A review of (GTAW) Gas Tungsten Arc Welding and its Parameters for Joining Aluminum Alloy

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Abstract*- There are number of welding methods available for joining of engineering materials, such as shielded metal arc welding, Gas metal arc welding, Flux cored arc welding, submerged arc welding, electro slag welding, electron beam welding, and Gas Tungsten arc welding methods. The choice of the welding depends on several factors; primarily among them are the compositional range of the material to be welded, the thickness of the base materials and type of current. GTAW is the most popular gas shielding arc welding process used in many industrial fields like Aircraft industries, Farm Machineries etc. Other arc welding processes have limited quality when they are compared to TIG welding processes. However, TIG welding also needs improvements regarding spatter reduction and weld quality of the bead. Shielding gas in TIG welding is desirable for protection of atmospheric contamination. TIG welding process has the possibility of becoming a new welding process giving high quality and provides relatively pollution free. This paper reviews the introduction of GTAW, various gases used in GTAW, Application of GTAW and its process parameters for joining alluminium alloy.*

Keywords- gas tungsten arc welding, process parameter, Application of GTAW etc.

I. INTRODUCTION

GTAW or TIG welding process is an arc welding process uses a non consumable tungsten electrode to produce the weld. The weld area is protected from atmosphere with a shielding gas generally Argon or Helium or sometimes mixture of Argon and Helium. A filler metal may also feed manually for proper welding. GTAW most commonly called TIG welding process was developed during Second World War. With the development of TIG welding process, welding of difficult to weld materials e.g. Aluminium and Magnesium become possible. The use of TIG today has spread to a variety of metals like stainless steel, mild steel and high tensile steels, Al alloy, Titanium alloy. Like other welding system, TIG welding power sources have also improved from basic transformer types to the highly electronic controlled power source today.

The Gas Tungsten arc welding system set up is illustrated in figure 1.1 here. Shielding gas is fed through the torch to protect the electrode, molten weld pool, and solidifying weld metal from contamination by the atmosphere. A constant-current welding power supply produces energy that is conducted across the arc through a column of highly ionized gas and metal vapors known as plasma. TIG provides the welder with greater control over the weld than competing procedures such as shielded metal arc welding (SMAW) and gas metal arc welding (GMAW), thus allowing for stronger, higher quality welds. However, GTAW/TIG is comparatively more complex and difficult to master closer tolerance requirements and filler metal usually added by other hand, and is significantly slower than most other welding techniques as well. It will also cover core competencies such as setting up equipment, preparing materials, fitting up, starting an arc, welding pipes and plates, and repairing welds.

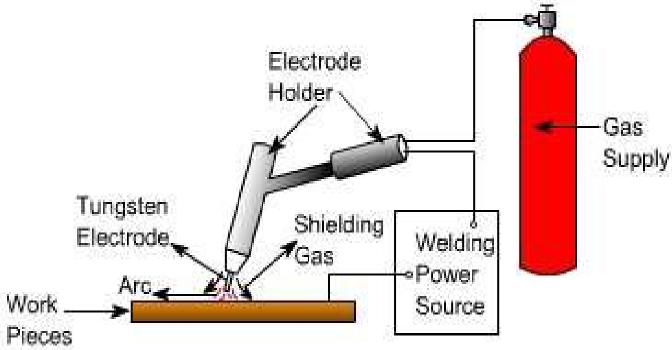

Figure 1. Schematic Diagram of TIG Welding System or set up

II. LITERATURE REVIEW

1) **Mohd. Shoeb, Prof. Mohd. Parvez and Prof. Pratibha Kumari** studied the various welding parameters such as welding speed, voltage and gas flow rate on HSLA steel. The effects of these parameters on weld bead geometry such as penetration, width & height have been studied. They also investigated the MIG welding was carried out on DC electrode (welding wire) positive polarity (DCEP). However DCEN in used (for higher burn off rate) with certain self- shielding and gas shield cored wires.

Mathematical equations have been developed using factorial technique and the result of various effects are indicated. They also investigated that Penetration is the distance that the fusion zone extends below the original surface of the parts being welded.

2) **Pawankumar, Kolhe K.P And C.K. Datta** studied that effects of pulse parameters on the bead geometry of welded Aluminium Alloy 7039. In this paper, the effect of pulse currents, secondary currents, pulse frequencies and pulse duty cycles on the bead geometry of GTA Welded AA7039 has been studied. From this investigation it is observed that the penetration and penetration / width ratio increased with increase in the heat input i.e. pulse currents, secondary currents, pulse frequencies and pulse duty cycles. During welding, they observed that on increasing of frequency, there was a harsh sound in the welding machine.

3) **Kamble A. G, Rao R. V and Kale A.V** studied that Welding process aims at obtaining a welded joint with the desired weld bead parameters, excellent mechanical properties with minimum distortion. Quality of weld joint depends upon welding input parameters. Manufacturer are facing problem of controlling the process input parameters to obtain a good welded joint with the bead geometry and also Prediction of weld bead geometry play very important role in determining the quality of weld.

4) **Pawankumar, Kolhe K. P, Morey S. J and Datta C. K** has studied the effect of process parameters of pulsed current tungsten inert gas welding on aluminum alloy 6061 using sinusoidal AC wave with argon and helium gas mixture. From the study they have found that pulse current pulse duty cycle, frequency, percentage of helium in argon plays an important role on microstructure, and hardness of weld, Pulsed current plays major role in all of them. Lower micro hardness was ob-served in the weld zone because of using filler rod, dendrites solidified microstructure and segregated phase. It is also ob-served that the pulsed parameters play an important role in development of fine microstructure.

5) **Pavankumar, Kolhe K.P and Datta C.K** has studied that the Process optimization of pulsed GTAW process for aluminium alloy 7039 using Ar + He gas mixtures. The present paper depicts the application of pulsed gas tungsten arc welding (pulsed GTAW) for aluminium alloy (AA7039) using various Ar + He (Argon + Helium) mixtures as a shielding gas with sinusoidal AC wave. In this investigation, Taguchi method is used to formulate the experimental layout, to analyze the effect of each process parameter on the bead geometry, and to predict the optimum setting for each welding process parameter. AA 7039 is employed in aircraft, automobiles, high speed trains and high-speed ships due to their low density, high specific strength and excellent corrosion resistance.

6) **Kolhe K. P and Dharaskar R. M** studied that GTAW welding is mostly used for welding agricultural machines are largely fabricated, by village craftsmen and small-scale industries. Tractor, engines and oil mills are manufactured by organized sectors. The small-scale industries seldom have R/D facilities and they depend upon public institutions for the advance technology. This paper focused on the advance of arc welding technology e.g. electric arc welding, gas metal arc welding, tungsten arc welding, submerged arc welding etc, to improve the mechanical properties such as strength, ductility hardness etc., Microstructure, Heat-affected zone and welded structure of farm machines.

1. Equipment used in TIG Welding.

The following equipment is required in TIG welding,

a) DC or AC power source
b) TIG torch
c) An inert gas cylinder
d) Welding cable for electrodes and ground connections.
e) Inert gas regulator & flow meter
f) Electrode holder
g) Non consumable tungsten electrode. Etc

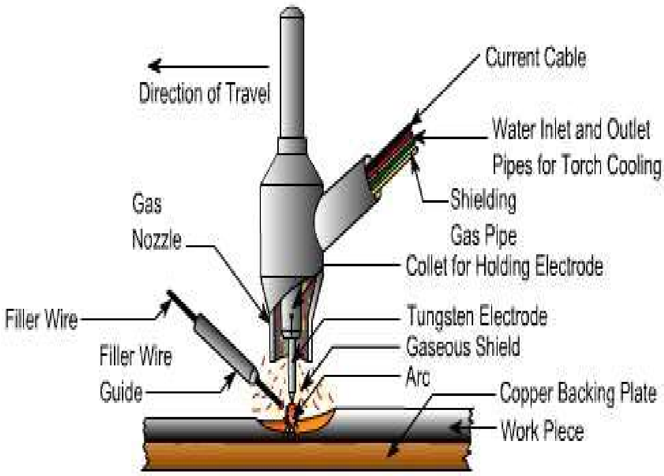

Figure 2. GTAW Process

2. GTAW's Principle of working

TIG uses the heat produced by the arc between the non-consumable tungsten electrode and the base metal. An inert shielding gas supplied through the torch shields the molten weld metal, heated weld zone, and non-consumable electrode from the atmosphere. The gas protects the electrode and molten material from oxidation, and provides a conducting path for the arc current. An electric current passing through an ionized gas produces an electric arc. In this process, the inert gas atoms are ionized by losing electrons and leaving a positive charge. Then the positive gas ions flow to the negative pole and the negative electrons flow to the positive pole of the arc. The intense heat developed by the arc melts the base metal and filler metal (if used) to make the weld. As the molten metal cools, coalescence occurs and the parts join. There is little or no spatter or smoke. The resulting weld is smooth and uniform, and requires minimum finishing (Figure 1.2). While there is not need to add filler metal when welding thinner materials, edge joints, or flange joints. This is known as autogenous welding. For thicker materials, an externally fed or "cold" filler rod is generally used. The filler metal in gas tungsten arc welding does not transfer across the arc, but is melted by it. strike the arc in one of three ways:

a) By briefly touching the electrode to the work and quickly withdrawing it a short distance.
b) By using an apparatus that will cause the arc to jump from the electrode to the work.
c) By using an apparatus that starts and maintains a small pilot arc. This pilot arc provides an ionized path from the main arc. The torch then progresses along the weld joint manually or mechanically after remaining in one place until a weld puddle forms. Once the welder obtains adequate fusion, the torch moves along the joint so the adjacent edges join and the weld metal solidifies along the joint behind the arc, thus completing the welding process.

3. Power source

TIG welding normally uses constant current type of power source with welding current ranging from 3-200A or 5-300A or higher and welding voltage ranging from 10-35V at 60% duty cycle. Pure tungsten electrode of ball tip shape with DCEN provides good arc stability. Moreover, thorium, zirconium and lanthanum modified tungsten electrodes can be used with AC and DCEP as coating of these elements on pure tungsten electrodes improves the electron emission capability which in turn enhances the arc stability. TIG welding with DCEP is preferred for welding of reactive metals like aluminium to take advantage of cleaning action due to development of mobile cathode spots in work piece side during welding which loosens the tenacious alumina oxide layer. This helps to clean the weld pool. DCEN polarity is used for welding of metal such as carbon steel that don’t require much cleaning.

4. GTAW Torch

The main purpose of the TIG torch is to carry the welding current and shielding gas to the weld. The TIG torch is constructed on the basis of the welding handle and a torch head that is coated with an electrically insulated material. The torch handle is usually fitted with a switch to turn the welding current and the shielding gas on and off. GTAW torch as shown in fig. 1.3.

1. Torch head
2. Handle
3. Control switch
4. Electrode cap
5. Sealing ring
6. Electrode collet
7. Heat shield
8. Collet body
9. Gas nozzle

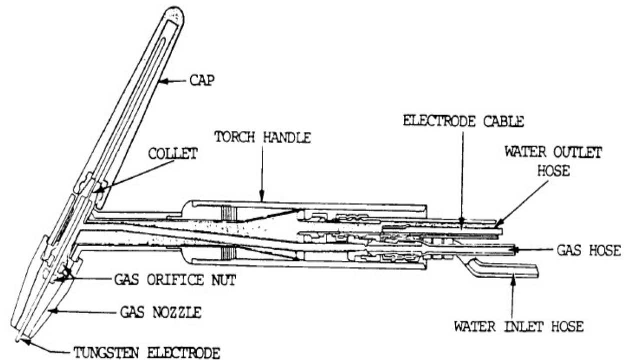

Figure 3. TIG welding torch

5. Applications of GTAW

Gas tungsten arc welding is widely used because of its versatility. When weld purity is important, this process welds stainless steel, low alloy steel, steel, nickel, cobalt, titanium, aluminum, copper, magnesium, and most other metals in all positions and produces clean weld deposits. Some application of GTAW are as follows,

a) Industrial Piping

Manual TIG is appropriate for welding pipe and tubing in all positions. The excellent control of heat input gives maximum penetration while preventing melt through on the root pass. Welders use TIG in both the manual and automatic methods to weld industrial piping made of various metals and thicknesses. The maximum thickness welded depends on the equipment available and the type of metal.

Sometimes, pipe welders will use consumable inserts in critical service applications. These inserts reduce porosity when alloyed with deoxidizers, improve the contour of the underside of the weld, and minimize cracking in the weld. In thin pipe wall (depending on the base metal), complete fusion is obtainable without using filler metal, but of course filler metals are used with thicker sections to fill the joint.

b) Nuclear Power Facilities

The construction and repair of nuclear power facilities requires critical welding. Many nuclear applications use both the manual and automatic methods because of their precise control of the welding. Gas tungsten arc welding performs the welding for end closure caps and plugs to fuel rods, and the airtight sealing of the end closures on fuel rods. This process is also a primary welding method for rod type fuel elements. It is used to close a backfilling hole that was used to pressure the fuel rods after welding the end closures.

c) Ships

TIG applies also to the shipbuilding industry because it uses different materials like aluminum, stainless steel, and molybdenum. On hydrofoils, which are primarily made of aluminum, light gauge material and root passes of heavier sections are welded by this process, with GMAW usually completing the weld on the heavier sections. Stainless steel hydrofoils and struts are virtually all welded by the TIG process. Liquefied natural gas (LNG) tanks have a stainless steel liner inside the vessel that is completely TIG welded.

d) Aerospace

The gas tungsten arc welding process is the major welding process used in the aerospace industry. This industry includes the welding of aircraft, spacecraft, and launch vehicles. Some of the materials welded include aluminum, titanium, low alloy steel, maraging steel, magnesium, nickel, stainless steel, and super alloys in both the manual and automatic methods. In the aircraft industry, examples of the many different welded parts and assemblies include the fuselage, wing and tail assemblies, landing wheels, engine parts, engine motor cases, and conventional aircraft assemblies such as ducts, fittings, accumulators, check valves, exhaust mufflers, and fairing and cowling components. Most aluminum tank fabricators use TIG for the critical pressure vessel butt welds.

e) Maintenance and Repair

TIG can provide maintenance and repair by both the manual and automatic methods. Several industries use this process because its versatility and weldability permit quality welding for various applications. The TIG process repairs cast aluminum engine blocks and heads. The area of a defect is puddle melted, scraped out with a steel rod, and finally filled. This process also repairs stainless valves and copper heat-sealing dies for heat exchangers. Repairing the part instead of buying a new one saves money and time. There are many other possible applications for gas tungsten arc welding in maintenance a repair.

6. various gases used for GTAW

Various gases used in GTAW are explained as follows,

a) Argon

Argon is a heavy gas obtained from the atmosphere by the liquefaction of air, and is available as a compressed gas or a liquid, depending on the volume of use. It is obtained at much lower prices in the bulk liquid form compared to the compressed gas form, and it is the most widely used type of shielding gas for gas tungsten arc welding. Argon has several advantages over helium:

1) Quieter and smoother arc action.
2) Easier arc starting.
3) Lower arc voltage for current settings and arc lengths. This is good on thin metals.
4) Good cleaning action, which is preferred for the welding of aluminum and magnesium
5) Lower flow rates are required for good shielding. Argon is heavier than air.
6) Lower cost and more availability.

b) Helium

Helium is a light gas obtained by separation from natural gas. It is available as a liquid but used more often as compressed gas in cylinders. Since helium is lighter than air, it leaves the welding area quicker and therefore requires higher flow rates. Another disadvantage is that it is more expensive and is less available than argon. Helium does have several advantages over argon shielding gas:

1. Gives a smaller heat affected zone.
2. Produces higher arc voltages for given current settings and arc lengths. This is good on thicker metals and metals with high conductivity.
3. It is better for welding at higher speeds.

4. Gives better coverage in vertical and overhead positions.
5. Provides deeper penetration because of more heat input.
6. Tends to flatten out the root pass of the weld bead when used as a backing gas.

c) Argon-Helium Mixtures

The argon-helium mixtures provide the better control of argon and the deeper penetration of helium. Common mixtures of these gases by volume are 75% helium- 25% argon, or 80% helium-20% argon. A wide variety of mixtures is available, particularly for their wide usage in automatic welding.

7. Filler Metals used for GTAW

Since the GTAW process can weld a wide variety of metals, it generates a need for various filler metals. The selection of the proper filler metal is primarily dependent on the chemical composition of the base metal; filler metals are often similar to the base metal, although not necessarily identical. Manufacturers produce filler metals with closer control on chemistry, purity, and quality than for base metals. The choice of a filler metal for a given application depends on the suitability for the intended operation, the cost, and the metallurgical compatibility. The required tensile strength, impact toughness, electrical conductivity, thermal conductivity, corrosion resistance, and weld appearance of a weldment are also important considerations. Deoxidizers added to the filler metals can give better weld soundness as well.

Selection of Filler Metal

The type of base metal and the specific mechanical and chemical properties desired are the major factors in determining the choice of a filler metal. You must be able to identify the base metal to select the proper filler metal. The selection of the proper filler metal for specific job applications is quite involved, but you should base it on the following factors:

1. Base metal strength properties — this is done by choosing a filler metal to match the tensile strength of the base metal. This is usually most important with steel.
2. Base metal composition — the chemical composition of the base metal must be known. Matching the chemical composition is not as important for mild steel as it is for stainless steels and non-ferrous metals. Closely matching the filler metal to the base metal is needed when corrosion resistance and color match are important considerations.
3. Thickness and shape of base metal weldments — Thick sections or complex shapes may require maximum ductility to avoid weld cracking. Filler metal types that give best ductility should be used.

8. Advantages of TIG welding

a) Produces high quality, low-distortion welds
b) Free from spatter & slag
c) Can be used with or without filler wire
d) Can be used with a range of premier supplies
e) Welds almost all metals
f) Give precise control of welding heat.

9. Limitations

1) Produces lower deposition rates than consumable electrode arc welding process.
2) Requires slightly more skill as compared to GMAW or shielded metal arc welding (SMAW)
3) Less economical for section thickness greater than 9.5 mm
4) Tungsten inclusion if the electrode is allowed to contact the weld pool.

10. Process parameters of GTAW

Control of the operating variables or process parameters in Gas Tungsten arc welding is essential if high production rates and the welds of good quality are to be obtained. The following are the important variables:

i. Welding current
ii. Welding voltage
iii. Welding speed and rate of heat input.
iv. Electrode size.
v. Gas flow rate

Explanation of these process parameters are as follows,

i. Welding current

Welding current is the most influential parameter because it affects bead shape, controls the rate at which electrode is melted and therefore also controls the deposition rate, the depth of penetration, and the amount of base metal melted. If the current is too high at a given welding speed, the depth of fusion or penetration will also be too high so that the resulting weld may tend to melt through the metal being joined. High current also leads to waste of electrodes in the form of excessive reinforcement and produces digging arc and undercut. This over welding increases weld shrinkage and causes greater distortion. The value of welding current used in TIG has the greatest effect on the deposition rate, the weld bead size, shape and the penetration. When all the other welding parameters are held constant, increasing the current will increase the depth and the width of the weld penetration and the size of the weld bead.

ii. Welding voltage

Welding voltage varies with the length of the arc between the electrode and molten weld metal. With the increase in arc length, the arc voltage increases because lengthening of the arc exposes more of the arc column to the cool boundary of the arc. The voltage principally determines the shape of the weld bead cross section and its external appearance. Increasing the welding voltage with constant current and welding speed produces flatter, wider, less penetrated weld beads and tends to reduce the porosity caused by rust or scale on steel.

iii. Welding speed and heat input

Welding speed is the linear rate at which an arc is moved along the weld joint. With any combination of welding voltage and welding current, the effect of changing the welding speed confirms to a general pattern. If the welding speed is increased, power or heat input per unit length of weld is decreased and less filler metal is applied per unit length of the weld, resulting in less weld reinforcement. Thus, the weld bead becomes smaller. Weld penetration is affected more by welding speed than any variable other than current. If welding speed is more than required heat input to the joint decreases, less filler metal is deposited than required, Reinforcement height decreases. If welding speed is slow, heat input rate increases, Weld width increases and reinforcement height also increases more convexity.

Calculation of heat input

Heat input serves a significant role in welding. The rate of heat input is directly proportional to the voltage and current and inversely proportional to the welding speed. Most of the heat of welding will be dissipated by conduction through the adjacent metal, although a small amount will be lost by radiation and convection to the surrounding environment. Heat input is typically calculated as follows:

$$H = \frac{60VI}{1000S}$$

Where,

H = Heat Input (kJ/mm),
V = Arc Voltage (Volts),
I = Current (Amps) and
S = Welding speed (mm/min).

iv. Electrode size

Electrode size affects the weld bead shape and the depth of penetration at fixed current. Electrode size also influences the deposition rate. At any given current, a small diameter electrode will have a higher current density and a higher deposition rate than a larger electrode. However, a larger diameter electrode can carry more current than a smaller electrode, and produce a higher deposition rate at higher amperage. Larger-diameter electrodes have a longer life but may be more difficult to arc-start at low amperages For the same values of current, arc voltage and welding speed, an increase in electrode diameter results in a slight increase in the spread of the bead.

v. Gas flow rate

The correct flow rate is an adequate amount to shield the molten weld pool and protect the tungsten electrode. Any greater amount than this is wasted. The correct flow rate in cubic feet per hour is influenced by many variables that must be considered on each application. When the welding current, nozzle diameter, or electrode stick out is increased, the flow rate should be increased. When welding in the AC mode the current reversals have a disturbing affect on the shielding gas and flow should be increased by 25%. And of course when welding in a drafty situation, flow rate should be doubled. When welding corner or edge joints, excessive flow rates can cause air entrapment. In this situation, the effectiveness of the shielding gas can be improved by reducing the gas flow by about 25%.

III. CONCLUSION

In this paper, we discuss the influence introduction to GTAW, application of the GTAW, various gases & filler wire used in GTAW, process parameter for joining the aluminium alloy of GTAW. To do these a thorough literature survey is carried out on various aspects of the proposed topic, in various reviewed journals, books and other research resources. The prominent results of the present study are summarized below. All the necessary TIG welding principles, equipments, parameters have been explained. From above review it is indicated that Gas Tungsten Arc Welding process parameters Welding Speed, Welding Voltage, Welding Current, Gas flow rate, Electrode size etc. are important control on welding materials. These parameters, if not carefully controlled, might result the damage of welding area. TIG welding parameters are affected the weld strength in terms of weld bead geometry and mechanical strength.

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