LN austenitic stainless steelhave been evaluated. The study found that the full depth of penetration in 10 mm thick 304LN and 12 mm thick 316LN could be achieved in a single pass when using the A-TIG welding technique. Miki and associates (2021)

The average weld toe radius after TIG treatment was found to be 5 mm. TIG may ignite between 3 and 4 mm below the surface. It was found that whereas TIG may effectively re-melt the original cracks in some specimens, other specimens still have underlying fissures. Chen and colleagues (2022) looked at the lowdeposition rate issue related to the TIG process. However, this method was not appropriate for joining high strength steel since it needed an oxidizing atmosphere to protect the weld pool. DE-GTAW was also used to increase the deposition rate. But the procedure necessitated a unique circuit configuration. Defects related to the traditional TIG and MIG procedures were still present in the aforementioned mixed arc techniques.

3. WORKING PRINCIPLE AND MECHANISM OF TIG WELDING

An arc is maintained between the work piece and a non-consumable tungsten electrode during tungsten inert gas welding. A gaseous shield of inert gas, such as argon, helium, or an argon-helium combination, shields this arc and the weld pool from air pollution. Depending on the welding requirements, the filler metal may or may not be employed. Regardless on the process type, this filler metal can be added manually or automatically. The actual TIG welding procedure might be either automated or manual. Depending on the amount of heat dissipation needed, the welding power supply can deliver either direct current or AC. When welding materials that are challenging to weld, TIG welding produces superior results. For a wide range of materials, TIG welding produces high-quality welding through the coalescence of heat produced by an electric arc formed between a tungsten electrode and the work piece. Due to their lack of chemical reactivity, helium and argon gases are the most suitable for shielding. Therefore, the purpose of shielding gas is to keep the surrounding air away from the weld pool, preventing oxidation, concentrating and transferring heat during welding, and assisting in the establishment and maintenance of a steady arc because of its low ionization potential. This is advantageous because the base metal undergoes changes as a result of the arc's superheating and rapid cooling rate while the operation is underway.

4. TYPES OF WELDING PARAMETERS

Voltage - Voltage controls the length of welding arc and resulting width and volume of arc cone. As voltage increases arc length gets longer (and arc cone broader), while as it decreases, the arc length gets shorter (and arc cone narrower).A high initial voltage allows for easy arc initiation and allows for greater range of working tip distance. Depth of penetration decreases as voltage increases. In GTAW welding process filler feeding or Filler melt off rate should be kept constant since it is manual process. Voltage is a controlling variable in manual processes because in manual process it is very difficult to consistently maintain the same arc length.

Welding Current and Polarity - The welding current, which is dependent on the material to be welded, material thickness, welding speed, and shield gas, is the amount of heat given to the component to influence the weld. Achieving flawless welds with the necessary penetration is the goal. Weld bead shape, welding speed, and weld quality are all directly impacted by current. Since direct current on electrode negative (DCEN) (straight polarity) produces a deeper weld penetration and a faster travel speed than on electrode positive (DCEP) (reverse polarity), it is used in the majority of GTAW welds. Furthermore, because the anode in a gas tungsten electric arc is hotter than the cathode, reversal polarity causes the electrode tip to heat up and degrade quickly.

Welding Speed - The effect of increasing the welding speed for the same current and voltage is to reduce the heat input. The weld speed increase produces a decrease in the weld cross section area, and consequently penetration depth (D) and weld width (W) also decrease.

Type of Shielding Gas and Its flow rate - The correct shielding gas selection for TIG welding has a big impact on welding speed and weld quality. Since argon, helium, and argon-helium combinations do not react with tungsten electrodes, they are used most frequently. They aren't having any negative effects on the weld's quality. Argon gas is more commonly used as a shielding gas medium because it produces a softer, smoother, and steadier arc at a lower cost. Argon is superior for welding, especially when it comes to magnesium and aluminum alloys. Another important factor influencing the quality of the weld is the shielding gas flow rate, which varies according to the kind and thickness of the material.

Arc Pulsing - Pulse frequency, pulse width (duty cycle), and current. Arc pulsing is the process of quickly switching the weld current from a high (peak current) to a low (background current) value utilizing the welding power source. This results in an overlapped spot weld seam. This method can enable faster welds while lowering the total amount of heat applied to the base material. The welding process benefits greatly from arc pulsing, which frequently improves weld quality and repeatability (Pramana Research Journal Volume 8, Issue 9, 2018 ISSN NO: 2249-2976 182 https://pramanaresearch.org). Sometimes the apulsed arc approach makes it simple to weld materials and weld connections with poor fit-up that are challenging to properly weld with a nonplussed arc.

Higher productivity and better weld quality are the outcomes. The distance between the electrode tip and the workpiece is known as the arc length. In GTAW, the arc length typically ranges from 2 to 5 mm.[10]. The voltage required to keep the arc stable must rise with increasing arc length, yet radiation losses from the arc's column cause the workpiece's heat input to drop. when a result, when arc length increases, weld penetration.

5. ELECTRODES AND ITS TYPES

A coated metal wire is called an electrode. It is composed of materials that are comparable to the metal that is being welded. 99.50 percent pure tungsten (EWP, green-colored code). When using conventional transformer-rectifier power sources for AC welding, this electrode works well. Because it retains a steady ball on the end despite the heat from AC, it is preferred for magnesium and aluminum. It helps reduce weld contamination since it contains slightly less than 0.5 percent of extra elements and compounds.

97.30 percent tungsten, 1.70 to 2.20 percent thorium, and 2 percent Thoriated (EWTh-2, color-coded red). Because thorium enhances the electrode's current capacity, it is simple to sharpen the electrode to a point where it produces better arc starters and a more stable arc. Additionally, it lowers electrode usage, which lowers the possibility of electrode material contaminating the weld puddle. For DC electrode-negative polarity welding on titanium, nickel, stainless steel, and carbon steel,it works well. 1.80 to 2.20 percent cerium, 97.30 percent tungsten, and 2 percent cerium (EWCe-2, color-coded orange). Because it keeps its sharp tip, this kind is preferred for DCEN welding.

1.30 to 1.70 percent lanthanum, 97.80 percent tungsten, and.5 percent lanthanated (EWLa-1.5, color-coded gold). This kind can carry a lot more current than a pure tungsten electrode of the same diameter and shares many traits with ceriated electrodes. It is appropriate for delicate parts and thin materials due to its good low-current DC arc beginnings. 0.15 to 0.40 percent zirconium, 99.10 percent tungsten, and zirconiated (EWZr-1, color-coded brown). This electrode resists tungsten spitting, which contaminates the weld, has a very stable AC arc, and it maintains a ball end well.

6. SHIELDING GAS AND THEIR TYPES

97.80% tungsten, 1.30 to 1.70 percent lanthanum, and 0.5 percent lanthanated (EWLa-1.5, color-coded gold). This type has many characteristics with ceriated electrodes and can carry a lot more current than a pure tungsten electrode of the same diameter. Its good low-current DC arc starts make it suitable for thin materials and fragile parts

Zirconiated (EWZr-1, color-coded brown), 99.10 percent tungsten, and 0.15 to 0.40 percent zirconium. This electrode maintains a ball end well, has a very stable AC arc, and is resistant to tungsten spitting, which contaminates the weld. It can carry at least as much current as thoriated tungsten Argon. Colorless, odorless, tasteless, and harmless, argon makes up little less than 1 percent of the earth's atmosphere. Argon does not react with other substances or elements because it is an inert gas. It cannot support life and is roughly 1.4 times heavier than air. Argon is employed in many welding procedures because of its inert qualities, which make it perfect as a barrier against air contamination. Because of its low ionization potential, argon encourages favorable arc-starting qualities and arc stability.

Helium. Helium is lighter than air and is the second-lightest element after hydrogen. It is chemically inert and cannot support life, just as argon. Helium is employed as a shielding gas when higher heat input is required and there is little tolerance for oxidizing elements, as in the case of welding magnesium and aluminum,

7. ADVANTAGES

It is preferred because of its low hydrogen properties and the match of mechanical and chemical properties with the base material. • Higher weld quality can be maintained by cleaning operations which are free from defects • Can be used with or without filler metal. • No use of flux hence no danger of flux entrapment when welding critical component of refrigeration. • Less Post Welding is required.

8. DISADVANTAGES

TIG is a time-consuming process. They are slower than any other welding process • Lower filler deposition rate • High initial cost • It cannot use in thicker sheets of metal

9. APPLICATIONS

It can weld aluminium, stainless steel, copper, nickel, magnesium and their alloys. • It can weld high temperature and hard surfacing alloys like titanium, zirconium etc. • It can join sheet metal and thinner sections too. • Due to high weld quality, it is used to weld expansion bellows, instrument diaphragms and transistor case • TIG is most preferable when it comes to precise weld joint in atomic energy, aircraft and chemical.

CONCLUSION

In summary, Tungsten Inert Gas (TIG) welding has important and wide-ranging scientific implications. TIG welding has the potential to completely transform several different sectors and businesses with continued study and development. Research endeavors are focused on optimizing welding parameters, including shielding gas composition, weld speed, and current. Researchers can improve TIG welding processes' quality, productivity, and efficiency by optimizing these factors, which will increase the integrity of the weld joint and decrease flaws. Research on TIG welding also explores metallurgy and material science, looking into the mechanical characteristics, phase changes, and microstructure of welds. This information aids researchers in creating methods to reduce distortion, regulate the heat-affected zone, and enhance the strength and toughness of the weld. Furthermore, TIG welding's capacity to fuse disparate.

The use of TIG welding in additive manufacturing, which makes it possible to create intricate geometries and useful prototypes, is another field of study. Research into TIG-based additive manufacturing's process parameters, deposition tactics, and post-processing methods adds to the creation of mechanically sturdy, highly accurate components. Finally, sustainability and the effects on the environment are the main topics of TIG welding study. Researchers hope to lower energy use, pollutants, and waste production related to TIG welding processes by investigating other shielding gases, consumables, and power sources. The larger objective of encouraging sustainability in the manufacturing sector is in line with this study. In general, research on TIG welding has applications in a variety of areas, such as automation, additive manufacturing, sustainability, material science, .

We can conclude that TIG welding is the most widely used circular segment welding process due to its vast array of advantageous circumstances over other welding processes after exerting ourselves to understand various literary works and reviewing the impact of process parameters, such as welding current, welding speed, welding extremity, arc length, types of protective gas along with their stream rate, and viewpoint proportion, on productivity and yield. It has been observed that TIG welding can be used to achieve its maximum yield when the aforementioned parameters are adjusted to the most suitable environment for the planned task. The choice of the necessary heat dispersion on the work piece or electrode determines the welding current. Typically, DCEN or DCSP is used. The tungsten electrode tip is also well formed. The type of protective gas used and the thickness of the material affect welding speed. The best joining technique for welding aluminum is TIG.

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