The Influence Of Process Parameters & Plasma Arc Welding

This chapter presents the influence of process parameters of pulse TIG welding process on the development of sound weld joint. Further, the concept of hot wire TIG welding process has also been elaborated. Additionally, basic principle of plasma arc welding has been described with help of suitable schematic diagrams.

Keyword: Peak current, background current, pulse frequency, hot wire GTAW, plasma arc welding, transferred and non-transferred arc welding,

16.1 Selection of pulse parameters

High peak current setting is required for welding of thick section of metal with high thermal conductivity. Background current or low level of current must be high enough to maintain the stable arc with lowest possible heat input so that solidification of the molten weld can take place without any heat buildup. Duration of the pulse and background currents determines the pulse frequency. The frequency of the pulses and so their durations are selected as per heat input and degree of control over the weld pool required. In Pulsed TIG welding , the weld bead is composed of a series of overlapping weld spots, especially when welding is done at low frequency (Fig. 16.1).

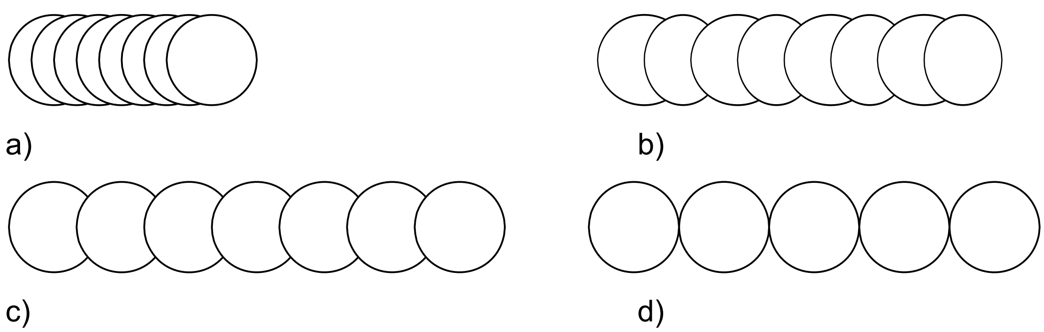


Fig. 16.1 The relationship between the overlapping of weld spot and pulse frequency in reducing order (for a given welding speed)

Average welding current during pulse welding for calculation of heat input can be obtained by using following equation:

I p= peak current (A).

T p= peak pulse current duration (ms).

I b= background current (A).

T b= background current duration (ms).

I_m= Average current (A), defined as:

$I_m = [(I_p \times t_p) + (I_b \times t_b)] / (t_p + t_b)$……………….Equation 16.1

16.1.1 Pulse current

Generally, background current varies from 10 to 25% of peak current depending upon the thickness base metal whereas peak current is generally set at 150 to 200% of steady current corresponding to the conventional TIG welding for the same base metal. Selection of the pulse peak current duration depends on the weld pool size and penetration required for welding of the work piece of a particular thickness while background current duration is determined on the basis of cooling rate required in weld to achieve better control over the weld pool and the microstructure of weld metal so that desired mechanical performance of the weld joints can be obtained.

16.1.2 Pulse Frequency

Very low pulse frequency (conversely longer background current duration and short peak current period) during Pulse TIG welding, reduces heat available for welding input which in turn increases the solidification rate. Too high solidification rate increases porosity formation in weld primarily due to inadequate opportunities for escaping of gases from the weld pool. A fine grained structure can be achieved using both low and high pulse frequencies. Fine microstructure is known to improve the mechanical properties of the weld joint in general except creep resistance. Low pulse frequency (up to 20 Hz) has more effect on the microstructure and mechanical properties. Pulse TIG welding is commonly used for root pass welding of tubes and pipe welding to take the advantage of low heat input.

16.2 Hot wire Tungsten Arc Welding

This process is based on the principle of using preheated filler in TIG welding and is primarily designed to reduce heat input to the base metal while realizing higher increase the deposition rate (Fig. 16.2). Preheating of the filler increases welding speed and so productivity. Preheating of the filler can be done using an external source of heat. AC current is commonly used to preheat the filler wire by electrical resistance heating (Fig. 16.3). This process can be effectively used for welding of ferrous metals and Ni alloys. Welding of aluminium and copper by this process is somewhat limited mainly due to difficulties associated with preheating of Al and Cu fillers as they need heavy current for electrical resistive heating of filler wire.

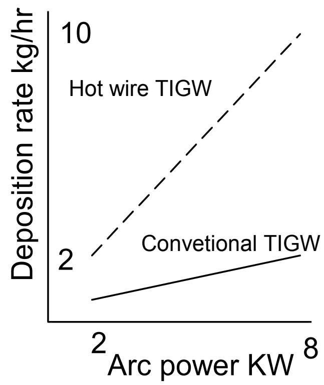


Fig. 16.2 Comparative deposition rates of conventional and hot wire GYAW process

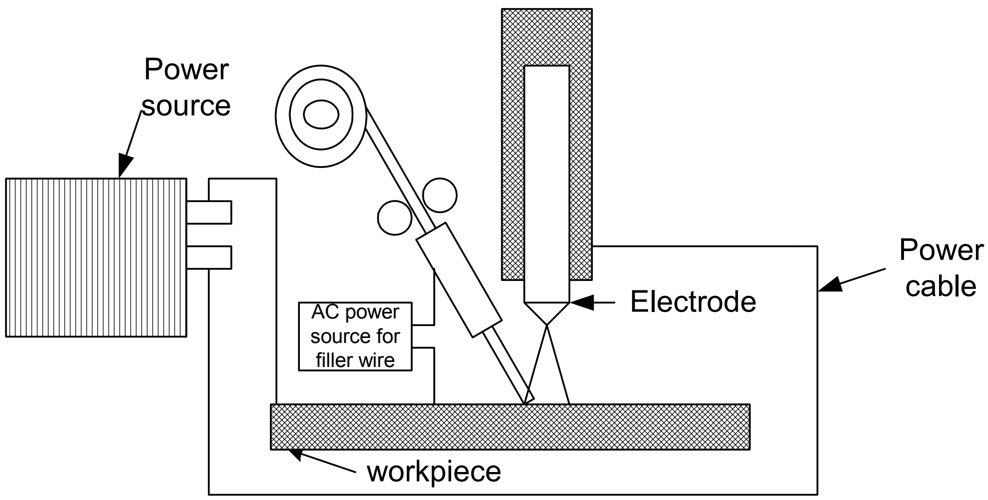
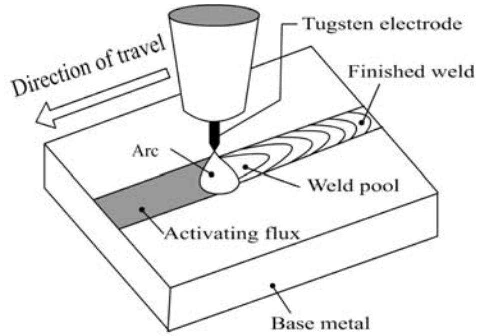


Fig. 16.3 Schematic showing the principle of hot wire GTAW process

16.3 Activated flux assisted welding processes

Activated flux assisted GTA and GMA welding processes are also being explored to take advantage of high penetration which is typically achieved by these processes. The flux assisted processes use common fluxes like TiO_2, SiO_2, Cr_2O_3, ZrO_2 halide fluxes. The flux is usually applied in the form of paste on to the faying surfaces of base metal followed by application of welding arc for melting the base metal. Application of these fluxes results in many desirable effects on the welding a) increasing the arc voltage compared with conventional GTAW or GMAW process under identical conditions of arc length, welding current which in turn burns the arc hotter and increases the depth of penetration and b) increasing the constriction of the arc which in turn facilitates the development of weld of high depth to width ratio. Increase in depth of the penetration in turn increases the rate of lateral heat flow from the weld pool to the base metal. Increased rate of heat flow from the weld pool causes grain refinement owing to the high cooling rate and low solidification time. High depth to width ratio, effect imparted to the weld pool by activated fluxes is found similar to the high energy density process. Activated flux assisted GTA and GMA welding processes have been developed for joining of titanium and steel for nuclear and aerospace applications.



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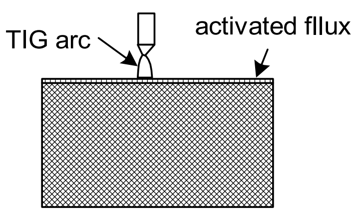
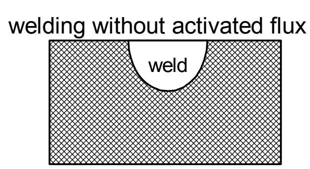
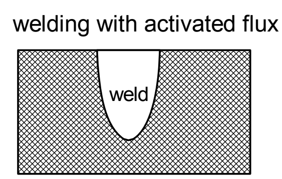
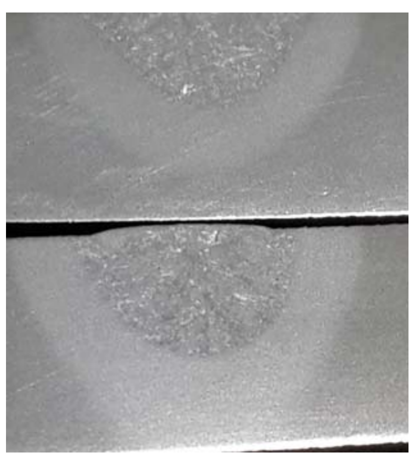






b) c) d)



e)

Fig. 16.4 Schematic of activated flux TIG welding: a) method of applying flux, b) application of flux and arc, c) weld bead geometry without activated flux and d) weld bead geometry without activated flux [H Huang, MTA, 41A, 2010, 2829] and e) photograph of weld bead geometry with activated flux and without GTAW

Plasma Arc Welding

16.4 Introduction

The plasma arc welding (PAW) can be considered as an advanced version of TIG welding. Like TIGW, PAW also uses the tungsten electrode and inert gases for shielding of the molten metal. Low velocity plasma and diffused arc is generated in the TIG welding while in case of PAW very high velocity and coherent plasma is generated. Large surface area of the arc exposed to ambient air and base metal in case of TIG welding causes greater heat losses than PAW and lowers the energy density. Therefore, TIG arc burns at temperature lower than plasma arc.

16.5 Principle of PAW

In plasma arc welding, arc is forced to pass through nozzle (water cooled copper) which causes the constriction of the arc (Fig. 16.5). Constriction of arc results in (a) reduction in cross-sectional area of arc, (b) increases (d) increases energy density and (c) increases to velocity of plasma approaching to the sound velocity and temperature to about 25000 ^{0}C. these factors together make PAW, a high energy density and low heat input welding process therefore; it poses fewer which in turn reduces problems associated with weld thermal cycle.

Constriction of arc increases the penetration and reduces the width of weld bead. Energy associated with plasma depends on plasma current, size of nozzle, plasma gas (Fig. 16.6). A coherent, calumniated and stiff plasma is formed due to constriction therefore it doesn’t get deflected and diffused. Hence, heat is transferred to the base metal over a very small area which in turns results in high energy density and deep of penetration and small width of the weld pool / key hole / cut. Further, stiff and coherent plasma makes it possible to work having stable arc with very low current levels (<15 A) which in turn has led to development micro-plasma system.

Energy density and penetration capability of plasma jet is determined by the various process parameters namely plasma current, nozzle orifice diameter and shape, plasma forming gas (Air, He, Ar) and flow rate of plasma carrying. Increasing plasma current, flow rate, thermal conductivity of plasma forming gas and reducing nozzle orifice diameter increases together result in the energy density and penetration capability of plasma jet. In general, the plasma cutting uses high energy density in combination with high plasma velocity and high flow rate of high thermal conductivity plasma forming gas. A combination of such characteristics for plasma cutting is achieved by controlling above process parameters. Further, thermal conductivity of plasma forming gas must be high enough for cutting operation so that heat can be effectively transferred rapidly to the base metal. Plasma welding needs comparatively low energy density and low velocity plasma to avoid melt through or blowing away tendency of molten metal.

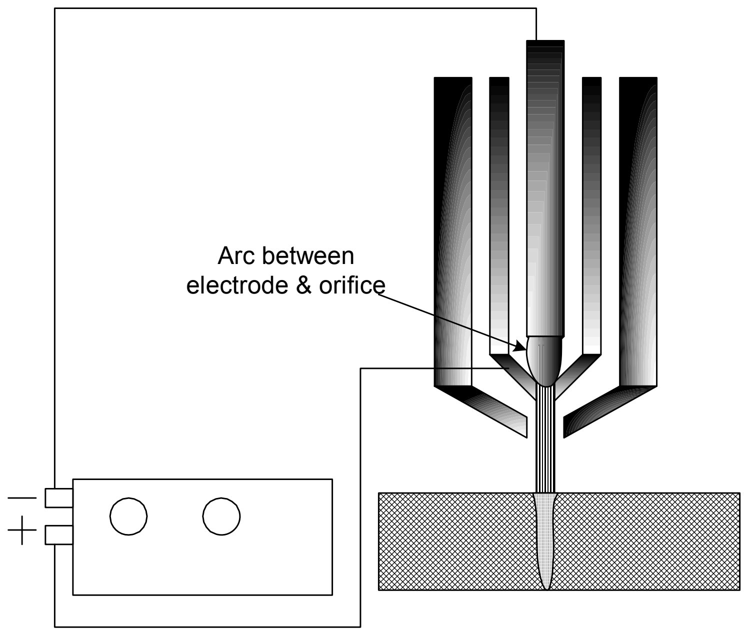


Fig. 16.5 Schematic of plasma arc welding system showing important components

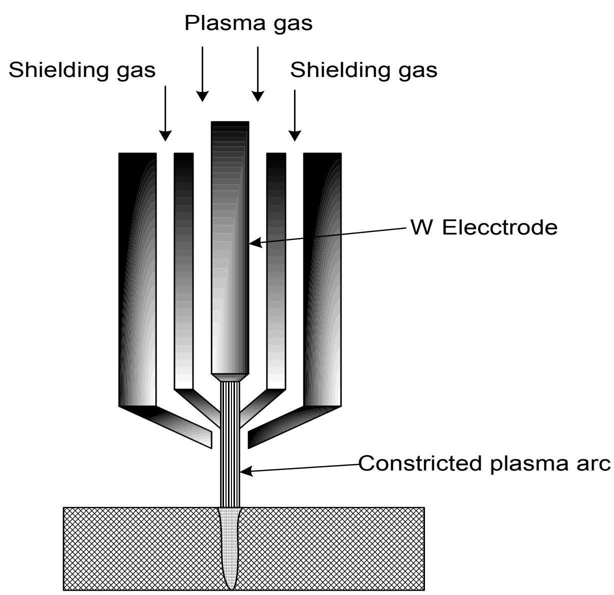


Fig. 16.6 Schematic of constriction of arc in PAW

High energy density associated with plasma arc produces a temperature of order of 25,000 ^{0}C. This process uses the heat transferred by plasma (high temperature charged gas column) produced by a gas (Ar, Ar-H_2 mixture) passing through an electric arc, for melting of faying surfaces. Inert gas (Ar, He) is used to protect the molten weld pool from the atmospheric gases. Charged particles (electrons and ions) formed as a result of ionization of plasma gas tends to reunite when they strike to the surface of work piece. Recombination of charged particles liberates heat which is also used in melting of base metal. Electric arc can be produced between non-consumable electrode and work-piece or non-consumable electrode and nozzle. As discussed above, plasma arc welding uses two types of gases one is called plasma gas and other is inert gas primarily for shielding the weld pool from the contamination by atmospheric gases. Plasma gas is primarily used to develop plasma by passing through arc zone and transfer the heat to the weld pool.

PAW uses the constant current type power source with DCEN polarity. The DCEN polarity is invariable used in PAW because tungsten electrode is used for developing the arc through which plasma forming gas is passed. Tungsten electrode has good electron emitting capability therefore it is made cathode. Further, DCEN polarity causes less thermal damage to the electrode during welding as about one third of total heat is generated at the cathode and balance two-third of arc heat is generated at the anode side i.e. work-piece. DCEP polarity does not help the process in either way. Current can vary from 2-200 A.

The plasma arc in PAW is not initiated by the conventional touch start method but it heavily depend on use of high frequency unit. Plasma is generated using two cycles approach a) producing very small high-intensity spark (pilot arc) within the torch body by imposing pulses of high voltage, high frequency and low current about 50A (from HF unit) between the electrode and nozzle which in turn generates a small pocket of plasma gas and then as soon as torch approaches the work-piece main current starts flowing between electrode and job leading to the ignition of the transferred arc. At this stage pilot is extinguished and taken off the circuit.

16.6 Types of PAW

Plasma generated due to the arc between the non-consumable electrode and work-piece is called transferred plasma whereas that due to arc between non-consumable electrode and nozzle is called non-transferred plasma. Non-transferred plasma system to a large extent becomes independent of nozzle to work piece distance.

Transferred plasma offers higher energy density than non-transferred plasma and therefore it is preferred for welding and cutting of high speed steel, ceramic, aluminium etc. Non-transferred plasma is usually applied for welding and thermal spray application of steel and other common metals. Depending upon the current, plasma gas flow rate, and the orifice diameter following variants of PAW has been developed such as:

- Micro-plasma (< 15 Amperes)
- Melt-in mode (15–400 Amperes) plasma arc
- Keyhole mode (>400 Amperes) plasma arc

Micro-plasma welding systems work with very low plasma forming current (generally lower than 15 A) which in turn results in comparatively low energy density and low plasma velocity. These conditions become good enough to melt thin sheet for plasma welding.

Plasma for melt-in mode uses somewhat higher current and greater plasma velocity than micro-plasma system for welding applications. This is generally used up to 2.4 mm thickness sheet. For thickness of sheet greater than 2.5 mm normally welding is performed using key-hole technique. The key hole technique uses high current and high pressure plasma gas to ensure key-hole formation. High energy density of plasma melts the faying surfaces of base metal and high pressure plasma jet pushes the molten metal against vertical wall created by melting of base metal and developing key-hole. Plasma velocity should be such that it doesn't push molten metal out of the hole. The key is formed under certain combination of plasma current, orifice gas flow rate and velocity of plasma welding torch and any disturbance to above parameters will cause loss of key-hole. For key-holing, flow rate is very crucial and therefore is controlled accurately $\pm$ 0.14 liter/min. Nozzles are specified with current and flow rate.

16.7 Advantage of PAW

With regard to energy density, PAW stands between GTAW/GMAW and EBW/LBW accordingly it can be used using melt-in mode and key-hole mode. Melt-in mode results in greater heat input and higher width to depth of weld ratio than key-hole mode. Higher energy density associated with PAW than GTAW produces narrow heat affected zone and lowers residual stress and distortion related problems. High depth to width ratio of weld produced by PAW reduces the angular distortion. It generally uses about one tenth of welding current as compared to GTAW for same thickness therefore it can be effectively applied for joining of the thin sheets. Further, non-transferred plasma offers flexibility of variation in stand off distance between nozzle and work-piece without extinction of the arc.

16.8 Limitation of PAW

Infrared and ultra-violet rays generated during the PA welding are found harmful to human being. High noise (100dB) associated with PAW is another undesirable factor. PAW is a more complex, costlier, difficult to operate than GTAW besides generating high noise level during welding. Narrow width of the PAW weld can be problematic from alignment and fit-up point of view. Productivity of the PAW in respect of welding speed is found lower than LBW.

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