Plasma Arc Machining (PAM)

Synopsis

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- Limitations
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Introduction

- A plasma is defined as a superheated, electrically ionized gas
- PAC uses a plasma stream operating at temperatures in the range from 10,000 to 14,000 ºC to cut metal by melting.
- The cutting action takes place by directing the high-velocity plasma stream at the work, thus melting it and blowing the molten metal through the kerf
- Plasma is encountered in electrical discharges, such as fluorescent tubes and electric arcs, lightning, high temperature combustion flames and the sun.
- Most application of PAC involve cutting of flat metal sheets and plates. Operations include hole piercing and cutting along a defined path.
- PAC was initially employed to cut metals that are difficult to machine by conventional methods. However, in recent years, PAC has also been used to cut plain carbon steel, stainless steel and aluminium

Principle

- When heated to elevated temperatures, gases turn into a distinctly different type of matter, which is plasma
- When gases are heated by an applied electric field, an igniter supplies the initial electrons, which accelerate in the field before colliding and ionizing the atoms. The free electrons, in turn, get accelerated and cause further ionization and heating of the gases. The avalanche continues till a steady state is obtained in which the rate of production of the free charges is balanced by recombination and loss of the free charges to the walls and electrodes.
- The actual heating of the gas takes place due to the energy liberated when free ions and electrons recombine into atoms or when atoms recombine into molecules

Mechanism of Material removal

- The metal removal in PAM is basically due to the high temperature produced.
- The heating of the work piece is, as a result of anode heating, due to direct electron bombardment plus convection heating from the high temperature plasma that accompanies the arc.
- The heat produced is sufficient to raise the work piece temperature above its melting point and the high velocity gas stream effectively blows the molten metal away.

Typical plasma torch construction

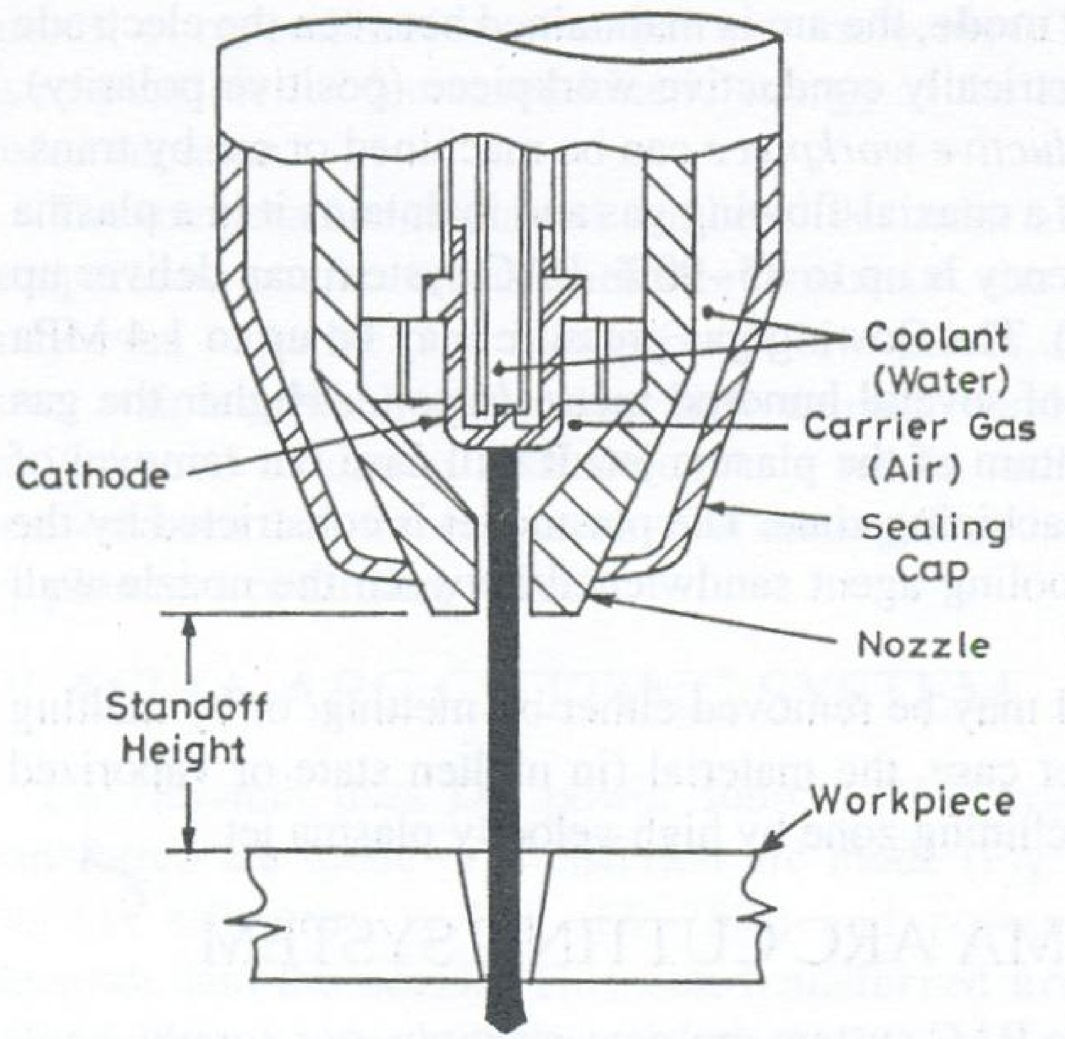


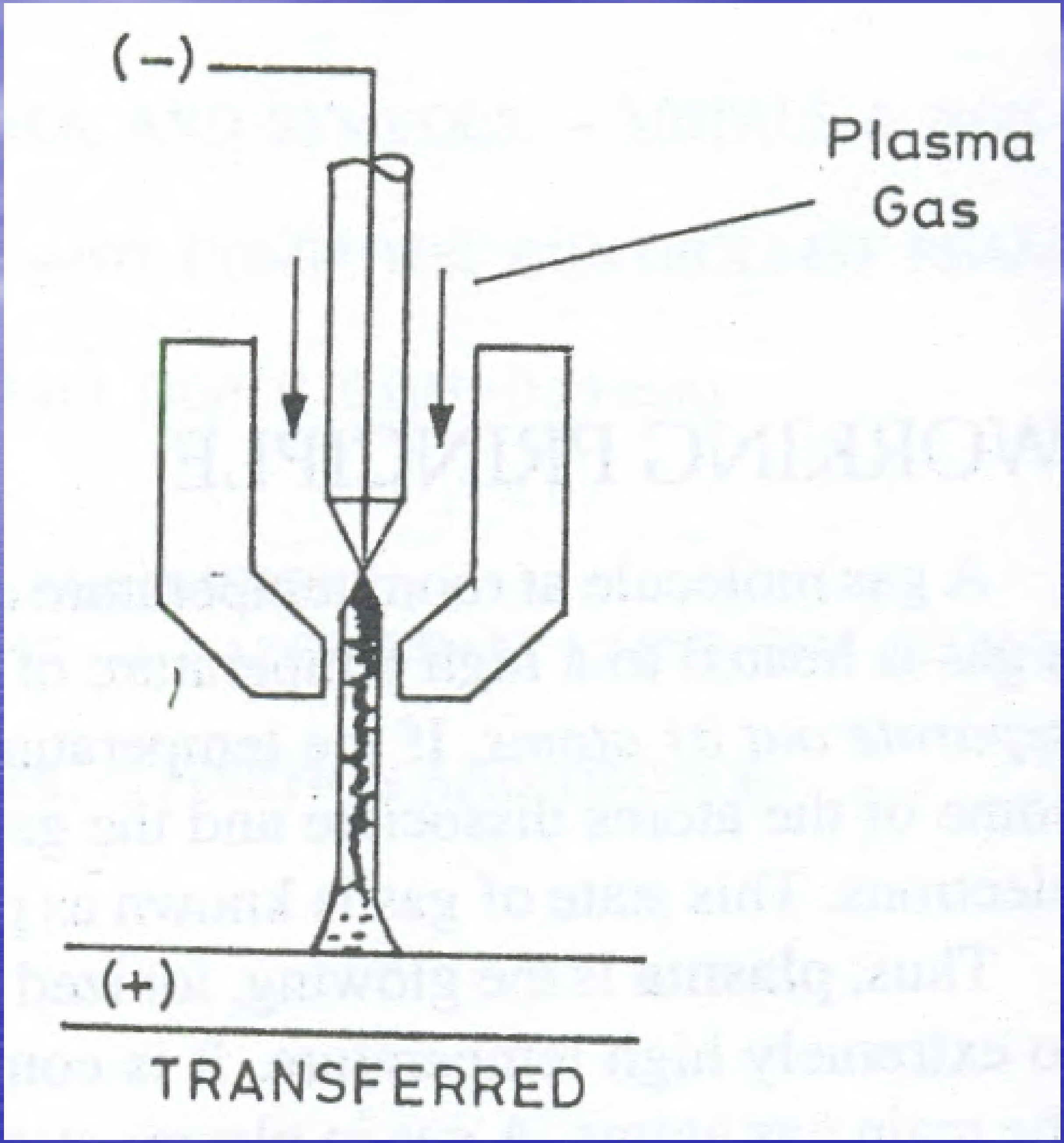
Fig. 9.2 Details of air plasma torch construction [*Benedict*, 1987; Courtesy: W.A. Whitney Corp. Rockford, III.]

Process - types

- Plasma generating torches are of two general designs – **transferred plasma torch** and **non-transferred plasma torch**.

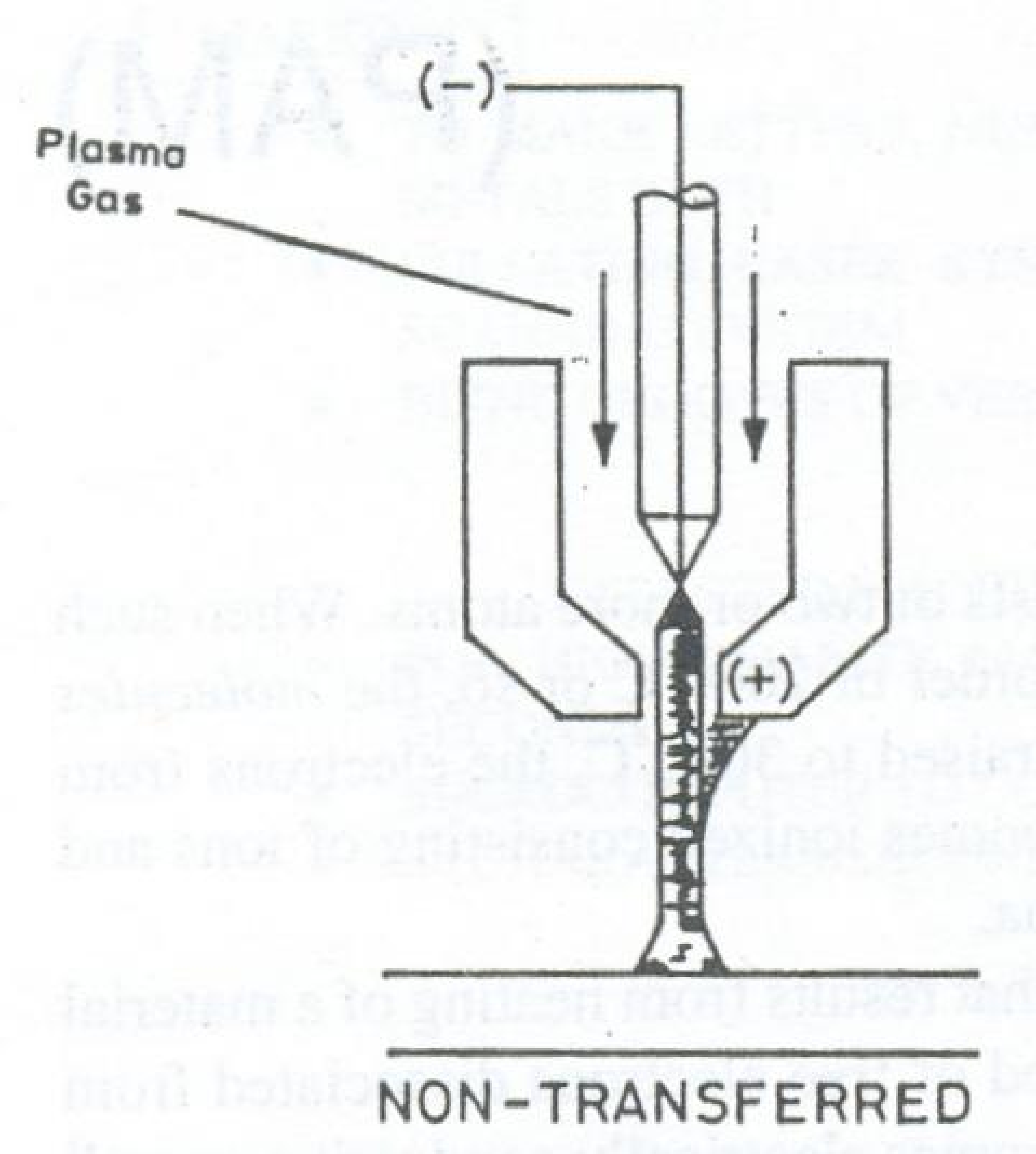
Transferred plasma torch

- In this torch, the cathode is connected directly to the negative of the D.C. source, while the anode nozzle is connected to the positive of the supply through a suitable resistor to limit the current through the nozzle to about 50amps.
- The metal workpiece to be processed is then connected directly to the positive of the supply. When ignited, a pilot plasma flame is established between the cathode and nozzle, which provides a conducting path for a high current constricted arc between the cathode and workpiece. Once this arc is struck, the pilot flame circuit is disconnected.
- This method is limited to cutting, welding and hard surfacing of metals.
- The electro thermal efficiency is about 85-90%


(−)
Plasma
Gas
(+)
TRANSFERRED

Non-transferred plasma torch

- In this torch, the D.C power source is connected directly across the cathode and the nozzle, thus ionizing a high velocity gas that is streaming towards the workpiece.
- The anode dissipation is lost in useless heating of the nozzle.
- The electro thermal efficiency is about 65-75%


(–)
Plasma
Gas
(+)
NON-TRANSFERRED

Process parameters

- Parameters that govern the performance of PAM can be divided into three categories:

1. Those associated with the design and operation of the torch – eletrical power delievered , the gases used to form the plasma, the flow rate of the gases through the torch, the orifice diameter through the nozzle duct
2. Those associated with the physical configuration of the set up – torch standoff, angle to the work, depth of cut, feed into the work and speed of the work toward the torch
3. Environment in which the work is performed – cooling that is done on the bar, any protective type of atmosphere used to reduce oxidation fo the exposed high temperature machined surface and any means that might be utilized to spread out or deflect the arc and plasma impingment area

Gas Cutting	PAM
1.Oxidation of the work piece melted generates the heat to melt the matl for (e.g) in cutting steel, fuel gas is used to heat it to 760°-870°C at while steel reacts rapidly with oxygen to form iron oxide. The heat generated by the burning iron is sufficient ot melt the iron oxide. 2.Oxy-fuel gas cutting is mostly limited to only ferrous metal especially plain carbon steels. 3.Cutting speed are lower for (e.g) in cutting mild steel 19mm thick can be cut at 500 mm /min. 4.Operating costs are higher 5.Limited to the max. temparature of the chemical reaction (burning) 6.Cost of equipment is lower. Surfaces are less smoother than those cut by PAM	1.Plasma is generated by subjecting a volume of gas to electron bombardment of an electric arc. The anode heating due to direct electron bombardment plus convective heating from the high temp plasma raises the matl to the molten point and the high velocity gas stream effectively blows the matl away. 2.Because of the high temp involved, the process can be used on almost all matl including those white are resistant to oxy- fuel gas cutting 3.Cutting speeds ae higher and leave a narrower kerf. They can cut mild steel 19mm thick at the rate of 1775mm /min. 4.Operating costs are lower.Ratio of savings in favor of PAM is about 3:1 5.Seems to be unlimited. The greater the power used, the greater the vol.of kerf matl that can be removed. 6.High initial cost of the equipment. 7.Surfaces cut by plasma torch are smoother but the edges are rounded.

Advantages

1. The main advantage of PAM is speed. For example, mild steel of 6mm thick can be cut at 3m/min
2. The plasma arc can be used to cut any metal or even to non-conducting materials like concrete etc., since it is primarily a melting process
3. Due to high speed of cutting the deformation of sheet metals is reduced while the width of the cut is minimum
4. Owing to the high productivity of the plasma arc cutting coupled with the tendency to use cheap and easily available plasma-forming media (air, water, ammonia etc.,), PAC is finding ever increasing application.
5. Smooth cuts free from contaminants are obtained in the process
6. Profile cutting of metals especially of stainless steel and aluminium can be very easily done by PAM
7. Operating costs are less when compared to oxy-fuel torch
8. Can be automated

Limitations

- The main disadvantage of PAC is the high initial cost of the equipment. However, it can be made economical, if the quantity involved is large and the thickness is up to 50mm.
- Well-attached drops on the underside of the cut can be a problem and there will be heat-affected zone (HAZ). The depth of HAZ depends on the material and its thickness
- Smoke and noise
- Sharp corners are difficult to produce because of the wide diameter of the plasma stream
- Burr is often produced
- Taper on the workpiece may occur

Applications

1. Chiefly used to cut stainless steel and aluminium alloys. It is preferred to oxy-fuel cutting because it produces comparatively smoother cuts and is free from contamination
2. Other metals which are resistant to oxy-fuel cutting and hence cut by PAC are magnesium, titanium, copper, nickel and alloys of copper and nickel
3. PAC can be used for stack cutting, plate beveling, shape cutting and piercing.
4. It can also be used for underwater cutting.
5. The plasma jets are used for welding materials like titanium, stainless steel etc.,
6. Plasma arc is used for depositing filler metal on surface to obtain desired properties like corrosion resistance, wear resistance, toughness or anti-friction properties – Plasma arc surfacing
7. The plasma arc can also be used for spraying a prepared surface of the base material with droplets of molten metal to obtain a surface of required thickness