MODULE-4

PLASMA ARC MACHINING (PAM)

⇒ PLASMA when gases are heated to elevated temperatures, they turn into a distinct different type of matter known as plasma.

The changes take place when gases are heated to few thousand degree are;

i) The number of collision between atoms increases

ii) The gas ionizes, so that a portion of atoms are stripped of their outer electrons, resulting in the creation of electrons & ions.

iii) The electrons thus produced, inturn, collide with atoms resulting in heating them through relaxation processes so that their thermal kinematic energy increases, and also excite them so that de-excitation light is emitted from the atoms & ionize them so that more electrons & ions are produced.

Thus, the new matter is characterised its ability to conduct electricity due to the presence of free charges.

The plasma is encountered in electrical discharges such as flourcent tubes & electric arcs, lightening, high temperature combustion flames & the sun.

⇒ GENERATION OF PLASMA

The method of heating the gases by first ionizing them is one of the most popular method of generating hot plasma. This can be done either by applying a suitable electric field across the gas column or by exposing the gas by ionizing radiation.

When gases are heated by an applied electric field, an ignitor supplies the initial electrodes, which ~~accelerate~~ accelerate before colliding and ionizing the atoms. The free electrons in turn, get accelerated & cause further ionization & heating of the gases. This continues till a steady state is obtained in which the rate of production of the free charges to the walls & electrodes.

The actual heating of the gas takes place due to the energy liberated when free ions & electrons recombine into atoms or when atoms recombine into molecules. The bonding energy thus liberated is ~~main~~ manifested in the form of kinetic energy of the atoms or molecules formed by the recombination. It is thus clear that the heat content of molecular gases is higher than that of mono-atomic gases.

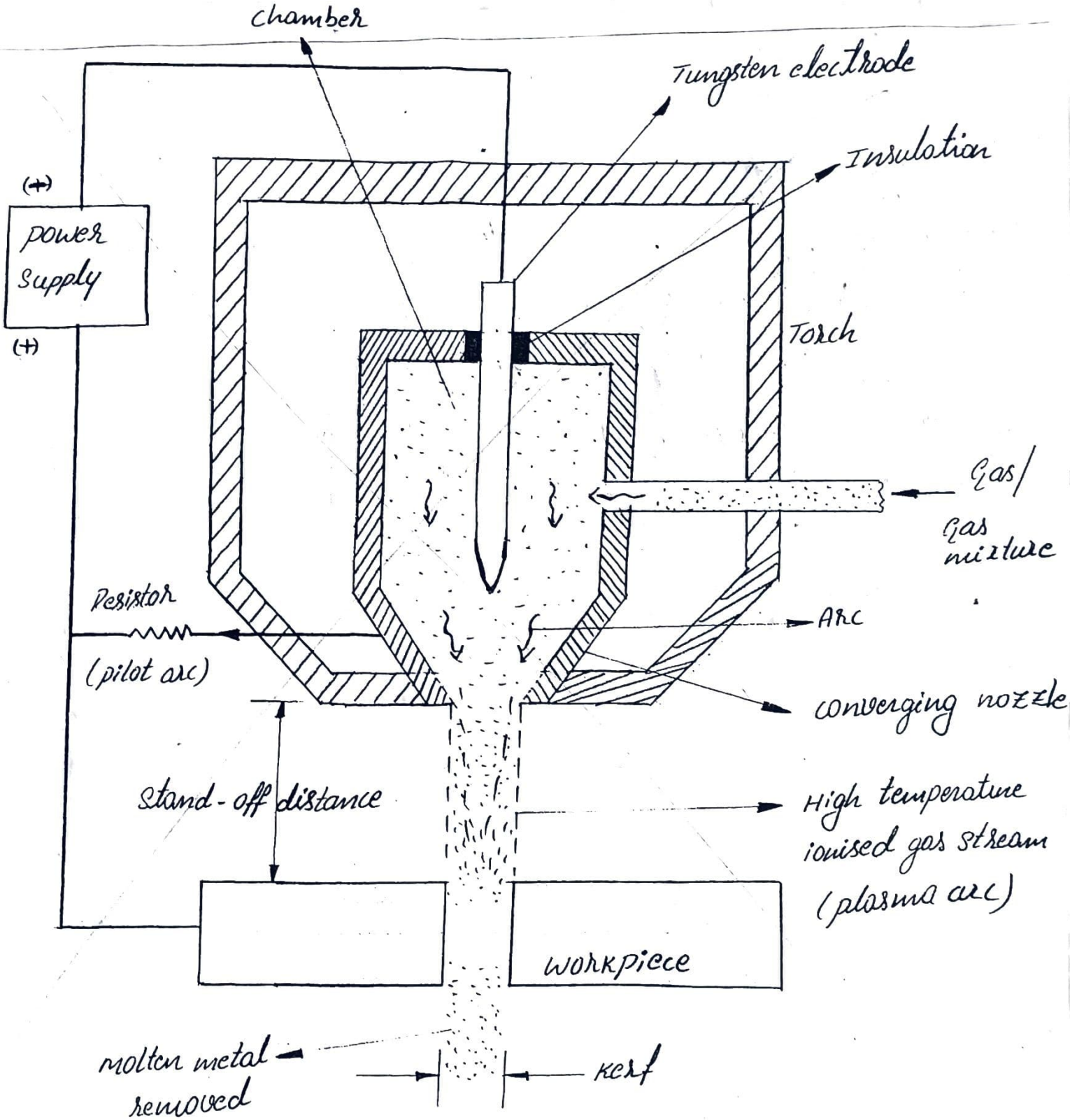
The principle of plasma generation is shown in fig. In this case, the high velocity electrons of the arc collide with the gas molecules & produce dissociation of diamatic molecules followed by ionization of the beam.

The plasma forming gas is forced through the nozzle duct in such a manner as to stabalize the arc. Much of the heating of the gas takes place in the constricted region of the nozzle duct resulting in relatively high exit gas velocity & very high core temperature upto 10,000°c

The figure shows a typical setup of plasma arc torch for cutting. A high frequency spark is used to initiate a pilot arc b/w the tungsten electrode [cathode] & the copper nozzle (anode), both of which are water cooled. The pilot arc is then cut off, & the external arc generates a plasma jet which exits through the nozzle at near sonic velocity. water injection is sometimes used to assist in constricting the arc, to blast away the scale & to reduce smoke. Greater nozzle life is also reported for torches with water injection type.

The plasma jet heats the workpiece by bombardment with electrons & by transfer of energy from the high temperature, high energy gas. The heat is effective in cutting the workpieces upto a thickness of 50mm. Cutting to a greater depth depends largely on gravity flow or forced flow of the superheated molten metal.

The Equipment can be used to machine a wide range of materials & thickness by suitable adjustment of the power level, gas type, gas flow rate, traverse speed & flame angle.



PLASMA ARC MACHINING

Same figure is used to describe.
Equipment of PAM (Elements)

⇒ ELEMENTS OF PLASMA ARC CUTTING:

The important elements of PAM are;

- → power supply system
- → Gas supply system
- → Cooling water system
- → plasma torch.

→ Power supply system

* The main function of the power supply is to provide the correct energy to maintain the plasma are after ionization.
* The output current of the power supply determines the speed and cut thickness capability of the system.
* The power supply system usually supplies the DC voltage in the range of 240 to 400 V.

→ Gas supply system

* Gas supply system supplies the required type of gas correctly with correct pressure and flow rate.

SL NO	Material to be cut	Gas/Gas mixture to be Used
1	Aluminium & Magnesium	Nitrogen, nitrogen-hydrogen mixture, argon-hydrogen mixture
2	Stainless steel and non-ferrous metals	Nitrogen-hydrogen mixture, argon-hydrogen mixture
3	Carbon and alloy Steels, Cast iron	Nitrogen-hydrogen mixture

* Few more gases that can be used as plasma gas are
  i) Air plasma
  ii) Nitrogen plasma
  iii) Argon / hydrogen plasma
  iv) Oxygen plasma.

i) Air plasma :-

- Only uncontaminated clean and dry air is recommended to be used as plasma gas.
- If any moisture is present in the air supply, it will lead to reduction in the life of the torch parts.
- Air plasma is mostly used for ferrous and carbon based materials.

ii) Nitrogen plasma :-

- Nitrogen can be used as plasma gas along with the secondary gas.
- Nitrogen gas provides much better life than air.
- Used to machine non ferrous materials such as Stainless steel and aluminium.

iii) Argon / hydrogen plasma

- Generally 65% argon and 35% hydrogen mixture should be used for plasma gas.
- These gases are used in the places where we want more quality on the thick plates.

iv) Oxygen plasma

- oxygen plasma is recommended for cutting ferrous metals.
- It provides faster cutting speed.

→ Cooling water system

* Cooling water system supplies the water to cool the torch
* water is supplied at the bottom of the plasma torch.

→ Plasma torch

* The torch serves as the holder for the consumable nozzle and electrode and provides cooling (either gas or water) to these parts.
* Based on the design, there are different types of plasma torch such as
  - i) Arc plasma
  - ii) Dual gas.
  - iii) water injected plasma torch and
  - iv) Oxygen injected.

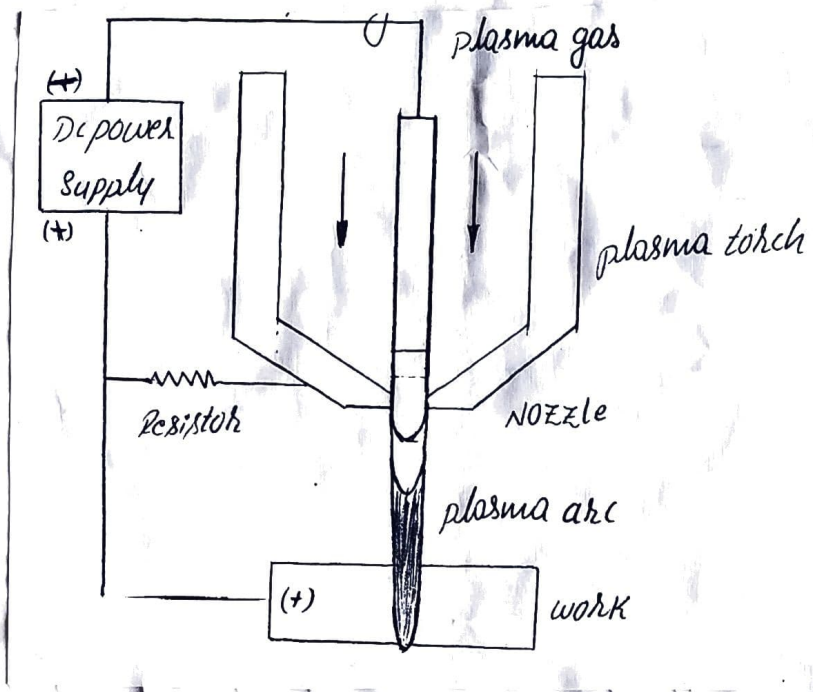
⇒ TYPES OF PLASMA ARC PRODUCTION

There are two different methods namely

→ Transferred Arc type

→ Non-transferred Arc type.

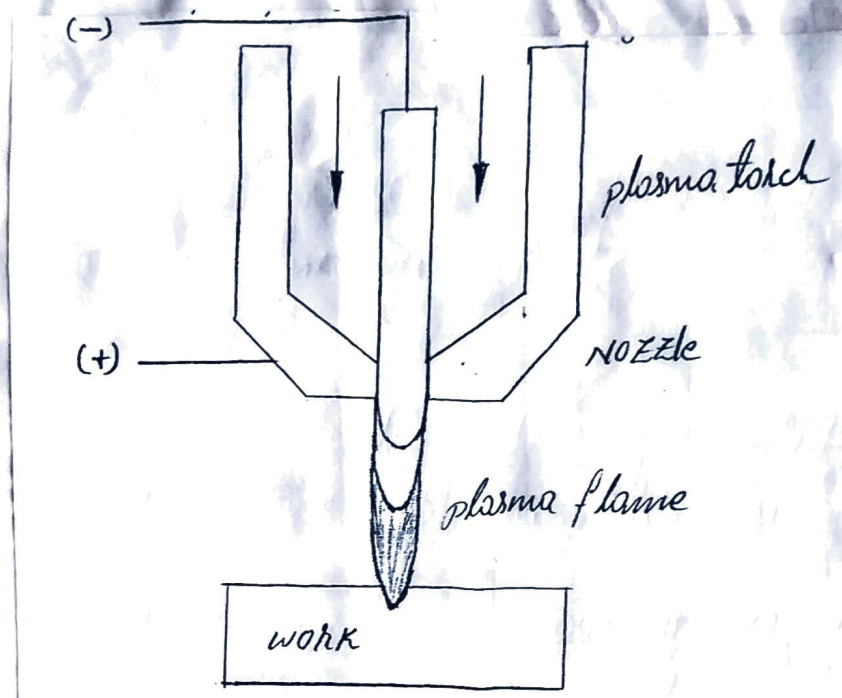
→ Transferred arc type



* In transferred type of arc production, electrode is connected with negative terminal and w/p is connected with positive terminal.
* In this method, arc is developed between the central electrode and work piece.
* conductive work piece materials can be machined effectively
* Provides higher Thermal efficiency in the range of 85- 90%.

→ Non- transferred type

* In Non- transferred type of arc production, electrode which is normally made of tungsten is connected with negative terminal and nozzle is connected with positive terminal.



* In this method arc is developed between the central electrode and nozzle body.
* This method is suitable to machine only electrically non-conductive material.
* Thermal Efficiency of this type is low (65-75%)

⇒ WORKING PRINCIPLE

* A hot tungsten electrode is connected with negative polarity to make it as cathode and work piece/ nozzle is connected to the positive polarity to make it as anode.
* A gas is introduced around the cathod and it flows through the anode.
* A strong arc is established b/w the two terminals, anode and cathode.

* There is collision between molecules of gas and the electrons of the established are.
* As the result of this collision gas molecules get ionized and heat is developed.
* with the high temperature (20,000°F - 50000°F), plasma are impinges on the workpiece material.
* Higher velocity gas effectively blows off the molten metal away, which maintains the work surface clean.

⟹ PROCESS PARAMETERS

In plasma arc machining the following factors are identified as the main process parameters.

→ Cutting Speed
→ Cutting Current
→ cutting height / Stand off distance (SOD)
→ Gas pressure and gas flow rate.

→ Cutting Speed

* Generally higher the cutting speed, the torch moves too fast, resulting in the formation of drag lines on the cutting surface.
* On the other hand, too low cutting speed results in over melting of the processing area.

→ Cutting Current

* Cutting current (or) current flow rate is the value of the current given during the cutting process.
* Cutting current has the strongest effect on the heat affected zone of the process
* Generally higher cutting current and lower cutting speed results in higher heat affected zone.

→ Cutting height / Stand off distance (SOD)

* Stand off distance is the distance maintained between the bottom surface of the torch and top surface of w/p while cutting.

→ Gas pressure and Gas flow rate

* It is essential to have the correct gas flow rate based on metal type and thickness of the workpiece being cut.
* Controlling the pressure of the gas is one way to control the gas flow.
* Too low gas flow rate results in a cut-having sharply beveled sides.
* Too high a gas flow will produce a poor cut because of turbulence in the plasma steam
Thicker the w/p, greater is the gas flow rate required.

⇒ PROCESS CAPABILITIES

→ Thick materials upto 150 mm can be easily machined by plasma arc machining.

→ Depending upon the thickness, tolerance in the range of 0.3 - 0.8 mm can be achieved by plasma arc machining

→ The cutting speed for PAM are typically five to eight times faster than oxy-fuel cutting.

→ PAM provides surface finish of approximately 5 - 7.5 µm for the cut edge.

⇒ APPLICATIONS OF PAM.

→ Pam PAM is chiefly used to cut stainless steel and aluminium alloys. Heavy duty plasma torches can cut stainless steel with thickness upto 100 - 125 mm & aluminium alloy with thickness upto 150 mm. Other materials that are resistant to oxy-fuel cutting & hence cut by plasma arc method are alloys of copper, magnesium, copper, nickel, titanium.

→ Inspite of the high rate of equipment & its operation, the high cutting rate of PAM makes it economical for straight cuts on several materials, if the quantity involved is large & the thickness is upto 50mm.

→ PAM has also been considered for lathe turning, milling & ~~planning~~ planing. It has been tried for rough turning of bar stock in moderate sizes, & it is applicable for the turning of hardened shaft end to make grooves in the pulleys.

→ Plasma arc is also used successfully in conventional turning & milling machines to machine very hard materials. The plasma arc torch mounted just a head of the cutting tool heats up the workpiece & a conventional turning tool or a milling cutter does the machine.

⟹ ADVANTAGES OF PAM

→ Any material, regardless of its hardness & refractory nature can be efficiently & economically machined.

→ Since there is no contact b/w the tool & the w/p, only a simply supported w/p structure is adjust.

→ The cutting rates in this process are high enough to facilitate this method tube used on almost all ~~machine~~ materials.

→ Faster cutting speeds due to high velocity & high temperature of gas.

→ Requires minimal operator training

⟹ Disadvantages Of PAM

→ The metallurgical alteration of the surface. Thus a secondary machining needs to be performed to remove this surface by 1.5mm or more, unless it can withstand the hardened & uneven surface.

→ Eye shielding & noise protection are necessary for the operator & those in nearby areas.

→ High Equipment cost.

⟹ Safety Precautions In PAM

Following are some of the safety precaution need to be considered in plasma arc machining.

→ The plasma flame emits ultraviolet & infrared radiations, which are harmful to human eyes & skin. Safety eye glasses or hand shields, asbestos gloves, & heat resistant clothes must be worn during the plasma operation.

→ It is necessary to carry out plasma operations in a ventilated room in order to ~~accord~~ avoid inhaling of fumes and gases emitted during the plasma generation. Gases, particularly oxides of nitrogen poses significant hazard to human operators. If ventilation is poor, air supplied respirators (masks) must be used.

→ Gas cylinder & their pressures must be maintained regularly for safety working conditions. Also electrical cable connections, power source supply, groundings, gas leaks, etc.. must be checked suitable prior to operation.

→ Plasma machining produced high levels of noise, and hence ~~ear~~ ear muffs or plugs must be worn.