Plasma arc welding

Objectives: At the end of this lesson you shall be able to
- **state the types of plasma arc welding**
- **state the equipments**
- **state the applications.**

Plasma Arc Welding is welding process in which plasma producing gas (Argon, Nitrogen, Helium, and Hydrogen) is ionized by the heat of an electric arc and passed through a small welding torch orifice. A shielding gas protects the plasma arc from atmospheric contamiantion in welding or cutting. A non-consumable Tungsten electrode is used in Plasma Arc Welding and additional metal is added to the weld with a filler rod.

Plasma Arc welding uses the keyhole method to obtain a full penetration and can be done manually or automatically. The works of temperature obtained in this process is about 20000ºC to 30,000ºC.

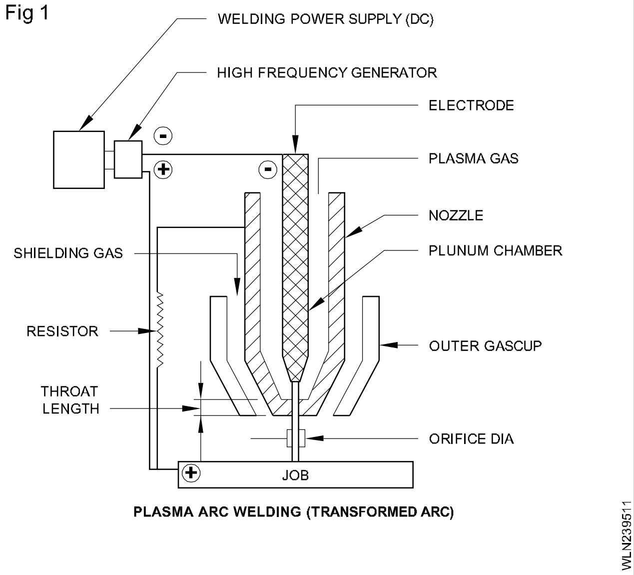
It is divided in to two basic types. They are:

1 Transferred arc

2 Non-transferred arc

Transferred arc process (Fig 1): The arc is formed between the electrode(-) and the work piece (+). In other words, arc is transferred from the electrode to the work piece. A transferred arc possesses high energy density and plasma jet velocity. For this reason it is employed to cut and melt metals. Besides carbon steels this proocess can cut stainless steel and nonferrous metals also where oxyacetylene torch does not succeed. Transferred arc can also be used for welding at high arc travel speeds.

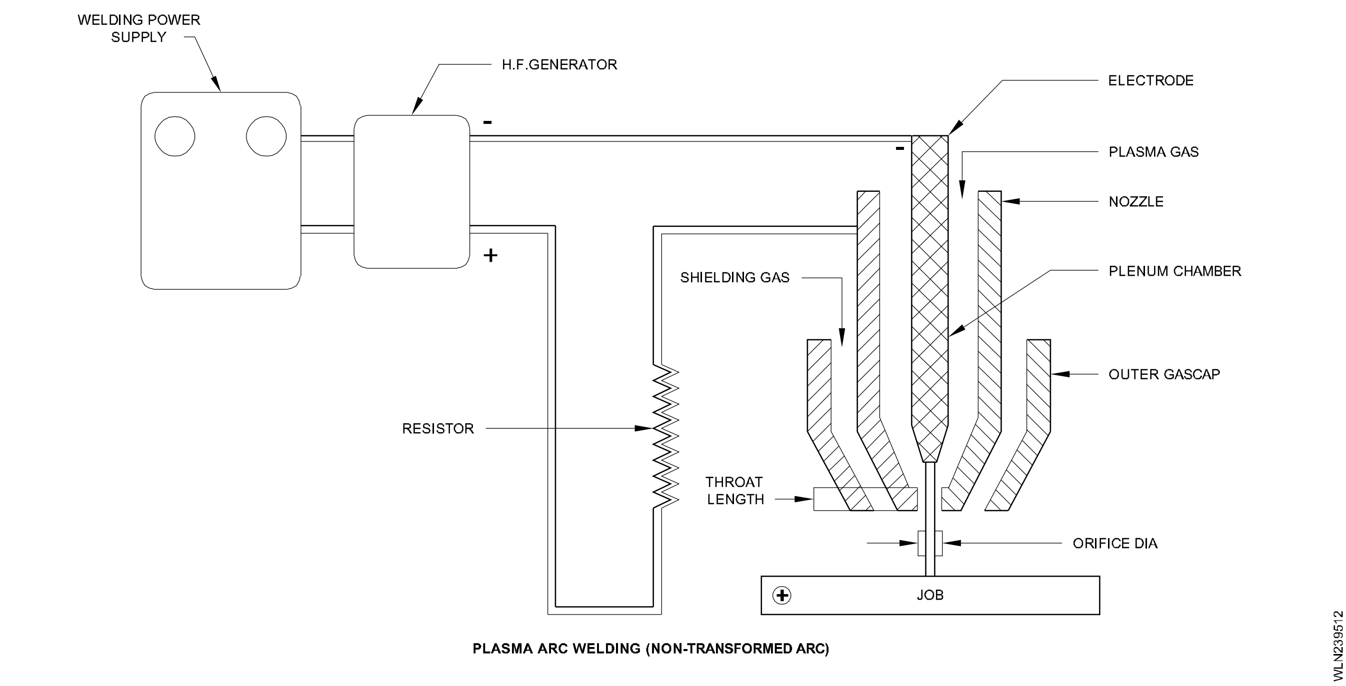
Fig 1



PLASMA ARC WELDING (TRANSFORMED ARC)

Non-transferred arc process (Fig 2)

Fig 2



PLASMA ARC WELDING (NON-TRANSFORMED ARC)

The arc is formed between the electrode(-) and the water cooled constricting nozzle(+). Arc plama comes out of the nozzle as a flame. The arc is independent of the work piece and the work piece does not form a part of the electrical circuit. Just as an arc flame, it can be moved from one place to another and can be better controlled. The non transferred arc plasma possesses comparatively less energy density as compared to a transferred arc plasma and it is employed for welding and in applications involving ceramics or metal plating (spraying).

Equipments

1 DC power source

2 Welding control console (Contain flow meter)

3 Recirculating water cooler

4 Plasma welding torch (up to 500 amps capacity)

5 Gas cylinders and a gas supply

6 Gas pressure regulator

7 Gas hoses and hose connections

8 Water cooled power cables

Gases for plasma welding

- Argon for carbon steel, titanium, zirconium, etc
- Hydrogen increase heat Argon + (5-15%) Hydrogen for stainless steel, Nickel alloys, Copper alloys

Plasma process techniques

1 Microplasma

- very low welding currents (0,1-15 Amps)
- very stable needle-like stiff arc & minimises arc wander and distortions
- for welding thin materials (down to 0,1 mm thick), wire and mesh sections

2 Medium current plasma

- higher welding currents (15-200 Amps)
- similar to TIG but arc is stiffer & deeper penetration
- more control on arc penetration.

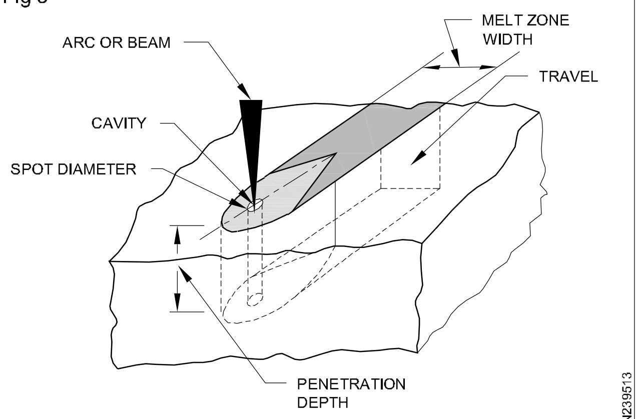
Microplasma and medium current plasma advantages

- energy concentration is greater & higher welding speed
- energy concentration is greater & lower current isneeded to produce a given weld & less distortions
- improved arc stability
- arc column has greater directional stability
- narrow bead & less distortions
- less need for fixturing
- variations in torch stand-off distance have little effect on bead width or heat concentration & positional weld is much easy
- tungsten electrode is recessed & no tungsten contami nation, less time for repointing, greater tolerance to surface contamination (including coatings).

Microplasma and medium current plasma limitations (Fig 3)

- narrow constricted arc & little tolerance for joint misalignment
- manual torches are heavy and bulky & difficult to manipulate
- for consistent quality, constricting nozzle must be well maintained

Fig 3



PLASMA PROCESS TECHNIQUE

3 Keyhole plasma welding (Fig 5)

- welding currents over 100 Amps
- for welding thick materials (up to 10 mm)

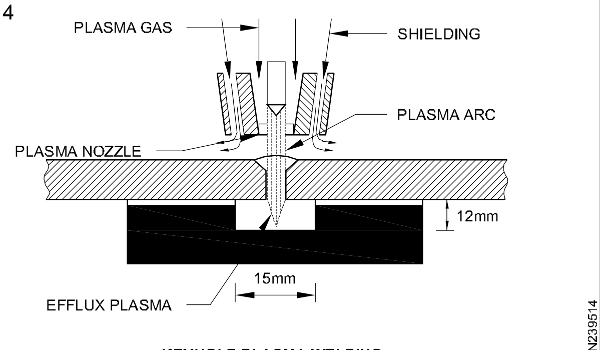
Keyhole plasma welding advantage

- Plasma stream helps remove gases and impurities.
- Narrow fusion zone reduces transverse residual stresses and distortions.
- Square butt joints are generally used and reduced time preparation.
- Single pass welds and reduced weld time

Keyhole plasma welding limitations

- more process variables and narrow operating windows
- fit-up is critical
- increased operator skill, particularly on thicker materials Ù high accuracy for positioning
- except for aluminium alloys, keyhole welding is restricted to downhand position
- for consistent operation, plasma torch must be well maintained

Fig 4



KEYHOLE PLASMA WELDING

Application of the plasma process

Three operating modes possible by varying current bore diameter and gas flow rate

- **Micro plasma:** 0.05 to 15 amps – used for welding thin sheet down to 0.1mm eg SS bellows and wire mesh, welding of surgical instruments, repair of gas turbine engine blades, electronic components and micro-switches etc.
- **Medium current:** 15 to 200 amps – used as alternative to conventional TIG for improved penetration and greater tolerance to surface contamination. Generally mechanised due to bulkiness of torch.
- **Keyhole plasma:** over 100 amps – By increasing current and plasma gas flow a very powerful beam is possible which can achieve full penetration in 10 mm stainless steel.During welding the hole progressively cuts through the metal with the molten weld pool flowing behind to form the weld bead.

Limitations of plasma arc welding

1 PAW requires relatively expensive and complex equipment as compared to GTAW; proper torch maintenance is critical

2 Welding procedures tend to be more complex and less tolerant to variations in fit-up, etc.

Types of plasma arc, advantages and applications

Objectives: At the end of this lesson you shall be able to
- **state the principle of plasma arc cutting**
- **explain the process variable of plasma cutting**
- **state the advantages of plasma cutting.**

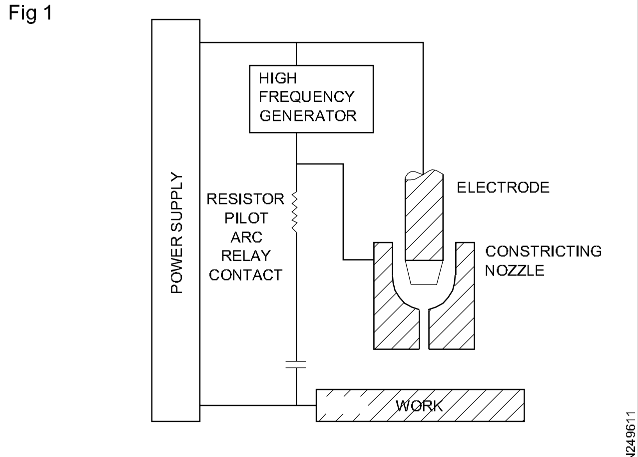
Cutting processes - plasma arc cutting

Plasma arc cutting process, was introduced in the industry in the mid 1950s. The process is used to cut all metals and non-metals. The common oxy-fuel cutting process (based on a chemical process) is suitable for cutting carbon steel and low alloy steel cutting only. Materials such as copper, aluminium and stainless steels were earlier separated by sawing, drilling or sometimes by power flame cutting. These materials are now cut using a plasma torch, at faster rates and more economically. The Plasma cutting process is basically a thermal cutting process, free of any chemical reaction, that means, without oxidation. In plasma arc cutting an extremely high temperature and high velocity constricted arc is utilized.

Principle of operation

Plasma arc cutting is a process resulting from ionizing a column of gas (argon, nitrogen, helium, air, hydrogen or their mixtures) with extreme heat of an electric arc. The ionized gas along with the arc is forced through a very small nozzle orifice, resulting into a plasma stream of high velocity (speed up to 600 m/sec) and high temperature (up to 20000°K). When this high speed is reached, high temperature plasma stream and electric arc strike the workpiece, and ions in the plasma recombine into gas atoms and liberate a great amount of latent heat. This heat melts the workpiece, vaporizes part of the material and the balance is blasted away in the form of molten metal through the heat (Fig 1).

Fig 1

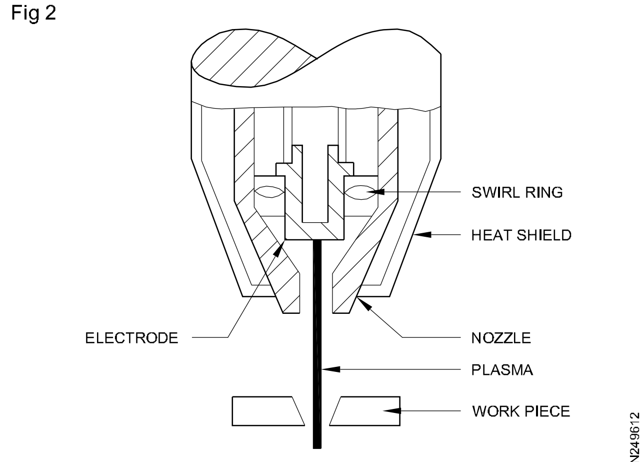


BASIC PLASMA ARC CUTTING CIRCUITRY

Plasma cutting system (Fig 2,3,4)

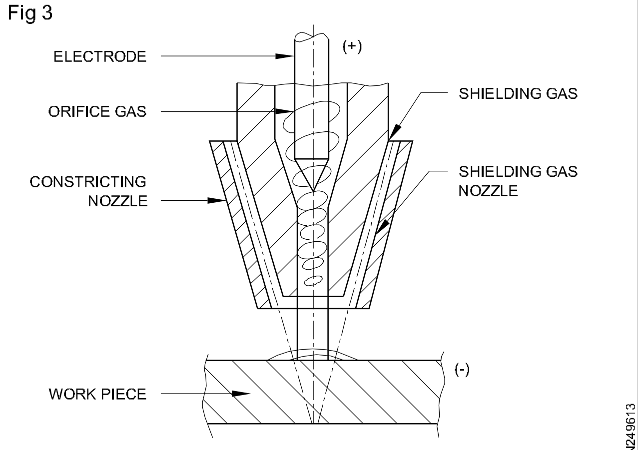
Plasma cutting requires a cutting torch, a control unit, a power supply, one or more cutting gases and a supply of clean cooling water (in case water-cooled torch is used).

Fig 2



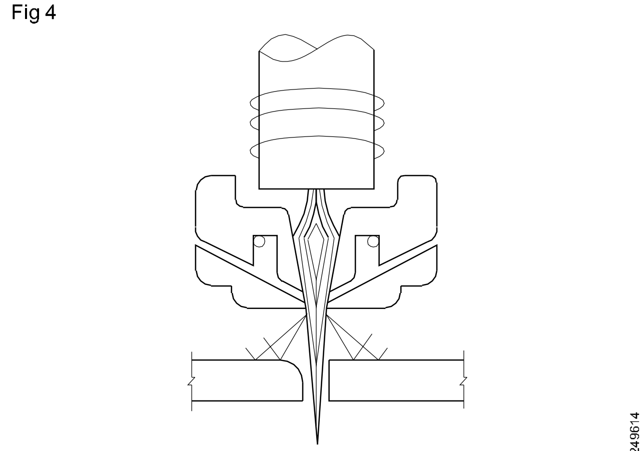
COMPONENTS OF AN AIR-PAC TORCH

Fig 3



DUAL FLOW PLASMA ARC CUTTING

Fig 4



Equipment is available for both manual and mechanical cutting. A basic plasma arc cutting circuit is shown in Fig.1. It employs direct current straight polarity (DCEN). The nozzle surrounding the electrode is connected to the workpiece (positive) through a current limiting reisitor and a pilot arc relay contact.

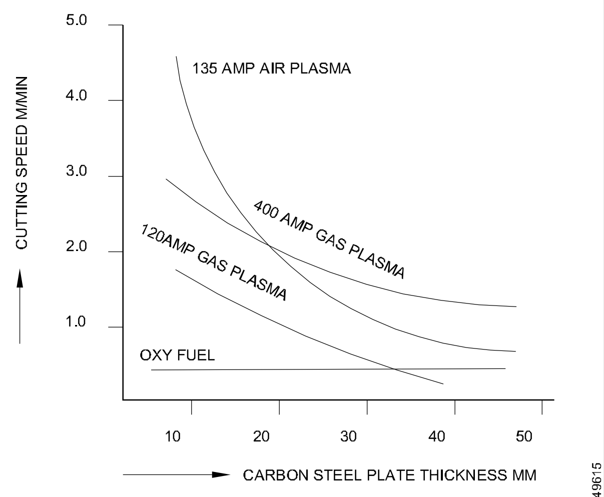
The pilot arc between the electrode and nozzle is initiated by a high frequency generator connected between the electrode and nozzle. The orifice gas ionized by the pilot arc is blown through the constricting nozzle orifice and forms a low resistance path to ignite the main transferred arc between the electrode and the workpiece when the ON/OFF switch is closed. The pilot arc relay may be opened automatically when the main arc ignites, to avoid unnecessary heating of the constricting nozzle. The constricting nozzle is of copper and normally water cooled to withstand the high plasma flame temperature (about 20000°K) and to have longer life.

In conventional gas plasma cutting, discussed above, the cutting gas can be argon, nitrogen, (argon + hydrogen), or compressed air. For all the cutting gases other than compressed air, the non-consumable electrode material is 2% thoriated tungsten. In air plasma cutting (Fig 2) where dry, clean compressed air is used as the cutting gas, the electrode of hafnium or zirconium. In used because tungsten is rapidly eroded in air. Wet and dirty compressed air reduces the useful life of consumable parts and produces poor quality.

Several process variations are used to improve the cut quality for particular applications. Auxiliary shielding in the form of gas or water is used (Fig 3) to improve the cut quality and to improve the nozzle life. Water injection plasma cutting (Fig 4) uses a symmetrical impinging water jet near the constricting nozzle orifice to further constrict the plasma flame and to increase the nozzle life. Good quality cut with sharp and clear edges with little or no dross is possible in water injection plasma cutting.

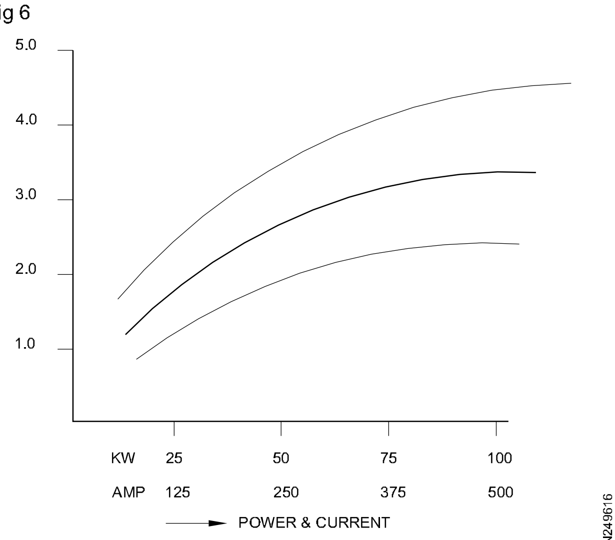
Process variables (Fig 5 & 6)

Fig 5



COMPARISON OF OXY FUEL AND PLASMA CUTTING PROCESSES

Fig 6



RELATIONSHIP BETWEEN CUTTING SPEED & POWER

i Torch design - constricting nozzle shape and size.

ii Process variation - dual gas flow, water injection, air plasma.

iii Cutting gas type and its flow rate.

iv Distance between nozzle and job.

v Cutting speed.

vi Plasma cutting current.

vii Power used during cutting.

viii Manual/machine cutting.

ix Material to be cut and its thickness.

x Quality of cut required - rough or smooth.

xi The bevel angle and round off corner etc.

Advantages of plasma cutting

i All metals and non-metals can be cut due to the high temperature and high velocity plasma flame.

ii Cuts are of very clear form with little or no dross.

iii High speed piercing is achieved.

iv Cutting of piled plates is possible, even with different materials.

v Cutting cost is quite low as compared to other processes, especially for stainless steels.

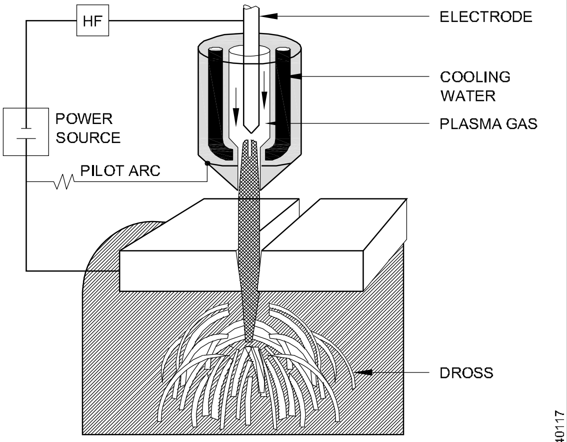
vi Cutting speed is high.

vii Cutting is possible in all positions and locations (underwater also).

Gases for plasma cutting (Fig.7)

- no need to promote oxidation & no preheat
- works by melting and blowing and/or vaporisation
- "gases : air, Ar, N_2, O_2, mix of Ar + H_2, N_2 + H_2
- air plasma promotes oxidation and increased speed but special electrodes need
- shielding gas - optional
- applications : stainless steels, aluminium and thin sheet carbon steel.

Fig 7



GASES FOR PLASMA CUTTING