Lecture 17

Metal Inert Gas Welding

This chapter presents the basic components and principle of metal inert gas welding (MIG) and pulse-MIG welding process with help of suitable schematic diagrams besides the influence of welding parameters in melting rate, and metal transfer. This process is also termed as gas metal arc welding (GMAW). Further, the factors affecting the metal transfer in MIG welding process have been elaborated.

Keywords: Metal inert gas welding, burn-off rate, electrode extension, metal deposition rate, metal transfer in GMAW, transition current, pulse GMAW

17.1 Fundamentals of MIG welding

This process is based on the principle of developing weld by melting faying surfaces of the base metal using heat produced by a welding arc established between base metal and a consumable electrode. Welding arc and weld pool are well protected by a jet of shielding inactive gas coming out of the nozzle and forming a shroud around the arc and weld. MIG weld is not considered as clean as TIG weld. Difference in cleanliness of the weld produced by MIG and TIG welding is primarily attributed to the variation in effectiveness of shielding gas to protect the weld pool in case of above two processes. Effectiveness of shielding in two processes is mainly determined by two characteristics of the welding arc namely stability of the welding arc and length of arc besides other welding related parameters such as type of shielding gas, flow rate of shielding gas, distance between nozzle and work-price. The MIG arc is relatively longer and less stable than TIG arc. Difference in stability of two welding arcs is primarily due to the fact that in MIG arc is established between base metal and consumable electrode (which is consumed continuously during welding) while TIG welding arc is established between base metal and non-consumable tungsten electrode. Consumption of the electrode during welding slightly decreases the stability of the arc. Therefore, shielding of the weld pool in MIGW is not as effective as in TIGW.

Metal inert gas process is similar to TIG welding except that it uses the automatically fed consumable electrode therefore it offers high deposition rate and so it suits for good quality weld joints required for industrial fabrication (Fig. 17.1). Consumable electrode is fed automatically while torch is controlled either manual or automatically. Therefore, this process is found more suitable for welding of comparatively thicker plates of reactive metals (Al, Mg, Stainless steel). The quality of weld joints of these metals otherwise is adversely affected by atmospheric gases at high temperature.

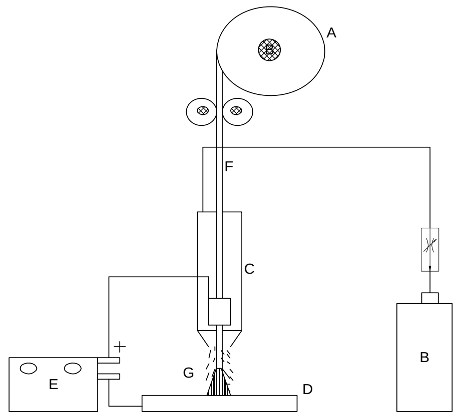

Fig. 17.1 Schematic of GMAW process showing important elements A) Welding spool, B) Shielding gas cylinder, C) welding torch, D) base plate, E) welding power source, and F) consumable electrode.

17.2 Power source for MIG welding

Depending upon the electrode diameter, material and electrode extension required, MIG welding may use either constant voltage or constant current type of the welding power source. For small diameter electrodes (< 2.4 mm) when electrical resistive heating controls the melting rate predominantly, constant voltage power source (DCEP) is used to take advantage of the self regulating arc whereas in case of large diameter electrode constant current power source is used with variable speed electrode feed drive system to maintain the arc length (Fig. 17.2).

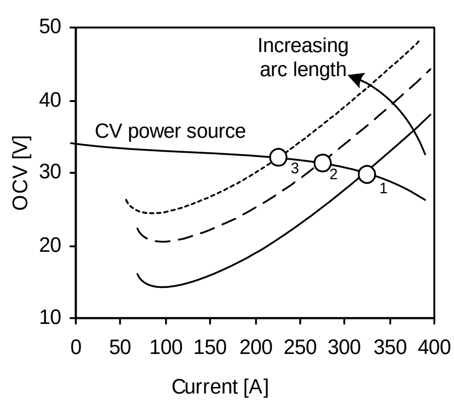

Fig. 17.2 Static characteristics of constant voltage power source showing effect of arc length on operating point

17.3 Shielding gases for MIG welding

Like TIG welding, shielding gases such as Ar, He, CO_2 and their mixtures are used for protecting the welding pool from the atmospheric gases. Effect of the shielding gases on MIG weld joints is similar to that of TIG welding. Inert gases are normally used with reactive metal like Al, Mg and while carbon dioxide can be used for welding of steel for reasonably good quality of weld joints. Application of CO_2 in welding of reactive none-ferrous metal is not preferred as decomposition of CO_2 in arc environment produces oxygen. Interaction of oxygen with reactive metals like Al and Mg (which show greater affinity to the oxygen) form refractory oxides having higher melting point than the substrate which interferes with melting as well as increases the inclusion formation tendency in the weld metal. Moreover, shielding gases in MIGW also affect the mode of metal transfer from the consumable electrode to the weld pool during welding (Fig. 17.3). MIG welding with Ar as shielding gas results in significant change in the mode of metal transfer from globular to spray and rotary transfer with maximum spatter while He mainly produces globular mode of metal transfer. MIG welding with CO_2 results in welding with a lot of spattering. Shielding gas also affects width of weld bead and depth of penetration owing to difference in heat generation during welding.

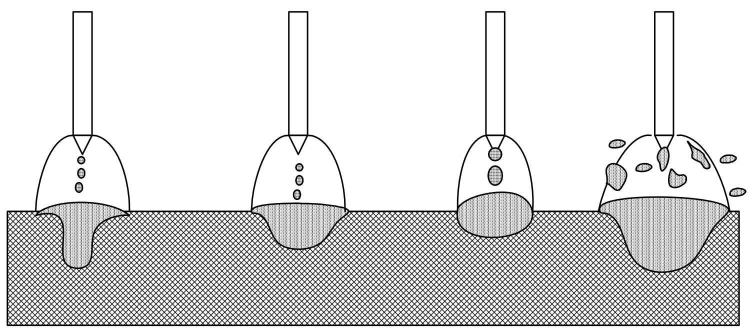

Fig. 17.3 Schematic showing influence of shielding gas on mode of metal transfer

17.4 Effect of MIG welding process parameters

Among various welding parameters such as welding current, voltage and speed probably welding current is most influential parameters affecting weld penetration, deposition rate, weld bead geometry and quality of weld metal (Fig. 17.4). However, arc voltage directly affects the width of weld bead. An increase in arc voltage in general increases the width of the weld. Welding current is primarily used to regulate the overall size of weld bead and penetration. Too low welding current results pilling of weld metal on the faying surface in the form of bead instead of penetrating into the work piece. These conditions increase the reinforcement of weld bead without enough penetration. Excessive heating of the work piece due to too high welding current causes weld sag. Optimum current gives optimum penetration and weld bead width.

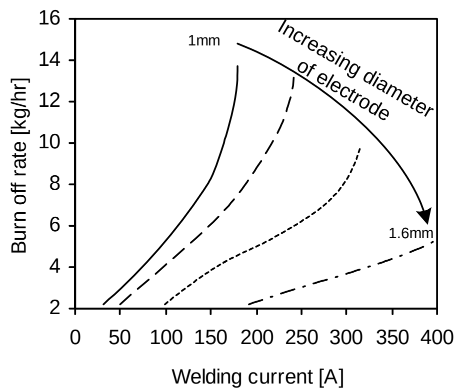

Fig. 17.4 Effect of welding current on melting of electrode of different diameters

Stick out of the electrodes (electrode extension) affects the weld bead penetration and metal deposition rate because it changes the electrode heating due to electric resistance. Increase in stick out increases the melting rate and reduces the penetration due to increased electrical resistive heating of the electrode itself. Selection of welding current is influenced by electrode stick out and electrode diameter. In general, high welding current is preferred for large diameter electrodes with small electrode extension in order to obtain optimal weld bead geometry (Fig.17.5). Increase in welding speed reduces the penetration.

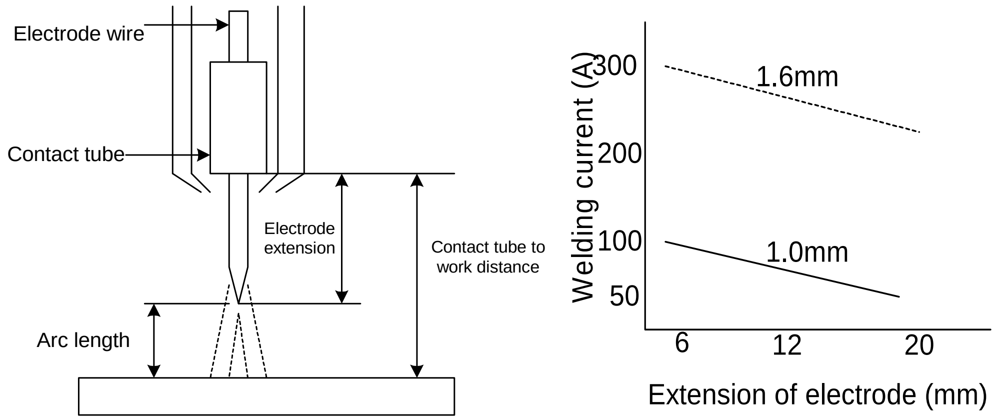

Fig.17.5 Schematic diagram showing a) electrode extension and b) effect of electrode extension on welding current for different electrode diameters

17.5 Metal transfer in MIG welding

Metal transfer during MIG welding depending up on the welding current, electrode diameter and shielding gas can take place through different modes such as short circuit, globular, spray (Fig. 17.6). Mechanisms for these metal transfer modes have already been describe and rotational transfer in section8.2.

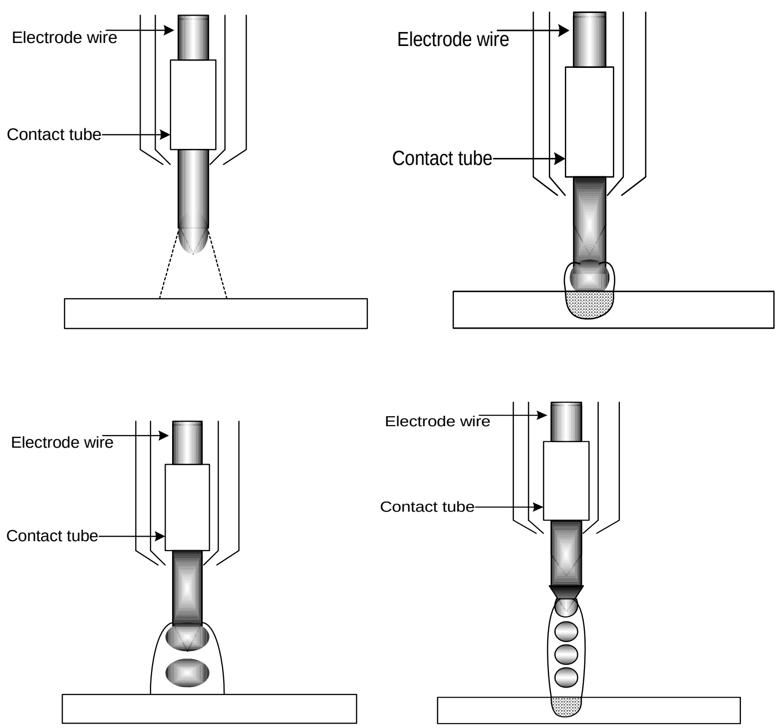

Fig. 17.6 Schematic of modes of metal transfer in MIG welding a) typical set, b) short circuiting transfer, c) globular transfer, and c) spray transfer

Increase in welding current changes mode of metal transfer from short circuiting to globular to spray transfer specially when Ar is used as a shielding gas(Fig. 17.7). Increase in welding current (over a narrow range) leads to significant increase in drop transfer rate per unit time coupled with reduction volume of drops being transferred due to two reasons a) increase in melting rate of the electrode and b) increase in pinch force. This current is called transition current at which major change in mode of metal transfer from globular to spray takes place.

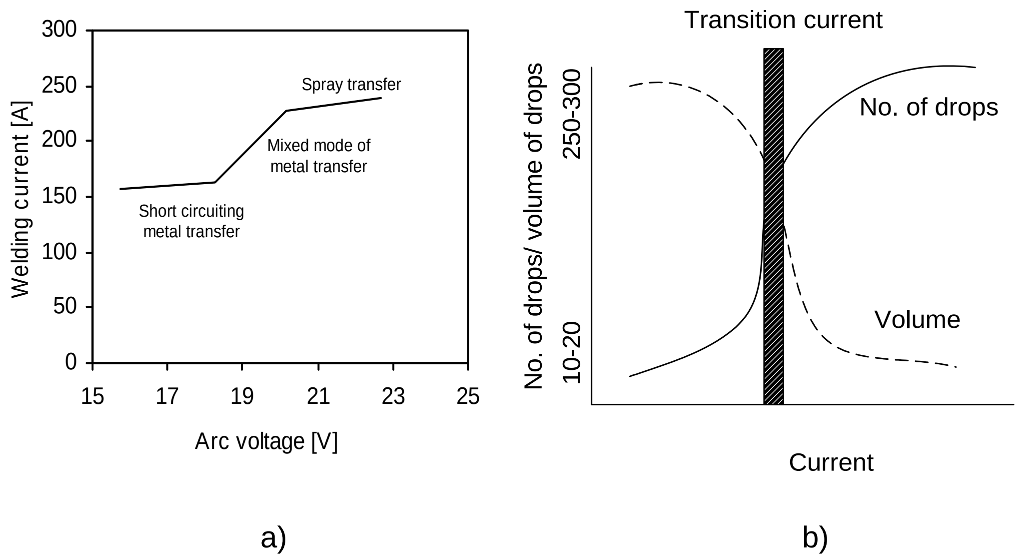

Fig. 17.7 Effect of a) welding parameters on modes of metal transfer and b) on number/volume of drops vs. welding current during metal transfer

17.6 Pulse MIG Welding

Pulse MIG welding is a variant of metal inert gas welding. Pulse MIG welding is also based on the principle of pulsation of welding current between a high and a low level at regular time intervals like Pulse TIG welding (Fig. 17.8). However, back ground and peak current perform slightly different roles. The low level current also called background current is mainly expected just to maintain welding arc while high level welding current called peak current is primarily used for a) melting of faying surfaces with desired penetration of the base metal and b) high melting rate of electrode and c) detachment of molten droplets hanging to the tip of the electrode by pinch force to facilitate spray transfer. An optimum combination of pulse parameters results in transfer of one molten metal drop per peak pulse. This feature of current pulsation in pulse MIG welding reduces net heat input to the base metal during welding which in turn facilitates welding of especially thin sheets and odd position welding.

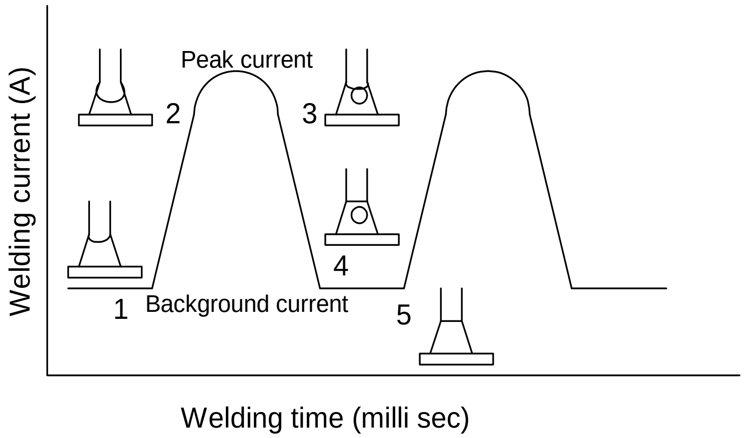

Fig. 17.8 The relationship between the welding current and time with metal drop formation tendency

17.7 Flux cored arc welding process

The flux cored arc welding (FCAW) is another variant of gas metal arc welding process. Like GMAW, this process mainly uses constant voltage power supply. The FCAW uses a tubular electrode filled with flux and other constituents that decompose at high temperature in arc environment to produce inactive gases to protect the weld pool and arc zone from contamination by atmospheric gases (Fig. 17.9). The role of flux in FCAW process is also similar to shielded metal arc welding, however unique feature of filling of flux in continuously fed tubular electrode associated with this process for welding gives freedom from regular stoppage of welding for replacement of electrode. This in turn results in high welding speed and productivity. Since protective gases are generated in the arc environment itself therefore ambient air flow/turbulence doesn't affect the protection of the weld pool appreciably.

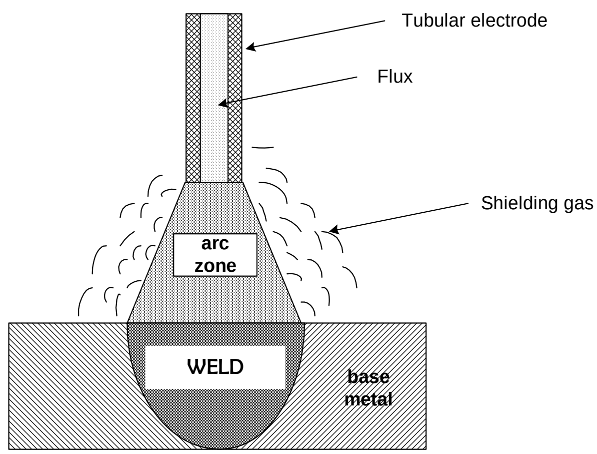

Fig. 17.9 Schematic of FCAW process without shielding gas

This process also used in two ways a) FCAW without shielding gas and b) FCAW with external shielding gas arrange like GMAW. The FCAW process with shielding gas results in somewhat more sound weld with better mechanical properties than FCAW without shielding gas owing to the possibility of formation of few weld discontinuities in weld metal like porosity, slag inclusion etc. in later case. FCAW without shielding gas suffers from a) poor slag detachability, b) porosity formation tendency, c) greater operator-skill requirement and d) emission of harmful noxious gases and smokes imposes need of effective ventilation. Further, excessive smoke generation in case of FCAW without shielding gas can reduce visibility of weld pool during welding which can make the process control difficult. FCAW with external shielding gas provide much better protection to the welding pool and arc zone. FCAW is commonly used for welding of mild steel, structural steel, stainless steel and nickel alloys.

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