UNIT –II
MECHANICAL ENERGY BASED PROCESSES
PART - A (2 MARKS)

1. **What is the principle of USM?**

   In USM, a slurry of small abrasive particles are forced against the work piece by means of a vibrating tool and it causes the removal of metal from the work piece in the form of extremely small chips.

2. **Why is AJM not recommended to machine ductile materials?**

   The following are the reasons for AJM is not suitable for ductile materials,
   - Machining accuracy is poor
   - Soft material cannot be machined due to poor surface finish

3. **What are the advantages of Ultrasonic machining?**

   The following are the advantages of USM,
   - Cost of metal removal is low
   - Noiseless operation
   - Equipment is safe to operate
   - High accuracy and good surface finish can be easily obtained.

4. **Write the formula for Material removal rate for ductile and brittle materials in AJM?**

   MRR for ductile materials = $\frac{M_a V^2}{2\sigma_w}$

   Where, Ma-Mass flow rate of abrasive V - Velocity

   σ_w - Flow strength of work piece material

5. **What are the abrasive used in AJM process?**

   The various abrasive particles used in Abrasive Jet Machining process are Aluminium oxide, Silicon Carbide, Glass powder, Dolomite and specially prepared Sodium bicarbonate.

6. **Write the typical applications of Ultrasonic Machining?**
   - Holes as small as 0.1 mm can be drilled.
   - Precise and intricate shaped articles can be machined.
   - It is used for making tungsten carbide and diamond wire drawing dies and dies for forging and extrusion processes.
   - It has been efficiently applied to machine glass, ceramics, tungsten, precision mineral stones, etc.

7. **What are the types of work materials for USM?**

   Hard and brittle metals like tungsten carbide, boron carbide, tool steel, germanium, etc., are used as work material in USM process. Non-metal like glass and ceramics are also used as work material.

8. **What is the transfer medium in AJM?**

   The following are the transfer medium for AJM,
   - Nitrogen,
   - carbon dioxide,
   - helium
   - compressed air

9. **List the process parameters of USM.**
   - Metal removal rate.
   - Tool material.
   - Tool wear rate.
   - Surface finish.
   - Work material.

10. What is the principle of WJM?

When the high velocity of water jet comes out of the nozzle and strikes the material, its kinetic energy is converted into pressure energy including high stresses in the work material. When this induced stress exceeds the ultimate shear stress of the material, small chips of the material get loosened and fresh surface is exposed.

11. Mention the salient features of USM.

- Extremely hard and brittle materials can be machined.
- Metal removal cost is low.
- Noiseless operation.
- High accuracy and good surface finish.

12. Write the application of AJM.

- Machining of hard and brittle materials like quartz, ceramics, glass, sapphire, etc.
- Fine drilling and micro welding.
- Cleaning and polishing of plastics, nylon and Teflon components.
- Machining of semiconductors.

13. List any four variables in abrasive jet machining that influence the metal removal rate.

- Mass flow rate.
- Abrasive grain size.
- Gas pressure.
- Velocity of abrasive particles.
- Mixing ratio
- Nozzle tip clearance.

14. What is the need for transducer in USM?

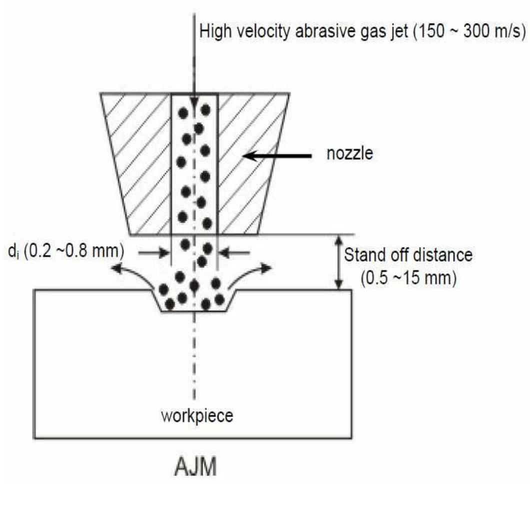
Transducer is a device which converts one form of energy into another form of energy. In ultrasonic machining process it converts the electrical energy into mechanical energy.

15. List the process parameters of WJM?

- Material Removal Rate.
- Geometry and surface finish of work material.
- Wear rate of the nozzle.

PART –B (16 MARKS)

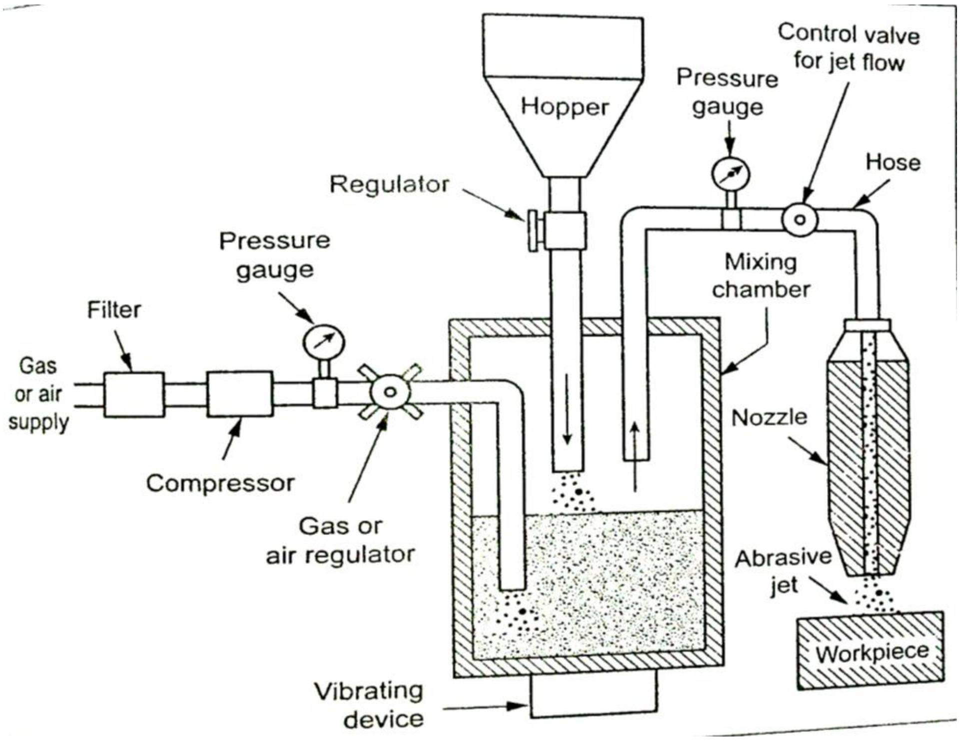
1. Explain the principle, construction and working of Abrasive jet machining (AJM) with a neat sketch. Also, State some of the advantages, disadvantages and its application.



Principle:

In abrasive jet machining process, a high speed stream of abrasive particles mixed with high pressure air or gas are injected through a nozzle on the workpiece to be machined.

The figure shows an abrasive jet machining process.



Construction:

- The schematic arrangement of AJM is shown in figure.
- It consists of a mixing chamber, nozzle, pressure gauge, hopper, filter, compressor, vibrating device, regulator, etc.
- The gases generally used in this process are nitrogen, carbon di oxide, or compressed air.
- The various abrasive particles used in this process are Aluminium oxide, silicon oxide, glass powder, dolomite and specially prepared sodium bicarbonate.
- Aluminium oxide (Al_2O_3) is a general purpose abrasive and it is used in sizes of 10, 25 and 50 microns. Silicon carbide (SiC) is used for faster cutting on extremely hard materials. It is used in sizes of 25 and 50 microns. Dolomite of 200 grit size is found suitable for light cleaning and etching. Glass powder of diameter 0.30 to 0.60 mm are used for light polishing and deburring.
- As the nozzle is subjected to a great degree of abrasion wear, it is made up of hard materials such as tungsten carbide, synthetic sapphire (ceramic), etc., to reduce the wear rate.
- Nozzles made up of tungsten carbide have an average life of 12 to 20 hours, whereas synthetic sapphire nozzle have an average life of 300 hours. Nozzle tip clearance from work is kept at a distance of 0.25 to 0.75 mm.
- The abrasive powder feed rate is controlled by the amplitude of the vibration of mixing chamber. A pressure regulator controls the gas or air flow and pressure. To control the size and shape of the cut, either the workpiece or the nozzle is moved by a well-designed mechanism such as cam mechanism, pantograph mechanism, etc.

Working:

- Dry air or gas (N_2 or CO_2) is entered into the compressor through a filter where the pressure of air or gas is increased.
- The pressure of the air is varies from 2 kg/cm^2 to 8 kg/cm^2.
- Compressed air or high pressure gas is supplied to the mixing chamber through a pipe line. This pipe line carries a pressure gauge and a regulator to control the air or flow and its pressure.
- The fine abrasive particles are collected in the hopper and fed into the mixing chamber. A regulator is incorporated in the line to control the flow of abrasive particles.

- The mixture of pressurized air and abrasive from the mixing chamber flow into the nozzle at a considerable speed.
- Nozzle is used to increase the speed of the abrasive particles and it is increased up to 300 m/s.
- This high speed stream of abrasive particles from the nozzle, impact the workpiece to be machined. Due to repeated impacts, small chips of material get loosened and a fresh surface is exposed.
- A vibrator is fixed at the bottom of the mixing chamber. When it vibrates, the amplitude of the vibrations controls the flow of abrasive particles.
- This process is widely used for machining hard and brittle materials, non-metallic materials (germanium, glass, ceramics and mica) of thin sections. This process is capable of performing drilling, cutting, deburring, etching and cleaning the surfaces.
- AJM process differs from sand blasting process. AJM is basically meant for metal removal with the use of small abrasive particles, whereas the sand blasting process is a surface cleaning process which does not involve metal cutting.

Advantages:

1. There is no direct contact between the tool and workpiece.
2. Low initial investment.
3. Good surface finish.
4. It can be used to cut intricate hole shapes in hard and brittle materials.

Disadvantages:

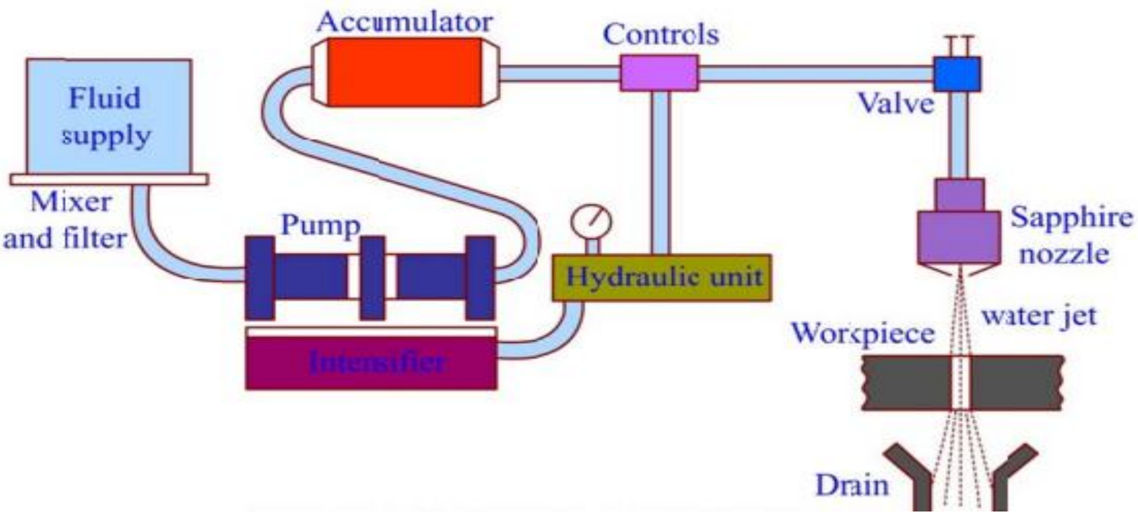
1. Material removal rate is slow.
2. Soft material cannot be machined.
3. Machining accuracy is poor.

   Nozzle wear rate is high.

Applications:

1. Machining of hard and brittle materials like quartz, ceramics, glass, sapphire, etc.
2. Fine drilling and micro welding.
3. Machining of semiconductors.
4. Machining of intricate profiles on hard and brittle materials.

2. **Explain the principle, construction and working of Water jet machining (WJM) with a neat sketch. Also, State some of the advantages, disadvantages and its application.**



Principle:

When the high velocity of water jet comes out of the nozzle and strikes the material, its kinetic energy is converted into pressure energy including high stresses in the work material. When this induced stress exceeds the ultimate shear stress of the material, small chips of the material get loosened and fresh surface is exposed.

Construction:

- The schematic diagram of WJM is shown in figure.
- It consists of pump, accumulator, control valve, regulating chamber, nozzle, etc.
- A pump or intensifier is used to raise the pressure of water. Pressure normally used in the system are in the range of 1500 to 4000 n/mm2.
- Since the cutting action may not be continuous, the accumulator is used to store the water and also it helps in eliminating pulsation.
- Nozzle is used to increase the velocity of the water jet. The nozzle is made up of sintered diamond, tungsten carbide or synthetic sapphire. The exit diameter of the nozzle is in the range of 0.05 to 0.35 mm and the exit velocity of the water jet from the nozzle varies up to 920 m/s.
- A regulating chamber is incorporated in the line to control the flow of water jet to the nozzle.

Working:

- The working principle of water jet machining is very similar to that of the abrasive jet machining.
- A pump or intensifier is used to increase the pressure of the water and the water passes onto accumulator from the pump.
- Water under pressure from hydraulic accumulator is passed through the orifice of a nozzle to increase its velocity.
- When the high velocity of water jet comes out of the nozzle and strikes the work material, its kinetic energy is converted into pressure energy including high stresses in the work material.
- When this induced stress exceeds the ultimate shear stress of the material, small chips of the material get loosened and fresh surface is exposed.

Advantages:

1. In WJM process, water is used as energy transfer medium. It is cheap, non-toxic and easy to dispose.
2. Low operating cost.
3. Low maintenance cost.
4. The work area remains clean and dust free.
5. Very less amount of heat is generated during cutting operation. So, there is no thermal damage to the work.
6. Easily automated.

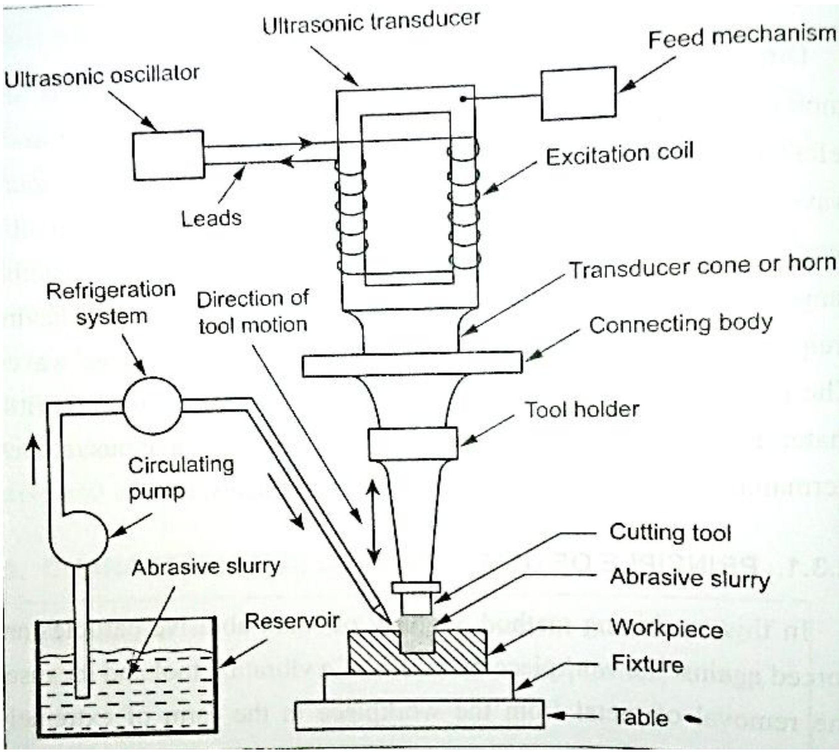
Disadvantages:

1. Initial cost of this process is high.
2. It is difficult to machine hard material.
3. Noise operation.

Applications:

1. This process is very convenient for cutting relatively soft and non-metallic materials like paper boards, plastics, wood, rubber, leather, fibre glass, etc.
2. It can be used to cut intricate contours.

3. **Explain the principle, construction and working of Ultrasonic machining (USM) with a neat sketch. Also, State some of the advantages, disadvantage and its application.**



Principle:

In this machining method, a slurry of small abrasive particles are forced against the workpiece by means of a vibrating tool and it causes the removal of metal from the workpiece in the form of extremely small chips.

Construction:

- The arrangement of USM is shown in figure.
- It consists of abrasive slurry, workpiece, fixture, table, cutting tool, circulating pump, reservoir, ultrasonic oscillator, leads, excitation coil, feed mechanisms, ultrasonic transducer, transducer cone, connecting body and tool holder.
- The ultrasonic oscillator and amplifier also known as generator is used to convert the applied electrical energy at low frequency to high frequency.
- The transducer is made up of magnetostrictive material and it consists of a stack of nickel laminations that are wound with a coil.
- The function of the transducer is to convert the electrical energy into mechanical energy.
- Generally tough and ductile tool material is used in this process. Low carbon steels and stainless steels are commonly used as tool materials.
- The tool is brazed, soldered or fastened mechanically to the transducer through a tool holder. Generally tool holder is of cylindrical or conical in shape.
- The material used for tool holders are titanium alloys, monel, aluminum, stainless steel, etc.
- An abrasive slurry, usually a mixture of abrasive grains and water of definite proportion (20-30%), is made to flow under pressure through the gap between tool and workpiece. The gap between the tool and workpiece is of the order 0.02-0.1 mm.
- The most commonly used abrasives are boron carbide (B_4C), silicon carbide (SiC), Aluminium oxide (Al_2O_3), and diamond. Boron carbide is most commonly used abrasive slurry, since it has the fastest cutting abrasive property.

Working:

- Electric power is given to ultrasonic oscillator and this oscillator converts the electrical energy at low frequency to high frequency (20 kHz).
- High frequency power (20 kHz) from oscillator is supplied to the transducer.
- The function of transducer is to convert the electrical energy into mechanical vibrations. The transducer is made up of magnetostrictive material, which is excited by flowing high frequency electric current and this results in the generation of mechanical vibrations. The vibrations are generated in the transducer of the order of 20 kHz to 30 kHz and hence ultrasonic waves are produced.
- These vibrations are then transmitted to the cutting tool through transducer cone, connecting body and tool holder. This makes the tool to vibrate in a longitudinal direction as shown in figure.
- Abrasive slurry is pumped from the reservoir and it is made to flow under pressure through the gap between tool and workpiece.
- In a abrasive slurry, when the cutting tool vibrates at high frequency, it leads in the removal of metal from the workpiece.
- The impact force arises out from the vibration of tool end and the flow of slurry through the workpiece-tool gap causes thousands of microscopic grains to remove the workpiece material by abrasion.
- A refrigerated cooling system is used to cool the abrasive slurry to a temperature of 5-6deg C.
- The ultrasonic machining process is a copying process in which the shape of the cutting tool is same as that of the cavity produced.

Advantages:

1. Extremely hard and brittle materials can be easily machined.
2. Cost of metal removal is low.
3. Noiseless operation.
4. High accuracy and good surface finish can be easily obtained.

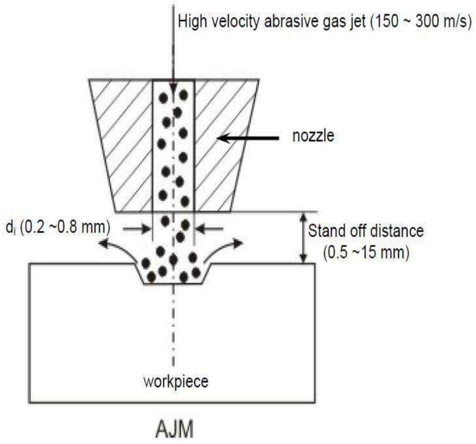
Disadvantages:

1. Metal removal rate is slow.
2. Softer materials are difficult to machine.
3. Wear rate of the tool is high.
4. The initial equipment cost is high.

Applications:

1. Holes as small as 0.1 mm can be drilled.
2. Precise and intricate shaped articles can be machined.
3. It has been efficiently applied to machine glass, ceramics, tungsten, precision mineral stones, etc.
4. It is used for making tungsten carbide and diamond wire drawing dies and dies for forging and extrusion processes.

4. Briefly discuss the principle, equipments being used and process parameters of an AJM process.



Principle:

In abrasive jet machining process, a high speed stream of abrasive particles mixed with high pressure air or gas are injected through a nozzle on the workpiece to be machined.

The figure shows an abrasive jet machining process.

Equipments:

- It consists of a mixing chamber, nozzle, pressure gauge, hopper, filter, compressor, vibrating device, regulator, etc.
- The gases generally used in this process are nitrogen, carbon di oxide, or compressed air.
- The various abrasive particles used in this process are Aluminium oxide, silicon oxide, glass powder, dolomite and specially prepared sodium bicarbonate.
- Aluminium oxide (Al2O3) is a general purpose abrasive and it is used in sizes of 10, 25 and 50 microns. Silicon carbide (SiC) is used for faster cutting on extremely hard materials. It is used in sizes of 25 and 50 microns. Dolomite of 200 grit size is found suitable for light cleaning and etching. Glass powder of diameter 0.30 to 0.60 mm are used for light polishing and deburring.
- As the nozzle is subjected to a great degree of abrasion wear, it is made up of hard materials such as tungsten carbide, synthetic sapphire (ceramic), etc., to reduce the wear rate.
- Nozzles made up of tungsten carbide have an average life of 12 to 20 hours, whereas synthetic sapphire nozzle have an average life of 300 hours. Nozzle tip clearance from work is kept at a distance of 0.25 to 0.75 mm.
- The abrasive powder feed rate is controlled by the amplitude of the vibration of mixing chamber. A pressure regulator controls the gas or air flow and pressure. To control the size and shape of the cut, either the workpiece or the nozzle is moved by a well-designed mechanism such as cam mechanism, pantograph mechanism, etc.

Process Parameters and Machining Characteristics

- Abrasive: Material – Al2O3 / SiC / glass beads
- Shape – irregular / spherical
- Size – 10 ~ 50 μm
- Mass flow rate – 2 ~ 20 gm/min
- Carrier gas: Composition – Air, CO2, N2
- Density – Air ~ 1.3 kg/m3
- Velocity – 500 ~ 700 m/s Pressure – 2 ~ 10 bar
- Flow rate – 5 ~ 30 lpm
- Abrasive Jet : Velocity – 100 ~ 300 m/s
- Mixing ratio – mass flow ratio of abrasive to gas
- Stand-off distance – 0.5 ~ 5 mm
- Impingement Angle – 60 ~ 90
- Nozzle: Material – WC
- Diameter – (Internal) 0.2 ~ 0.8 mm
- Life – 10 ~ 300 hours

5. Explain the transducers used in USM process with neat sketches. List out the advantages and limitations.

Transducers:

Transducers is a device which converts one form of energy into another form of energy. In ultrasonic machining process it converts the electrical energy into mechanical energy.

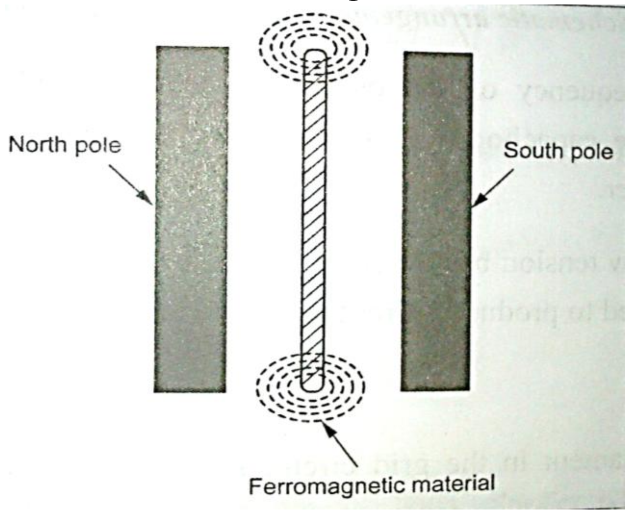
There are two types of transducers. They are

1. Magnetostriction transducer.
2. Piezoelectric transducer.

1. Magnetostriction transducer.

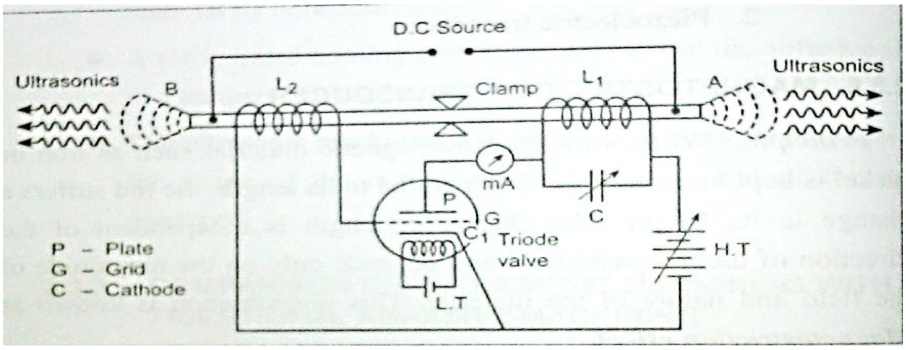
Principle:

When a rod of ferromagnetic material such as iron or nickel is kept in a magnetic field parallel to its length, the rod suffers a change in its length. The change in length is independent of the direction of the magnetic field and depends only on the magnitude of the field and nature of the material. This phenomenon is known as Magnetostriction Effect.



Construction:

- A rod of (AB) ferromagnetic materials such as iron or nickel is clamped at the middle.
- The two ends (A and B) of the rod is wound by the coil L_1 and L_2. The coil L_1 wound on the right hand portion of the rod along with a variable capacitor C_1. The coil L_2 wound on the left hand portion of the rod is connected to the grid circuit.
- The frequency of the oscillatory circuit is adjusted by the variable capacitor (C_1) and the current is noted by the milli ammeter.
- The low tension battery (LT) and high tension battery (HT) are provided to produce current in the grid circuit.



Working:

- The filament in the grid circuit is heated by the low tension battery (L.T). This causes the production of electrons and these electrons are accelerated to a very high velocity by using high tension battery (HT). So, the alternating current is produced in the circuit (L, C).
- This alternating current passing through the coil L_1 produces an alternating magnetic field along the length of the rod.
- The result is, the rod starts to vibrate due to the magnetostrictive effect. The vibrations of the rod create ultrasonic waves which are sent out as shown in Fig.2.14.
- The longitudinal expansion and contraction of the rod (AB) produces an e.m.f in the coil L_2. This induced e.m.f is fed to the grid circuit continuously as a feedback. In this way, the current is built up and the vibrations of the rod is maintained.
- When the frequency of the oscillatory circuit is equal to the frequency of the vibrating rod, resonance occurs. At resonance, the rod vibrates vigorously and ultrasonic waves are produced with very high frequencies.

$$\left.\begin{array}{l}\text{Frequency of the}\\ \text{oscillatory circuit}\end{array}\right\} = \left\{\begin{array}{l}\text{Frequency of the}\\ \text{vibrating rod}\end{array}\right.$$

$$\frac{1}{2\pi\sqrt{L_1 C_1}} = \frac{1}{2l}\sqrt{\frac{E}{\rho}}$$

where,

E – Young's modulus of the rod material, N/m^2,

l – Length of the rod, m,

ρ – Density of the rod material, kg/m^3.

2.3.7. ADVANTAGES

1. Production cost is low.
2. Very simple design.
3. At low ultrasonic frequencies, large power output is possible without any damage to the oscillatory circuit.

Piezoelectric transducer is more efficient than magnetostriction transducer. Therefore, modern ultrasonic transducers are of this type. It is based on the piezoelectric effect.

Piezoelectric Effect

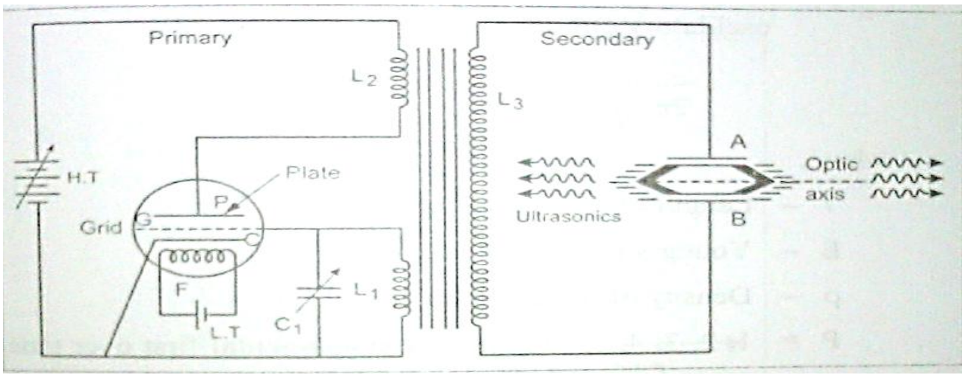
When mechanical force is applied to one pair of opposite faces of certain crystals like quartz, tourmaline, *etc.*, equal and opposite electrical charges appear across its other faces.

But ultrasonic wave generation is based on inverse piezoelectric effect.

Inverse Piezoelectric Effect

When an a.c. voltage is applied across the piezoelectric crystal, it starts vibrating at the frequency of the applied voltage.

Diagram:



Construction:

- It consists of primary and secondary circuits. The primary circuit is arranged with coils L_1 and L_2.
- Coil L_1 is connected to the grid circuit and the coil L_2 is connected to the plate circuit. The frequency of the oscillatory circuit is varied by using the capacitor C_1.
- The quartz crystal is placed between two metal plates A and B. The plates are connected to the secondary (L_3) of the transformer.

Working:

- The filament in the grid circuit is heated by the low tension battery (LT). This causes the production of electrons and these electrons are accelerated with a very high velocity by high tension battery (HT). So, the alternating current is produced in the circuit.
- This alternating current is passed through the coil L_1 and L_2 of the primary circuit and it is transferred to the secondary circuit

(L_3) due to transformer action from the secondary coil L_3. This current is passed to the plates A and B and it leads the crystal to vibrate due to the principle of inverse piezoelectric effect. The vibrations of the crystal create ultrasonic waves.

- When the frequency of the oscillatory circuit is equal to the frequency of the vibrating crystal, resonance occurs. At resonance, the crystal vibrates vigorously and ultrasonic waves are produced with very high frequencies.

$$\left.\begin{matrix}\text{Frequency of the}\\ \text{oscillatory circuit}\end{matrix}\right\} = \left\{\begin{matrix}\text{Frequency of the}\\ \text{vibrating crystal}\end{matrix}\right.$$

$$\frac{1}{2\pi\sqrt{L_1 C_1}} = \frac{P}{2l}\sqrt{\frac{E}{\rho}}$$

where,

l – Length of the crystal, m,

E – Young's modulus of the crystal, N/m^2,

ρ – Density of the crystal, kg/m^3,

P = 1, 2, 3, 4, ……, *etc.*, for fundamental first over tone, second over tone respectively.

Advantages:

1. It is more efficient than magnetostriction transducer.
2. It can produce frequency upto 500 MHz.
3. It is not affected by temperature and humidity.

Disadvantages:

The cost of piezoelectric quartz is high and the cutting and shaping of quartz crystal is very complex.

6. **Briefly discuss the principle, equipments being used and process parameters of a USM process.**

Principle:

In this machining method, a slurry of small abrasive particles are forced against the workpiece by means of a vibrating tool and it causes the removal of metal from the workpiece in the form of extremely small chips.

Equipments:

- It consists of abrasive slurry, workpiece, fixture, table, cutting tool, circulating pump, reservoir, ultrasonic oscillator, leads, excitation coil, feed mechanisms, ultrasonic transducer, transducer cone, connecting body and tool holder.
- The ultrasonic oscillator and amplifier also known as generator is used to convert the applied electrical energy at low frequency to high frequency.
- The transducer is made up of magnetostrictive material and it consists of a stack of nickel laminations that are wound with a coil.

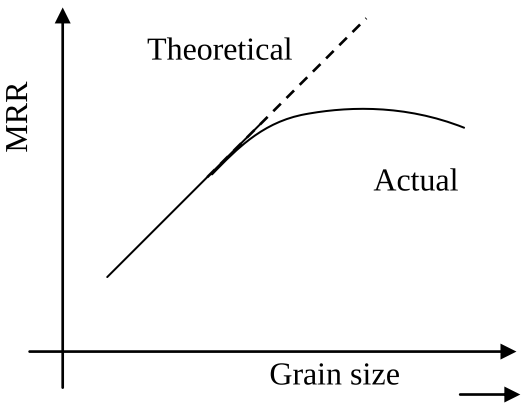
- The function of the transducer is to convert the electrical energy into mechanical energy.
- Generally tough and ductile tool material is used in this process. Low carbon steels and stainless steels are commonly used as tool materials.
- The tool is brazed, soldered or fastened mechanically to the transducer through a tool holder. Generally tool holder is of cylindrical or conical in shape.
- The material used for tool holders are titanium alloys, monel, aluminum, stainless steel, etc.
- Abrasive slurry, usually a mixture of abrasive grains and water of definite proportion (20-30%), is made to flow under pressure through the gap between tool and workpiece. The gap between the tool and workpiece is of the order 0.02-0.1 mm.
- The most commonly used abrasives are boron carbide (B4C), silicon carbide (SiC), Aluminium oxide (Al2O3), and diamond. Boron carbide is most commonly used abrasive slurry, since it has the fastest cutting abrasive property.

Process parameters

Process parameters

1. Amplitude of vibration (15 to 50 microns)

2. Frequency of vibration (19 to 25 kHz).
3. Feed force (F) related to tool dimensions
4. Feed pressure
5. Abrasive size



Material removal rate and surface finish are greatly influenced by grit or grain size of the abrasive. For roughing work operation, grit sizes of 200-400 are used and for finishing operation, grit size of 800-1000 are used. The following figure shows the effect of grain size for the material removal rate (MRR) in ultrasonic machining process.

6. Abrasive material

** Al203, SiC, B4C, Boron silicon carbide, Diamond.

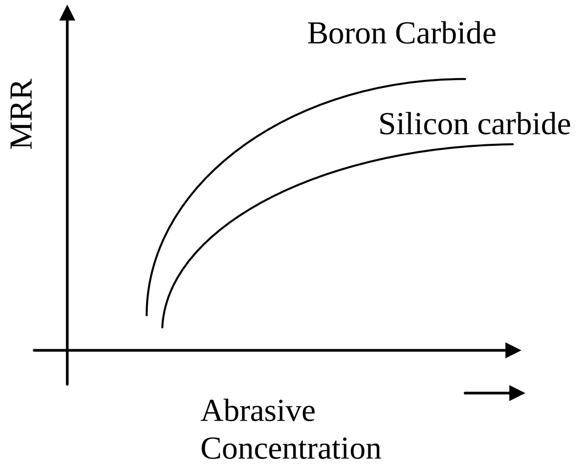
- The most commonly used abrasives are boron carbide (B4C), silicon carbide (SiC), Aluminium oxide (Al2O3), and diamond. Boron carbide is most commonly used abrasive slurry, since it has the fastest cutting abrasive property.

7. Flow strength of the work material
8. Flow strength of the tool material
9. Contact area of the tool
10. Volume concentration of abrasive in water slurry
11. Tool

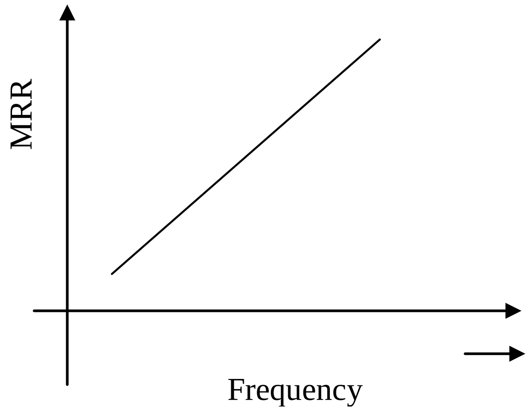
a. Material of tool

b. Shape

c. Amplitude of vibration



d. Frequency of vibration



e. Strength developed in tool
12. Work material
a. Material
b. Impact strength
c. Surface fatigue strength
13. Slurry
a. Abrasive – hardness, size, shape and quantity of abrasive flow
b. Liquid – Chemical property, viscosity, flow rate
c. Pressure
d. Density

- An abrasive slurry, usually a mixture of abrasive grains and water of definite proportion (20-30%), is made to flow under pressure through the gap between tool and workpiece. The gap between the tool and workpiece is of the order 0.02-0.1 mm.

7. **Briefly explain the following terms of USM Process**
   a. **Types of transducers used in USM**
   b. **Functions of slurry & oscillator in USM**
   c. **Types of abrasives used in USM**
   d. **Grain size vs Machining rate**

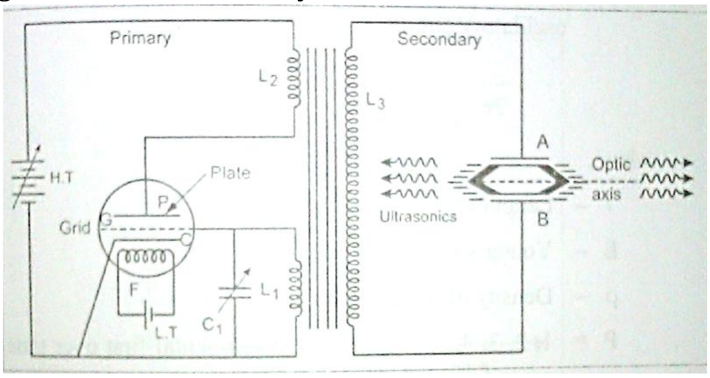
a. Transducer in USM

The high frequency electrical signal is transmitted to traducer which converts it into high frequency low amplitude vibration. Essentially transducer converts electrical energy to mechanical vibration. There are two types of transducer used

1. Piezo electric transducer
2. Magnetostrictive transducer.

Piezo electric transducer:

These transducer generate a small electric current when they are compressed. Also when the electric current is passed though crystal it expands. When the current is removed, crystal attains its original size and shape. Such transducers are available up to 900 Watts. Piezo electric crystals have high conversion efficiency of 95%.

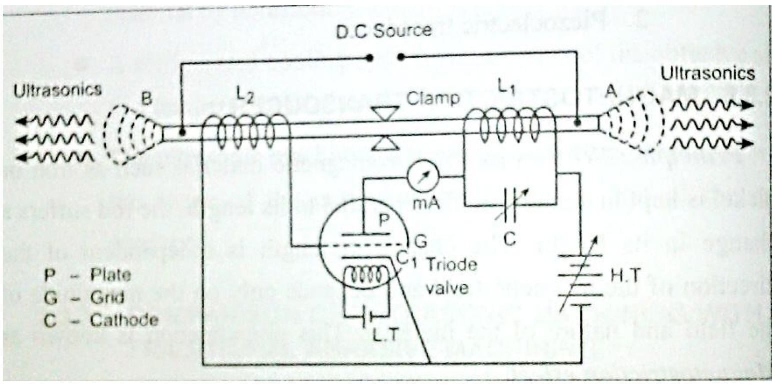


Refer Question No.5 for working principle

Magneto-strictive transducer:

These also changes its length when subjected to strong magnetic field. These transducer are made of nickel, nickel alloy sheets.

Their conversion efficiency is about 20-30%. Such transducers are available up to 2000 Watts. The maximum change in length can be achieved is about 25 microns.



Refer Question No.5 for working principle

b. Functions of slurry & oscillator in USM

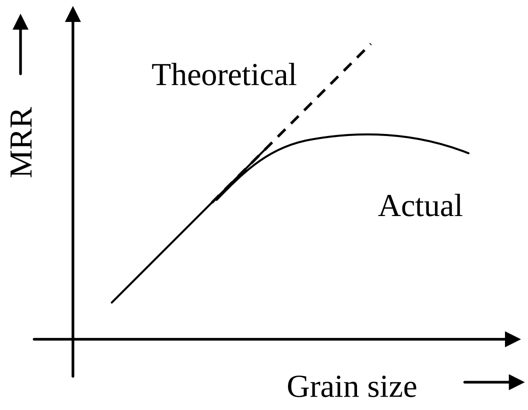
- An abrasive slurry, usually a mixture of abrasive grains and water of definite proportion (20-30%), is made to flow under pressure through the gap between tool and workpiece. The gap between the tool and workpiece is of the order 0.02-0.1 mm.
- The ultrasonic oscillator and amplifier also known as generator is used to convert the applied electrical energy at low frequency to high frequency.

c. Types of abrasives used in USM

- The most commonly used abrasives are boron carbide (B4C), silicon carbide (SiC), Aluminium oxide (Al2O3), and diamond. Boron carbide is most commonly used abrasive slurry, since it has the fastest cutting abrasive property.

d. Grain size vs Machining rate

Material removal rate and surface finish are greatly influenced by grit or grain size of the abrasive. For roughing work operation, grit sizes of 200-400 are used and for finishing operation, grit size of 800-1000 are used. The following figure shows the effect of grain size for the material removal rate (MRR) in ultrasonic machining process.



8. **i) List out the advantages, disadvantages and applications of AJM**

Advantages:

1. This process is suitable for cutting all materials. Even diamond can be machined by using diamond as abrasive.
2. There is no heat generation during this process. So, thermal damage to the workpiece is avoided.
3. Very thin and brittle materials can be cut without any risk of breaking.
4. There is no direct contact between the tool and workpiece.
5. Low initial investment.
6. Good surface finish.
7. It can be used to cut intricate hole shapes in hard and brittle materials.

Disadvantages:

1. Material removal rate is slow.
2. Soft material cannot be machined.
3. Machining accuracy is poor.
4. Nozzle wear rate is high.
5. The abrasive powder used in this process cannot be reused.
6. There is always a danger of abrasive particles getting embedded in the workpiece. So, cleaning is essential after the operation.
7. It requires some kind of dust collection system.

Applications:

1. Machining of hard and brittle materials like quartz, ceramics, glass, sapphire, etc.
2. Fine drilling and micro welding.
3. Machining of semiconductors.
4. Machining of intricate profiles on hard and brittle materials.
5. Cleaning and polishing of plastics, nylon and Teflon components.
6. Frosting of interior surface of the glass tubes.
7. Surface etching and surface preparation.

ii) List the Characteristics of AJM process.

Work material	–	Hard and brittle materials like glass, quartz, ceramics, mica, *etc.*
Abrasive	–	Aluminium oxide (Al_2O_3), Silicon carbide (SiC), Glass powder, dolomite.
Size of abrasive	–	Around 25 μm
Flow rate	–	2 – 20 g/min
Medium	–	N_2 (or) CO_2 (or) Air
Velocity	–	125 – 300 m/s
Pressure	–	2 to 8 kg/cm^2
Nozzle material	–	Tungsten carbide (WC) or synthetic sapphire
Life of nozzle	–	Tungsten carbide – 12 to 20 hours Sapphire – 300 hours
Nozzle tip clearance	–	0.25 to 15 mm
Tolerance	–	± 0.05 mm
Machining operation	–	Drilling, cutting, deburring, cleaning, *etc.*

9. **i) Explain the three types of feed mechanisms in USM process with neat sketch.**
   Feed mechanism in USM process:

The three types of feed mechanisms which are used in USM are:

1. Gravity feed mechanism.
2. Spring loaded feed mechanism.
3. Pneumatic or Hydraulic feed mechanism.

1. Gravity Feed Mechanism

Fig.2.19 shows the operation of gravity feed mechanism. In this mechanism, counter weights are used to apply the load to the head through a pulley as shown in Fig. In order to reduce the friction, ball bearings are used. Gravity feed mechanism is generally preferred because of its simple construction.

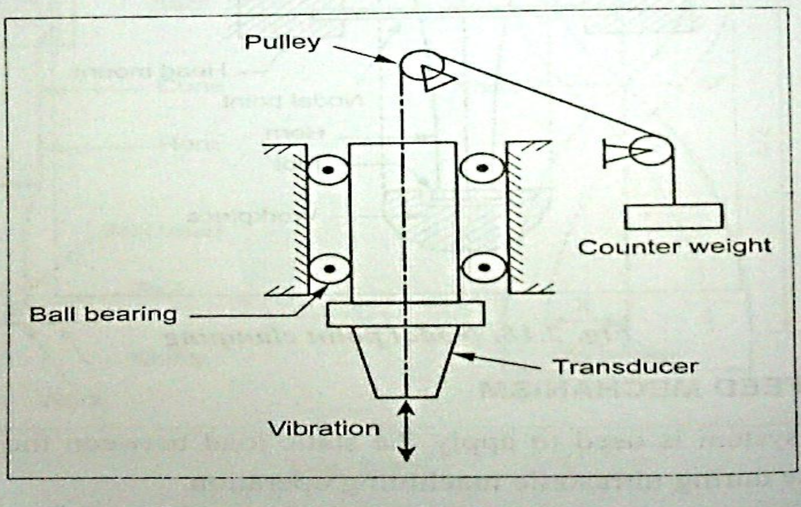


Fig. 2.19. Gravity feed mechanism

2. Spring Loaded Feed Mechanism

The arrangement of spring loaded feed mechanism is shown in Fig.2.20. In this mechanism, spring pressure is used to feed the tool during machining operation. This type of mechanism is also preferred because of its sensitivity and compactness.

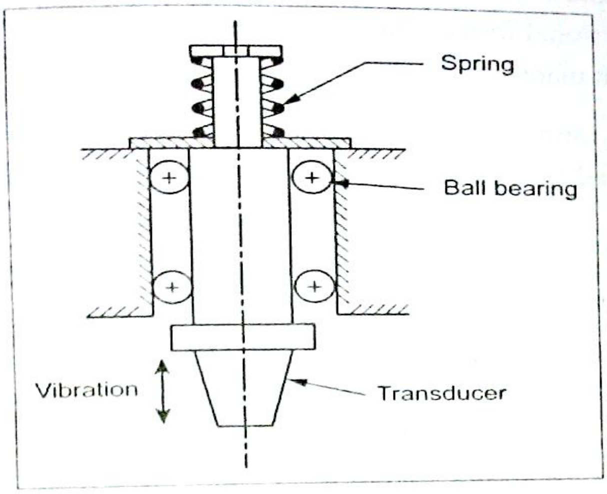


Fig. 2.20. Spring loaded feed mechanism

3. Pneumatic or Hydraulic Feed Mechanism

In order to get high feed rate, pneumatic feed mechanism is used.

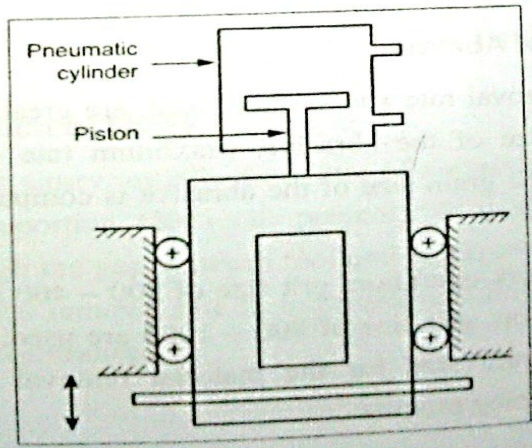


Fig. 2.21. Pneumatic feed mechanism

ii) List the Characteristics of WJM process.

Work material	–	Soft and non-metallic materials like paper boards, wood, plastics, rubber, *etc.*
Tool	–	Water or water with additives.
Additives	–	Glycerin, polyethylene oxide.
Pressure of water	–	100 to 1000 MPa
Mass flow rate	–	8 lit/min
Power	–	45 KW
Metal removal rate	–	0.6 mm^3/s
Feed rate	–	1 – 4 mm/s
Nozzle material	–	Tungsten carbide, synthetic sapphire
Stand off distance	–	2 to 50 mm

10. i) List out the advantages, disadvantages and applications of USM

Advantages:

1. Extremely hard and brittle materials can be easily machined.
2. Cost of metal removal is low.
3. Noiseless operation.
4. High accuracy and good surface finish can be easily obtained.
5. There is no heat generation in this process. So, the physical properties of the work material remain unchanged.
6. Equipment is safe to operate.
7. Non-conducting materials of electricity such as glass, ceramics and semi-precious stones can be easily machined.
8. The machined workpieces are free of stresses.

Disadvantages:

1. Metal removal rate is slow.
2. Softer materials are difficult to machine.
3. Wear rate of the tool is high.
4. The initial equipment cost is high.
5. For effective machining, the abrasive materials should be replaced periodically since the dull abrasives stop cutting action.
6. High power consumption.
7. Tool cost is high.
8. The size of the cavity that can be machined is limited.

Applications:

1. Holes as small as 0.1 mm can be drilled.
2. Precise and intricate shaped articles can be machined.
3. It has been efficiently applied to machine glass, ceramics, tungsten, precision mineral stones, etc.
4. It is used for making tungsten carbide and diamond wire drawing dies and dies for forging and extrusion processes.
5. Several machining operations like drilling, grinding, turning, threading, profiling, etc., on all materials both conducting and non-conducting.

ii) List the Characteristics of USM process.

Metal removal mechanism : Slurry of small abrasive particles is forced against the workpiece by means of a vibrating tool and it causes the removal of metal from the workpiece.

Abrasive : Boron carbide (B_4C), silicon carbide (SiC), aluminium oxide (Al_2O_3) and diamond.

Abrasive slurry : Abrasive grains + Water (20 – 30 percent)

Vibration frequency : 20 to 30 kHz

Amplitude : 25 to 100 μ

Wear Ratio : 1.5 : 1 for tungsten carbide, 100 : 1 for glass, 50 : 1 for quartz, 75 : 1 for ceramics and 1 : 1 for tool steel.

Work material : Tungsten carbide, germanium, glass, ceramic, quartz, tool steel, *etc.*

Tool material : Low carbon steels, stainless steels.

Surface finish : 0.2 to 0.7 μ