The principle Of Tungsten Inert Gas (TIG) Welding Process

This chapter presents the principle of tungsten inert gas (TIG) welding process besides important components of TIG welding system and their role. This process is also known as gas tungsten arc welding (GTAW) process. Further, fundamentals of heat generation, arc stability and arc efficiency have also been described. Additionally, comparison of argon and helium as shielded gases has been discussed.

Keywords: Tungsten inert gas welding, shielding gas, welding torch, arc stability, Arvs. He

14.1 Introduction

Tungsten inert gas welding process also called as gas tungsten arc welding is named so because it uses a) electrode primarily made of tungsten and b) inert gas for shielding the weld pool to prevent its contamination from atmospheric gases especially when joining high strength reactive metals and alloys such as stainless steel, aluminium and magnesium alloys, wherever high quality weld joints need to be developed for critical applications like nuclear reactors, aircraft etc. Invention of this process in middle of twentieth century gave a big boost to fabricators of these reactive metals as none of the processes (SMAW and Gas welding) available at that time were able to weld them successfully primarily due to two limitations a) contamination of weld from atmospheric gases and b) poor control over the heat input required for melting (Fig. 14.1). Moreover, welding of aluminium and its alloys with shielded metal arc welding process can be realized using halide flux coated electrodes by overcoming the problems associated with Al_2O_3, however, halides are very corrosive and therefore welding of aluminium is preferable carried out using inert shielding environment with the lerp of processes like GTAW and GMAW. Despite of so many c process is invariably recommended for join less than 1mm.

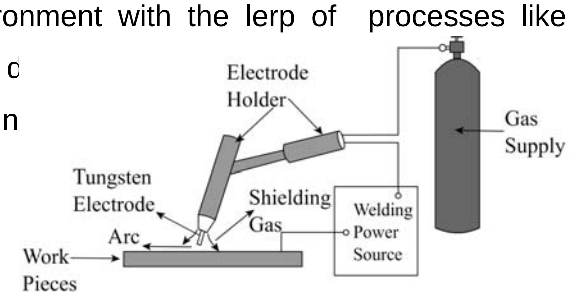


Fig. 14.1 Schematic of tungsten inert gas welding process

14.2 TIG welding system

There are four basic components (Fig. 14.2) of TIG welding system namely a) DC/AC power source to deliver the welding current as per needs, b) welding torch (air/water cooled) with tungsten electrode and gas nozzle, c) inert shielding gas (He, Ar or their mixture) for protecting the molten weld pool contamination from atmospheric gases and d) controls for moving the welding torch as per mode of operation (manual, semi-automatic and automatic). This process uses the heat generated by an electric arc between the non-consumable tungsten electrode and work piece (mostly reactive metals like stainless steel, Al, Mg etc.) for melting of faying surfaces and inert gas is used for shielding the arc zone and weld pool from the atmospheric gases.

14.2.1 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.

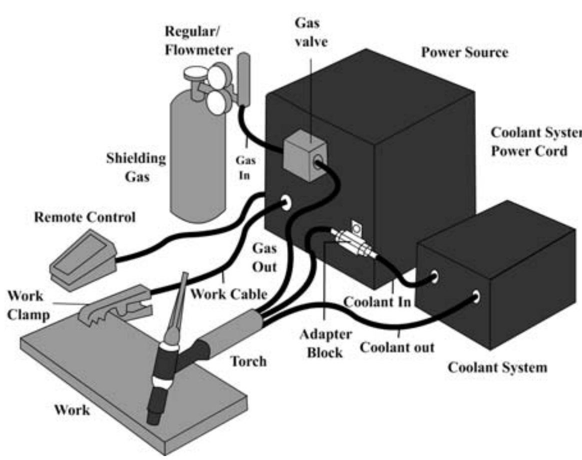


Fig. 14.2 Details of components of GTAW system [Millerweld.com]

14.2.2 Welding Torch

TIG welding torch includes three main parts namely non-consumable tungsten electrode, collets and nozzle. A collet is primarily used to hold the tungsten electrodes of varying diameters in position. Nozzle helps to form a firm jet of inert gas around the arc, weld pool and the tungsten electrode. The diameter of the gas nozzle must be selected in light of expected size of weld pool so that proper shielding of the weld pool can be obtained by forming cover of inert gas. The gas nozzle needs to be replaced at regular interval as it is damaged by wear and tear under the influence of intense heat of the welding arc. Damaged nozzle does not form uniform jet of inert gas around the weld pool for protection from the atmospheric gases. Typical flow rate of shielding inert gas may vary from 5-50 liters/min.

TIG welding torch is generally rated on the basis of their current carrying capacity as it directly affects the welding speed and so the production rate. Depending upon the current carrying capacity, the welding torch can be either water or air cooled. Air cooled welding torch is generally used for lower range of welding current than water cooled torches.

14.2.3 Filler wire

Filler metal is generally not used for welding thin sheet by TIGW. Welding of thick steel plates by TIG welding to produce high quality welds for critical applications such as joining of nuclear and aero-space components, requires addition of filler metal to fill the groove. The filler wire can be fed manually or using some wire feed mechanism. For feeding small diameter filler wires (0.8-2.4mm) usually push type wire feed mechanism with speed control device is used. Selection of filler metal is very critical for successful welding because in some cases even use of filler metal similar to that base metal causes cracking of weld metal especially when their solidification temperature range is every wide (>50^{o}C). Therefore, selection of filler wire should be done after giving full consideration to the following aspects such as mechanical property requirement, metallurgical compatibility, cracking tendency of base metal under welding conditions, fabrication conditions etc.

For welding of aluminium alloys, Al-(5-12wt.%) Si filler is used as general purpose filler metal. Al-5%Mg filler is also used for welding of some aluminium alloys.

Welding of dissimilar steels namely stainless steel with carbon or alloy steels for high temperature applications needs development of buttering layer before welding for reducing carbon migration and residual stress development related problems.

14.2.4 Shielding gas

Helium, Argon and their mixtures are commonly used as inert shielding gas for protecting the weld pool depending upon the metal to be welded, criticality of application and economics. Helium or hydrogen is sometimes added (1-2%) in argon for specific purposes such as increasing the arc voltage and arc stability which in turn helps to increase the heat of arc. The selection of inert gases to be used as shielding gas in GTAW and GMAW process depends upon the type of metal to be welded and criticality of their applications. Carbon dioxide is not used with GTAW process, at high temperature in arc environment, the thermal decomposition of the carbon dioxide produces CO and O_2. Generation of these gases adversely affect the quality and soundness of the weld joint and reduces the life of tungsten electrode.

Inert Gases

Argon and helium are the mostly commonly used shielding gases for developing high quality weld joints of reactive and ferrous metals. Small amount of hydrogen or helium is often added in argon to increase the penetration capability and welding speed. These two inert gases as shielding gas are different in many ways. Some of these features are described in following section.

A. Heat of welding arc

The ionization potential of He (25eV) is higher than Ar (16eV). Therefore, application of He as shielding gas results in higher arc voltage and hence different VI arc characteristics of arc than when argon is used as shielding gas. In general, arc voltage generated by helium for a given arc length during welding is found higher than argon. This results in hotter helium arc than argon arc. Hence, helium is preferred for the welding of thick plates at high speed especially metal systems having high thermal conductivity and high melting point.

B. Arc efficiency

Helium offers higher thermal conductivity than argon. Hence, He effectively transfers the heat from arc to the base metal which in turn helps in increasing the welding speed and arc efficiency.

C. Arc stability

He is found to offer more problems related with arc stability and arc initiation than Ar as a shielding gas. This behaviour is primarily due to higher ionization potential of Hethan Ar. High ionization potential of helium means it will result in presence of fewer charged particles between electrode and work piece required for initiation and maintenance of welding arc. Therefore, arc characteristics are found to be different for Ar and He. A minima arc voltage is found in VI characteristics curve of an arc when both the gases are used as shielding gas but at different level of welding currents. With argon as shielding gas the welding current corresponding to the lowest arc voltage is found around 50A while that for helium occurs at around 150A (Fig. 14.3). Reduction in welding current below this critical level (up to certain range) increases the arc voltage; which permits some flexibility in arc length to control the welding operation.

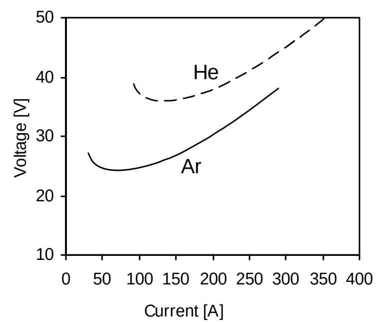


Fig. 14.3 Influence of shielding gas on VI characteristics of GTAW process

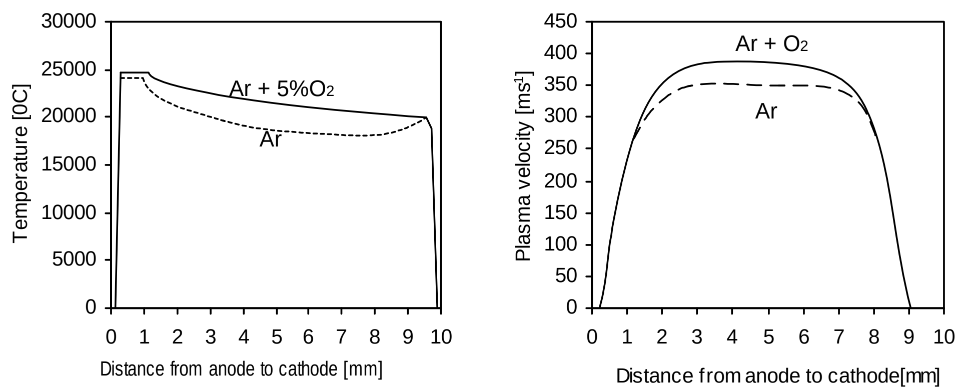
D. Flow rate of shielding gas

Argon (density 1.783g/l) is about 1.33 and 10 times heavier than the air and the helium respectively. This difference in density of air with shielding gases determines the flow rate of particular shielding gas required to form a blanket over the weld pool and arc zone to provide protection against the environmental attack. Helium being lighter than air tends to rise up immediately in turbulent manner away from the weld pool after coming out of the nozzle. Therefore, for effective shielding of the arc zone, flow rate of helium (12-22 l/min) must be 2-3 times higher than the argon (5-12 l/min).

Flow rate of shielding gas to be supplied for effective protection of weld pool is determined by the size of molten weld pool, sizes of electrode and nozzle, distance between the electrode and work piece, extent of turbulence being created ambient air movement (above 8-10km/hr). For given welding conditions and welding torch, flow rate of the shielding gas should be such that it produces a jet of shielding gas so as to overcome the ambient air turbulence and provides perfect cover around the weld pool. Unnecessarily high flow rate of the shielding gas leads to poor arc stability and weld pool contamination from atmospheric gases due to suction effect.

E. Mixture of shielding gases

Small addition of hydrogen in argon increases arc voltage which burns the arc hotter and this in turn increases the weld penetration and welding speed like He. To take the advantage of good characteristics of He (thermal conductivity, high temperature arc) and Ar (good arc initiation and stability) a mixture of these two gases Ar-(25-75%)He is also used. Increasing proportion of He in mixture increases the welding speed and depth of penetration of weld. Addition of oxygen in argon also helps to increase the penetration capability of GTAW process owing to increase in arc temperature and plasma velocity (Fig. 14.4)



a) b)

Fig. 14.4 Influence of oxygen addition in Ar on a) arc temperature and b) plasma velocity of GTAW process

F. Advantages of Ar over He as Shielding Gas

For general, purpose quality weld, argon offers many advantages over helium a) easy arc initiation, b) cost effective and good availability c) good cleaning action with (AC/DCEP in aluminium and magnesium welding) and d) shallow penetration required for thin sheet welding of aluminium and magnesium alloys.

References and books for further reading

- Metals Handbook-Welding, Brazing and Soldering, American Society for Metals, 1993, 10th edition, Volume 6, USA.
- R S Parmar, Welding process and technology, Khanna Publisher, New Delhi

- R S Parmar, Welding engineering & technology, Khanna Publisher, 2002, 2nd edition, New Delhi.
- Richard Little, Welding and Welding Technology, McGraw Hill, 2001, 1st edition.
- H Cary, Welding Technology, Prentice Hall, 1988, 2nd edition.
- S V Nadkarni, Modern Arc Welding Technology, Ador Welding Limited, 2010, New Delhi.
- Welding handbook, American Welding Society, 1987, 8th edition, volume 1 & 2, USA.
- http://www.millerwelds.com/resources/tech_tips/TIG_tips/setup.html

Source:
http://nptel.ac.in/courses/112107090/14