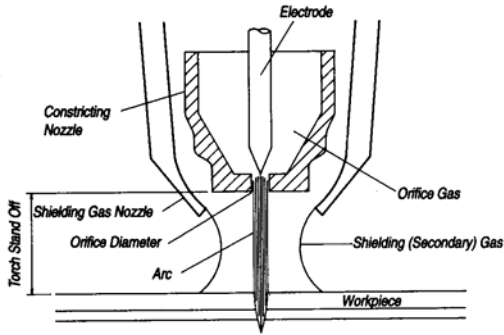


PLASMA

Definition

The plasma arc process utilises an arc between an electrode and the base metal formed through a constricting nozzle.

Figure 1.1
The Plasma Arc

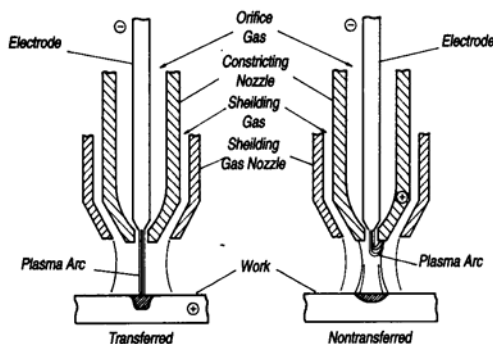


Inert gas usually argon or nitrogen is fed through the torch to surround the electrode. Here it is ionised to form the arc. The resulting 'plasma arc' emanating from the orifice of the constricting nozzle reaches temperatures of 17,000°C hot enough to melt any metal.

Plasma Arc Welding – PAW

Plasma arc welding is an arc welding process in which the joining of metals is produced by the heat of constricted arc between an electrode and base metal (transferred arc) or between the electrode and the constricting nozzle (non transferred arc).

Figure 1.2
Transferred and Non Transferred Plasma Arc Modes

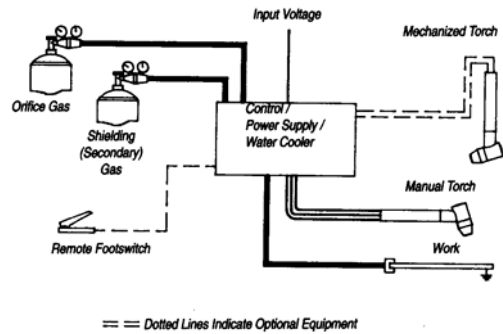


Shielding is generally obtained from the hot ionized gas issuing from the torch and is usually supplemented by an auxiliary supply of inert gas. Filler metal may or may not be added.

Process Definition

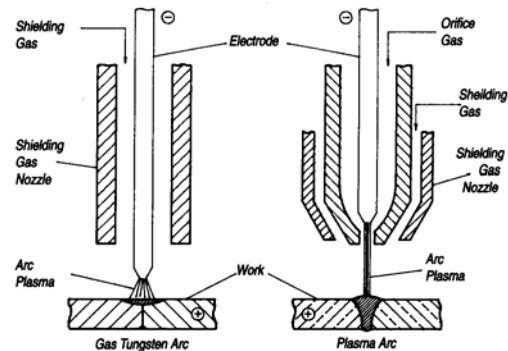
The PAW process equipment is illustrated below in **Figure 1.3**

Figure 1.3
The Process Description



The Plasma arc welding process is very similar to conventional gas tungsten arc welding.

Figure 1.4
Comparison of Gas Tungsten Arc and Plasma Arc Welding Process



The electrode of the GTAW torch extends beyond the end of the shielding gas nozzle. The arc is not restricted and assumes a conical shape. Penetration and weld bead size varies with arc amperage and stand off distance.

In contrast the electrode in a PAW torch is recessed within the constricting nozzle. The arc is squeezed through the constricting nozzle and focused on a relatively small area of the workpiece. Because the shape of the arc is essentially cylindrical, the process is less sensitive to variations in torch to workpiece distance.

Since the electrode of the PAW torch is recessed inside the arc constricting nozzle it is not possible to touch the electrode to the workpiece, this greatly reduces the risk of contamination.

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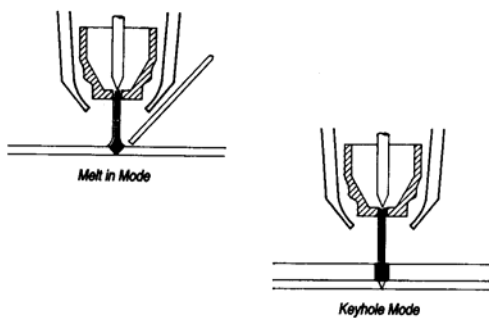
The arc developed in the PAW process has a higher current density than that of GTAW. The increased temperature of the Plasma arc is not its chief advantage, however, the main advantage of the plasma arc is its definite directional stability and focusing effect with smaller heat affected zones, as well as its insensitivity to the torch stand off distance.

At low currents (under 100A) needle arc welding is possible. This long needle shaped arc is used for joining very thin metals from approximately 0.05mm to 3.2mm. The results are comparable with those of mechanised versions of other fusion welding processes that require far more sophisticated controls to maintain precise torch to workpiece distance.

At higher currents (up to 400A), high quality welds can be made on materials up to 25mm.

There are two modes of penetration in plasma arc welding, melt in and key hole.

Figure 1.5
Melt in and Keyhole Mode



Melt in mode utilizes the plasma arc for conventional, manual and mechanized fusion welding. The major advantages over Tig welding are better operator control of torch to workpiece distance and the elimination of tungsten electrode contamination since the electrode is protected inside the nozzle. High quality narrow butt or lap welds on joint thickness up to 3.2mm can be accomplished. Filler metal can be used.

In keyhole plasma arc welding a long, narrow arc completely penetrates the workpiece to form a 'keyhole'. As the torch travels forward, molten metal forms at the leading side of the arc, flows around the arc and rises to form a small weld bead behind it. A complete weld on both the top and bottom surfaces is formed in one pass. The complete penetration of the workpiece thickness and the movement of the molten metal purges impurities and gases from the weld prior to solidification, so that highest possible weld quality is assured. Keyhole welding can be done with metals up to 6.5mm in thickness.

Arc Initiation

The use of a low current pilot arc between the electrode and constricting nozzle usually generated by an AC high frequency or a DC pulse, ionizes the gas such that it conducts the pilot arc current. The ionised gas from the pilot arc forms a low resistance path between the electrode and work. When the power source is energised the main arc is initiated between the electrode and work. The pilot arc is used only to assist in starting the main arc. Once the main arc is initiated the pilot arc is usually extinguished.

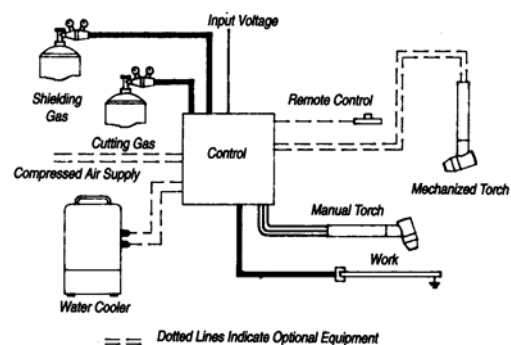
Plasma Arc Cutting - PAC

The Plasma arc cutting process severs metal by using a constricted arc to melt a localised area of workpiece and removing the molten metal with a high velocity jet of ionised gas from the constricting nozzle orifice.

Process Equipment

The equipment required for the PAC is illustrated in Figure 1.6.

Figure 1.6
Equipment Required for PAC Process

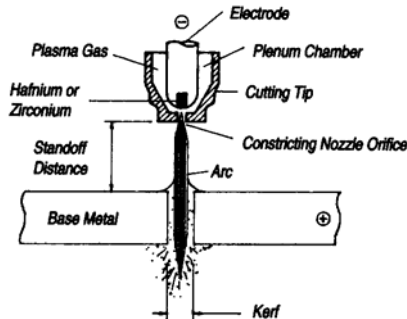


Process Description

The arc is constricted by passing it through an orifice downstream of the electrode. As plasma gas passes through the arc, it is heated rapidly to a high temperature, expands, and is accelerated as it passes through the constricting orifice towards the workpiece. The intensity and velocity of the plasma is determined by several variables including the type of gas, its pressure, the flow pattern, current, the size and shape of the orifice, and the distance to the workpiece.

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Figure 1.7
Plasma Arc Cutting



The orifice directs the super heated plasma stream from the electrode toward the workpiece. When the arc melts the workpiece, the high-velocity jet blows away the molten metal to form the kerf or cut.

The different gases used for plasma arc cutting include nitrogen, argon, air, oxygen, and mixtures of nitrogen/hydrogen and argon/hydrogen.

PAC torches are available in various current ranges, generally categorized as low power those operating at 30A or less, medium power level 30-100A, and high power from 100-1000A. Different power levels are appropriate for different applications, within higher power levels being used for cutting thicker metal at higher speeds.

Arc Initiation

One of two starting methods is used to initiate the cutting arc; pilot arc starting or electrode (or tip) retract starting.

The most common pilot arc starting technique is to strike a high-frequency spark between the electrode and the torch tip. A pilot arc is established across the resulting ionised path. When the torch is close enough to the workpiece an electrically conductive path from the electrode to the workpiece is established. The cutting arc will follow this path to the workpiece.

Retract starting torches have a moveable tip or electrode so that the tip and electrode can be momentarily shorted together and then separated or 'retracted' to establish the cutting arc.

Torches

The Plasma cutting process is used with either a handheld torch or a mechanically mounted torch. There are several types and sizes of each, depending on the thickness of metal to be cut. Some torches can be dragged along in direct contact with the workpiece, while others require that a standoff be maintained between the tip of the torch and workpiece.

Mechanized torches can be mounted either on a tractor or a on a computer-controlled cutting machine or robot. Usually a standoff is maintained between the torch tip and workpiece for best-cut quality. The standoff distance must be maintained with fairly close tolerances to achieve uniform results. Some mechanised torches are equipped with an automatic standoff controlling device to maintain a fixed distance between the torch and workpiece. In other cases mechanical followers are used to accomplish this.

PAC torches operate at extremely high temperatures, and various parts of the torch must be considered to be consumable. The tip and electrode are the most vulnerable to wear during cutting, and cutting performance usually deteriorates as they wear. The timely replacement of consumable parts is required to achieve good quality cuts.

Modern plasma torches have self-aligning and self-adjusting consumable parts. As long as they are assembled in accordance with the manufacturers instructions, the torch should require no further adjustment for proper operation.

Other torch parts such as shield cups, insulators, seals etc may also require periodic inspection and replacement if they are worn or damaged.

Cut Quality

Factors to consider in evaluating the quality of a cut include surface smoothness, kerf width, kerf angle, dross adherence and sharpness of the top edge. These factors are affected by the type of material being cut, the equipment being used and the cutting conditions.

Plasma cuts in plates up to approximately 75mm thick may have a surface smoothness very similar to that produced by oxyfuel gas cutting. On thicker plates, low level travel speeds produce a rougher surface and discolouration.

Kerf widths of plasma arc cuts are 1 ½ to 2 times the width of oxyfuel gas cuts in plates up to 50mm thick. For example, a typical kerf width in 25mm stainless steel is approximately 5mm. Kerf width increases with plate thickness. A plasma cut in 180mm stainless steel made at approximately 3mm/s has a kerf width of 28mm.

The plasma jet tends to remove more metal from the upper part of the kerf than from the lower part. This results in bevelled cuts wider at the top than at the bottom. A typical included angle of a cut in 25mm steel is four to six degrees. This bevel occurs on one side of the cut when orifice gas swirl is used. The bevel angle on both sides of the cut tends to increase with cutting speed.

Dross is the material that melts during cutting and adheres to the bottom edge of the cut face. With present mechanised equipment, dross-free cuts can

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be produced on aluminium and stainless steel up to approximately 75mm thickness and on carbon steel upto approximately 40mm thickness. Selection of speed and current are more critical. Dross is usually present on thick materials.

Top edge gouging will result when excessive power is used to cut a given plate thickness or when the torch standoff distance is too large. It may also occur in high speed cutting of materials less than 6mm thick.

Plasma Gas Selection for Plasma Arc Cutting

Air Plasma

1. Mostly used on ferrous or carbon based materials to obtain good quality a faster cutting speeds.
2. Only clean, dry air is recommended to use as plasma gas. Any oil or moisture in the air supply will substantially reduce torch parts life.
3. Air Plasma is normally used with air secondary.

Nitrogen Plasma

1. Can be used in place of air plasma with air secondary.
2. Provides much better parts life than air
3. Provides better cut quality on non-ferrous materials such as stainless steel and aluminium.
4. A good clean welding grade nitrogen should be used.

Argon/Hydrogen Plasma

1. A 65% argon/35% hydrogen mixture should be used.
2. Recommended use on 19mm and thicker stainless steel. Recommended for 12mm and thicker non-ferrous material. Ar/H₂ is not normally used for thinner non-ferrous material because less expensive gases can achieve similar cut quality.
3. Provides faster cutting speeds and high cut quality on thicker material to offset the higher cost of the gas.
4. Poor quality on ferrous materials.

Oxygen Plasma

1. Oxygen is recommended for cutting ferrous metals.
2. Provides faster cutting speeds.
3. Provides very smooth finishes and minimizes nitride build-up on cut surface (nitride build-up can cause difficulties in producing high quality welds if not removed).

Secondary Gas Selection for Plasma Cutting

Air Secondary

1. Air secondary is normally used when operating with air plasma and occasionally with nitrogen plasma.
2. Inexpensive - reduces operating costs
3. Improves cut quality on some ferrous materials

CO₂ Secondary

1. CO₂ secondary is used with nitrogen or Ar/H₂ plasma.
2. Provides good cooling and maximizes torch parts life.
3. Usable on any ferrous or non-ferrous material
4. May reduce smoke when used with Ar/H₂ plasma.

Nitrogen Secondary

1. Nitrogen secondary is used with Ar/H₂ plasma.
2. Provides smooth finish on non-ferrous materials.
3. May be used with nitrogen plasma in order to operate from one compressed gas cylinder – but torch parts life may be shorter than with CO₂ secondary.
4. May reduce smoke when used with Ar/H₂ plasma

Table 1.1 Cut Quality: Plasma and Secondary Gas Selection for Various Material and Material thickness

| Gas | Material Thickness | Material | | |
|--|---|--|--|--|
| | | Carbon Steel | Stainless Steel | Aluminium |
| Air Plasma Air Secondary | Gage Gage to 12mm 12mm and Up | Good / Excellent Excellent Excellent | Good / Excellent Good Fair | Good / Excellent Good Fair |
| Nitrogen Plasma Air Secondary Or CO ₂ Secondary | Gage Gage to 12mm 12mm and Up | Good / Excellent Good / Excellent Good / Excellent | Good / Excellent Good / Excellent Good / Excellent | Good / Excellent Good / Excellent Good / Excellent |
| Ar/H ₂ Plasma N ₂ or CO ₂ Secondary | Gage to 6mm 6mm to 30mm 12mm and Up | NR NR NR | NR Good Good / Excellent | NR Excellent Excellent |

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