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Introduction to Non-Traditional Machining BME405A

Ultrasonic Machining (USM)

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Module 2

Ultrasonic Machining (USM):

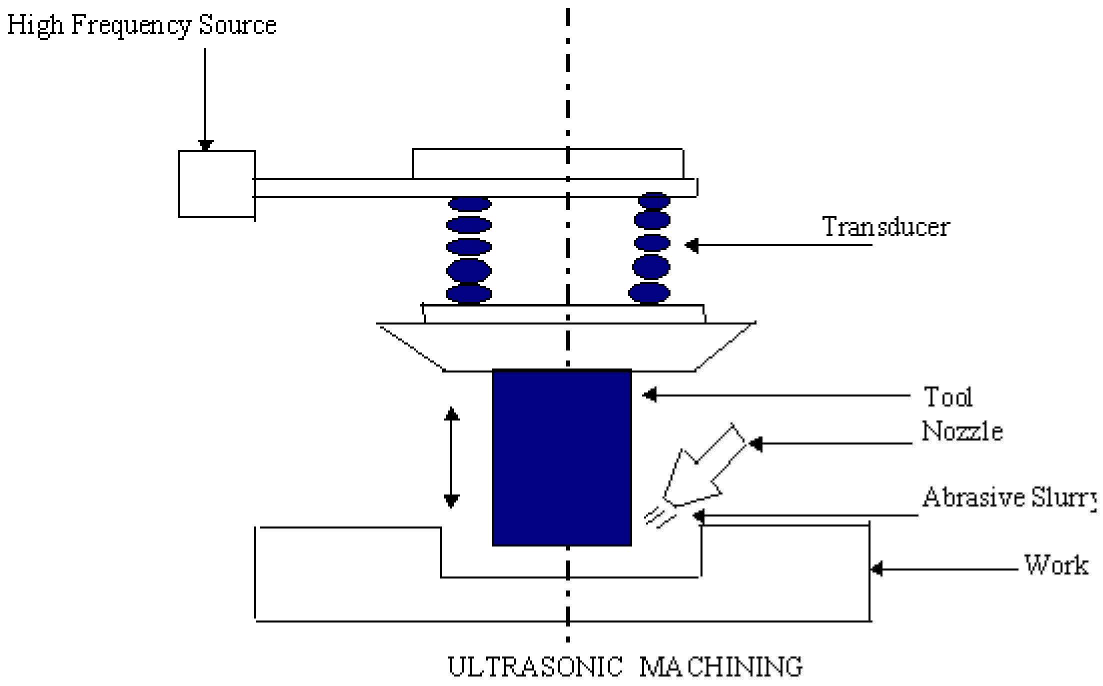
- Introduction, Equipment and material process
- Effect of process parameters: Effect of amplitude and frequency, Effect of abrasive grain diameter, effect of slurry, tool & work material.
- Process characteristics: Material removal rate, tool wear, accuracy, surface finish
- Applications, advantages & limitations of USM.

Abrasive Jet Machining (AJM):

- Introduction, Equipment and process of material removal,
- Process variables: carrier gas, type of abrasive, work material, stand-off distance (SOD).
- Process characteristics-Material removal rate, Nozzle wear, accuracy & surface finish.
- Applications, advantages &limitations of AJM.

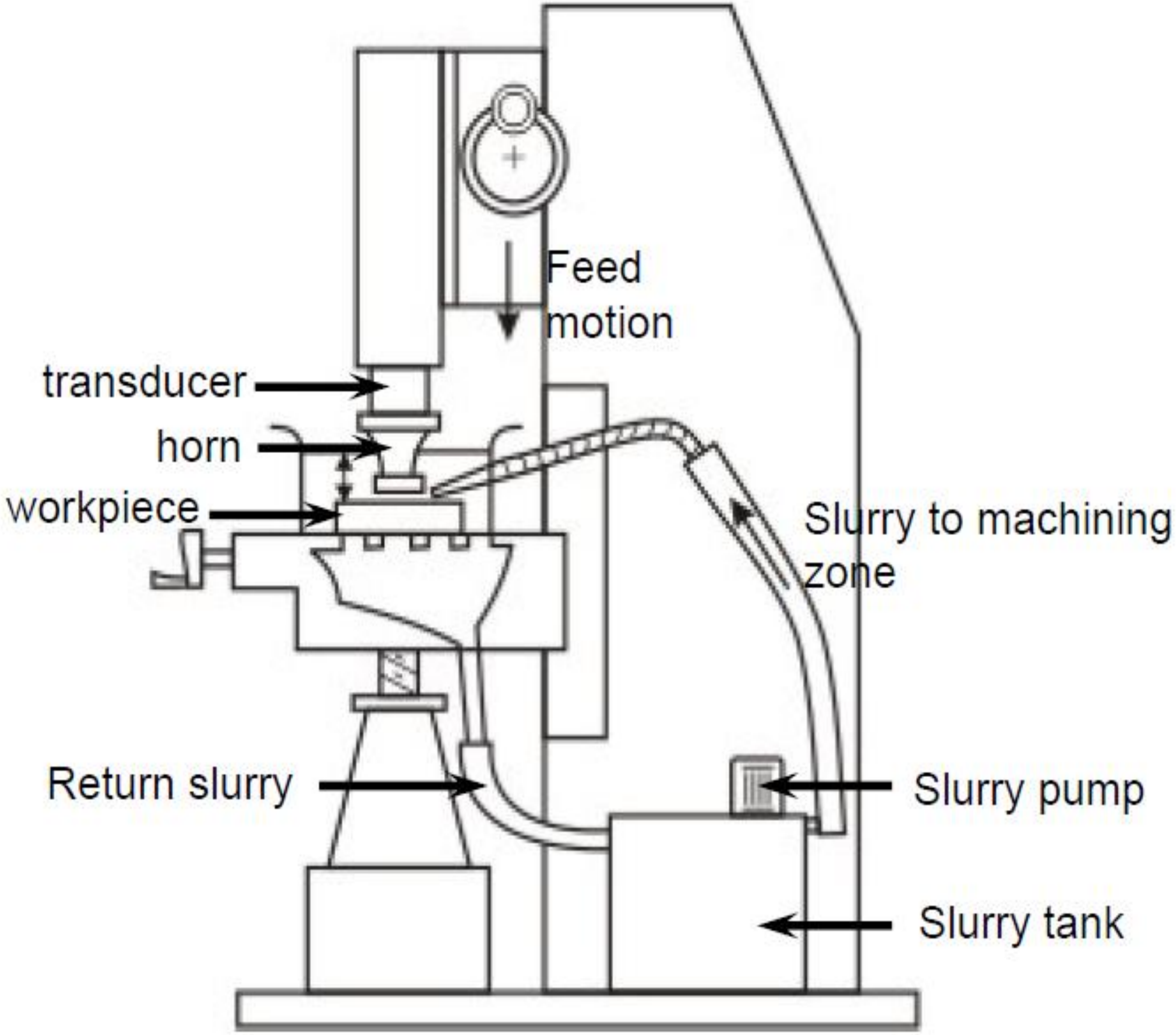
Principle of Ultrasonic machining

- In the process of Ultrasonic Machining, material is removed by micro-chipping or erosion with abrasive particles.
- In USM process, the tool, made of softer material than that of the workpiece, is oscillated by the Booster and Sonotrode at a frequency of about 20 kHz with an amplitude of about 25.4 um (0.001 in).



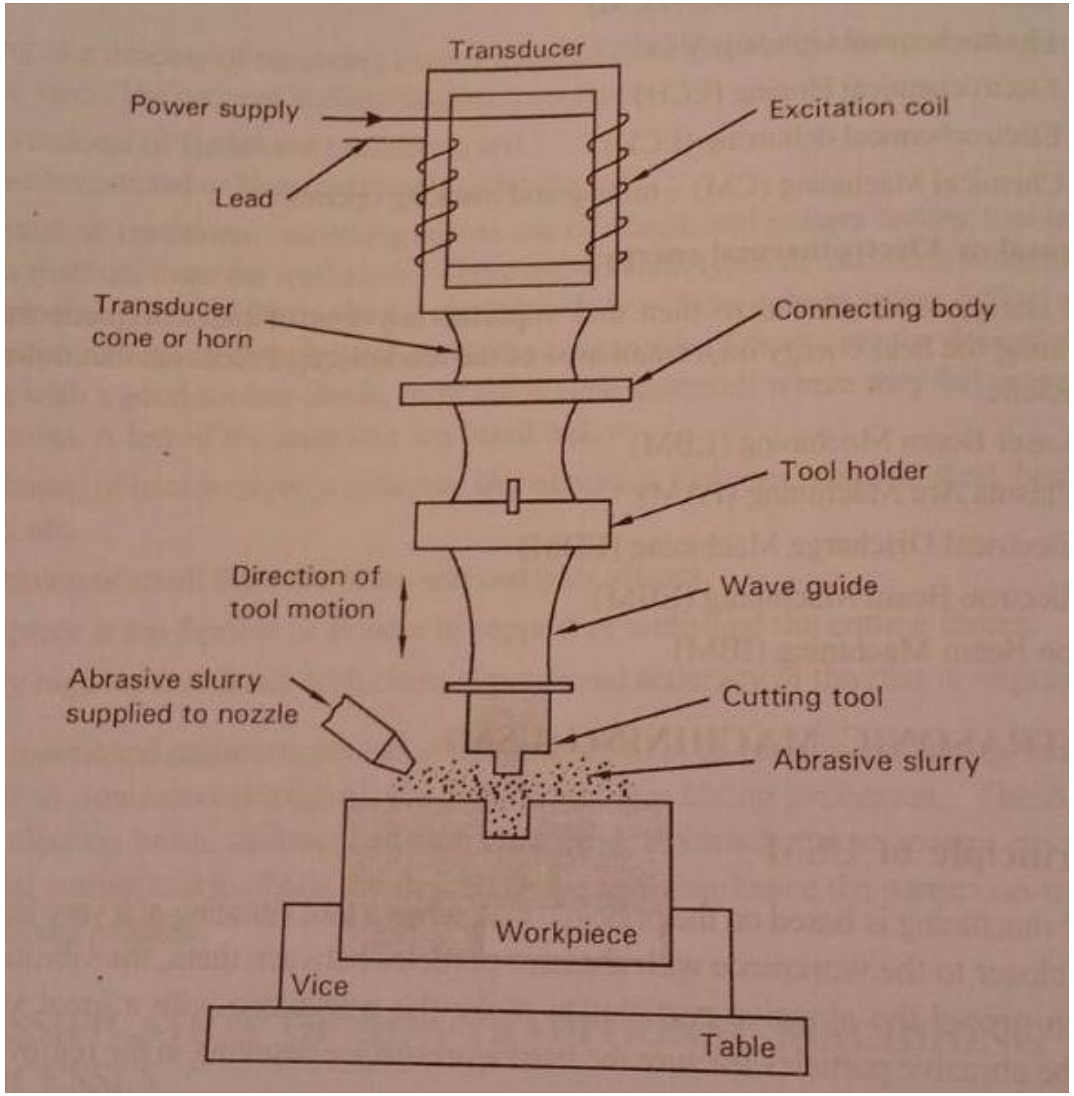
- The tool forces the abrasive grits, in the gap between the tool and the workpiece, to impact normally and successively on the work surface, thereby machining the work surface.
- During one strike, the tool moves down from its most upper remote position with a starting speed at zero, then it speeds up to finally reach the maximum speed at the mean position.

Equipment of Ultrasonic machining



- The process is performed by a cutting tool, which oscillates at high frequency, typically 20-40 kHz, in abrasive slurry.
- The tool is gradually fed with a uniform force.
- The high-speed reciprocations of the tool drive the abrasive grains across a small gap against the workpiece.
- The impact of the abrasive is the energy principally responsible for material removal in the form of small wear particles that are carried away by the abrasive slurry.
- The shape of the tool corresponds to the shape to be produced in the workpiece

Equipment of Ultrasonic machining



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Components of Ultrasonic machining

1. Transducer
2. Tool Holder/ Acoustic Head
3. Abrasive and Abrasive Slurry
4. Tool

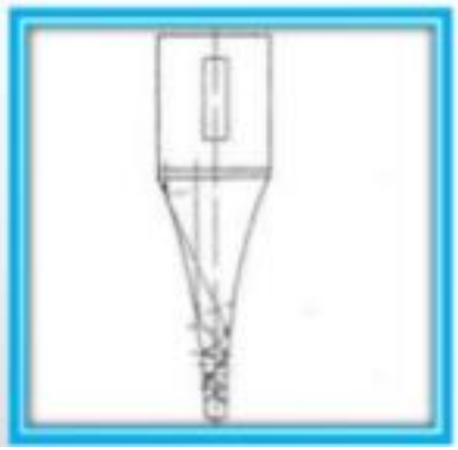
1. Transducer

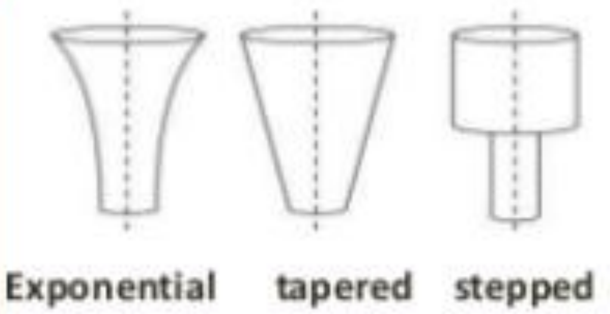
- Piezoelectric transducers utilize crystals like quartz whose dimensions alter when being subjected to electrostatic fields.
- The charge is directionally proportional to the applied voltage.
- To obtain high amplitude vibrations the length of the crystal must be matched to the frequency of the generator which produces resonant conditions.

Components of Ultrasonic machining

2. Tool Holder/Acoustic head

- The shape of the tool holder is cylindrical or conical, or a modified cone which helps in magnifying the tool tip vibrations.
- Its function is to increase the tool vibration amplitude and to match the vibrator to the acoustic load. Therefore it must be constructed of a material with good acoustic properties and be highly resistant to fatigue cracking.
- Monel and titanium have good acoustic properties and are often used together with stainless steel, which is cheaper.





Components of Ultrasonic machining

3. Abrasive

- **Abrasive Slurry**

- common types of abrasive
- Boron carbide (B_4C) good in general, but expensive
- Silicon carbide (SiC) glass, germanium, ceramics
- Corundum (Al_2O_3)
- Diamond (used for rubies , etc)
- Boron silicon-carbide (10% more abrasive than B_4C)

Liquid

- Water most common
- Benzene
- Glycerol
- Oils
- High viscosity decreases MRR

Components of Ultrasonic machining

4. Tool

- Tool material should be tough and ductile. Low carbon steels and stainless steels give good performance.
- Tools are usually 25 mm long ; its size is equal to the hole size minus twice the size of abrasives.
- Mass of tool should be minimum possible so that it does not absorb the ultrasonic energy.
- It is important to realize that finishing or polishing operations on the tools are sometimes necessary because their surface finish will be reproduced in the workpiece.
- Tool and toolholder are often attached by silver brazing.

Mechanism of Metal Removal in Ultrasonic machining

- Machining occurs when the abrasive particles, suspended in the slurry between the tool and workpiece, are struck by the downstroke of the vibration tool.
- The impact propels the particles across the cutting gap, hammering them into the surface of both tool and workpiece. Collapse of the cavitation bubbles in the abrasive suspension results in very high local pressures.
- Under the action of the associated shock waves on the abrasive particles, micro cracks are generated at the interface of the workpiece – brittle fracture.
- The brittle fracture lead to chipping of particles from the workpiece.

Tool feed mechanism

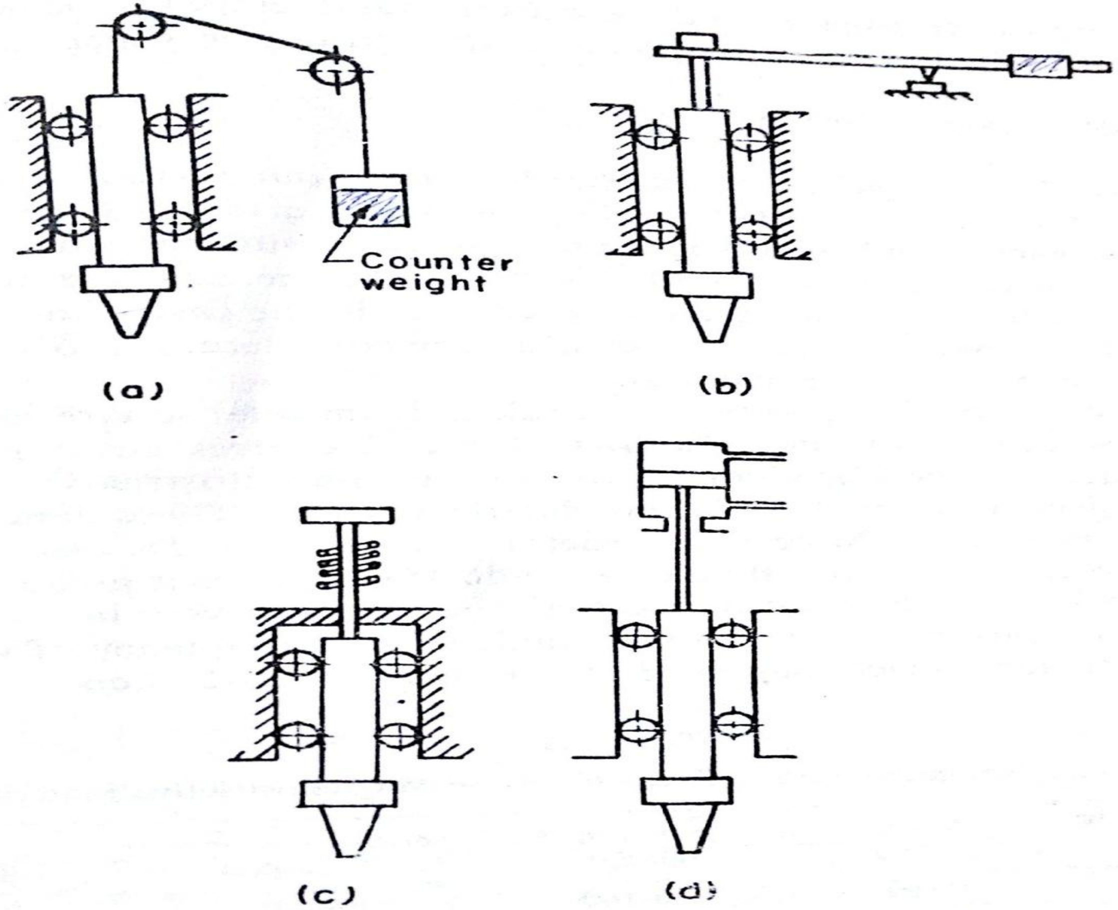


Fig. 2.3 Schematic representation of some types of tool feed systems in ultrasonic machining

Effect of parameters (Variables) of USM

01 Effect of Abrasive Grain

02 Effect of Amplitude & Frequency of vibrations

03 Effect of Applied Static Load

04 Effect of Slurry

05 Effect of Tool

06 Effect of Work Material

Effect of Abrasive Grain

- Grain size of the abrasive has a strong influence on the material removal rate & surface finish.
- Grain size determines the accuracy of the cavity configuration in USM.
- When the grain size becomes comparable to the tool amplitude, a maximum rate of machining is achieved but increase in grain size will reduce the machining rate.
- Grain size of 200-400 are used for roughing & 800-1000 for finishing.
- Boron Carbide is the fastest cutting abrasive & is commonly used.
- Aluminum oxide & silicon carbide are also employed.

Effect of Abrasive Grain Diameter

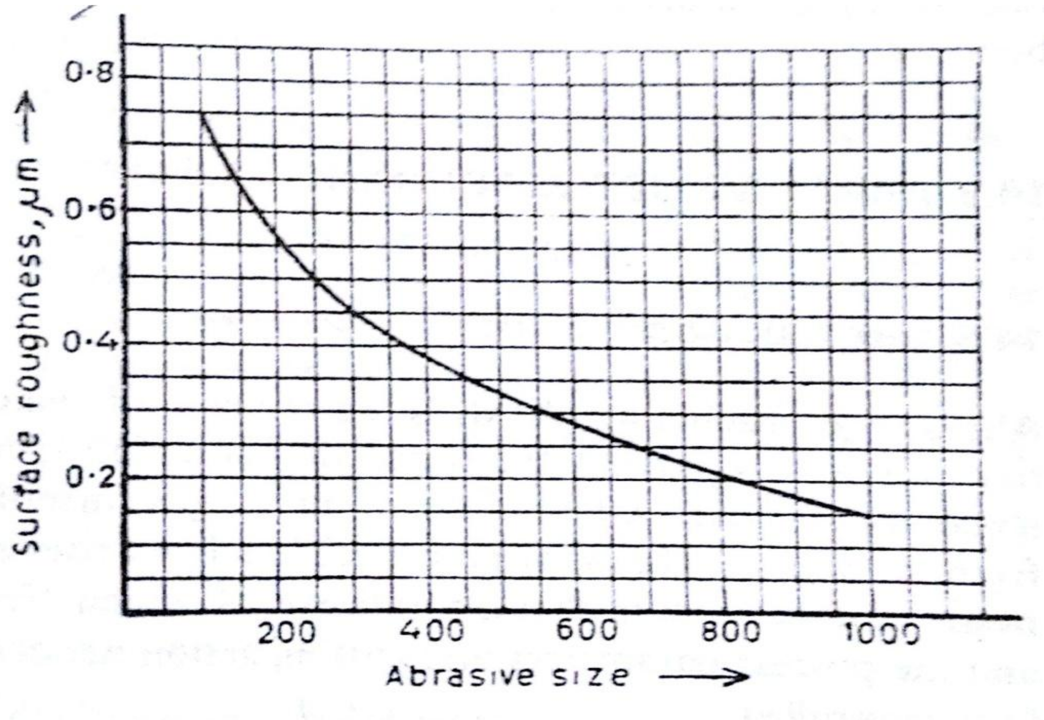
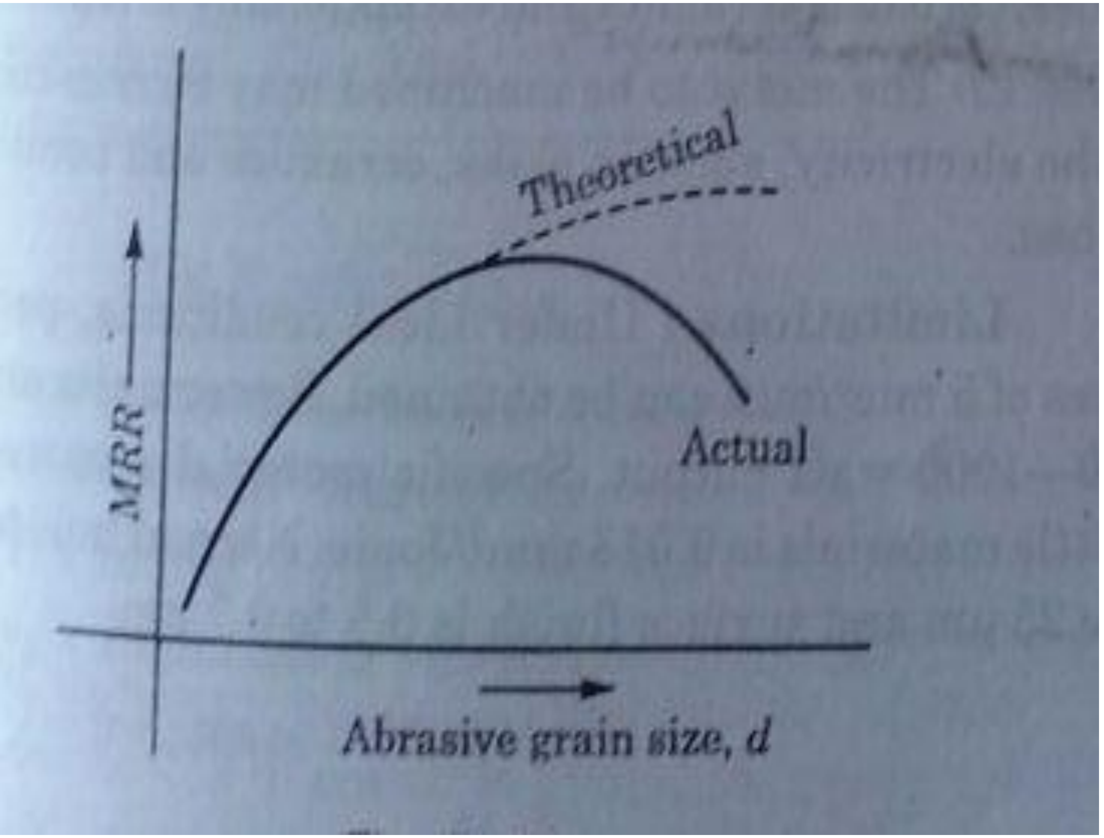
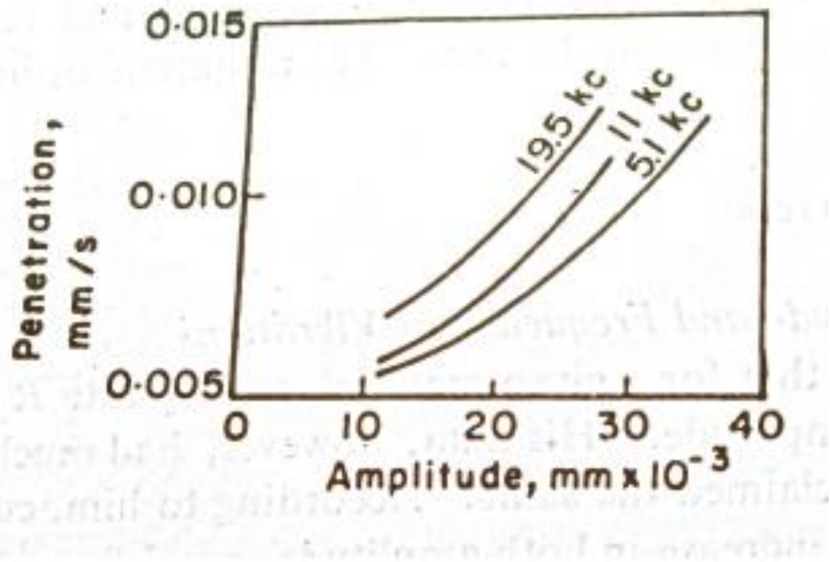


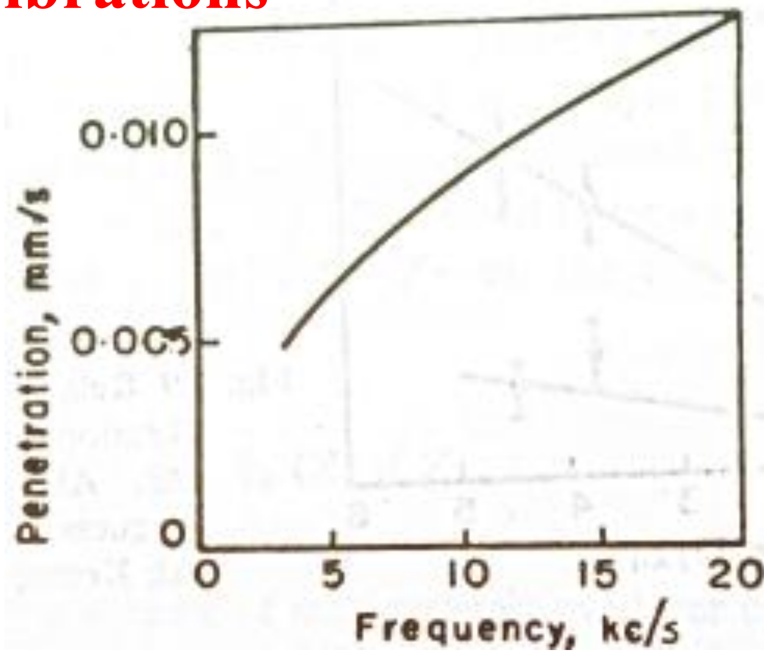
Fig. 14.78 Effect of abrasive grit size on surface roughness



Effect of Amplitude & Frequency of vibrations



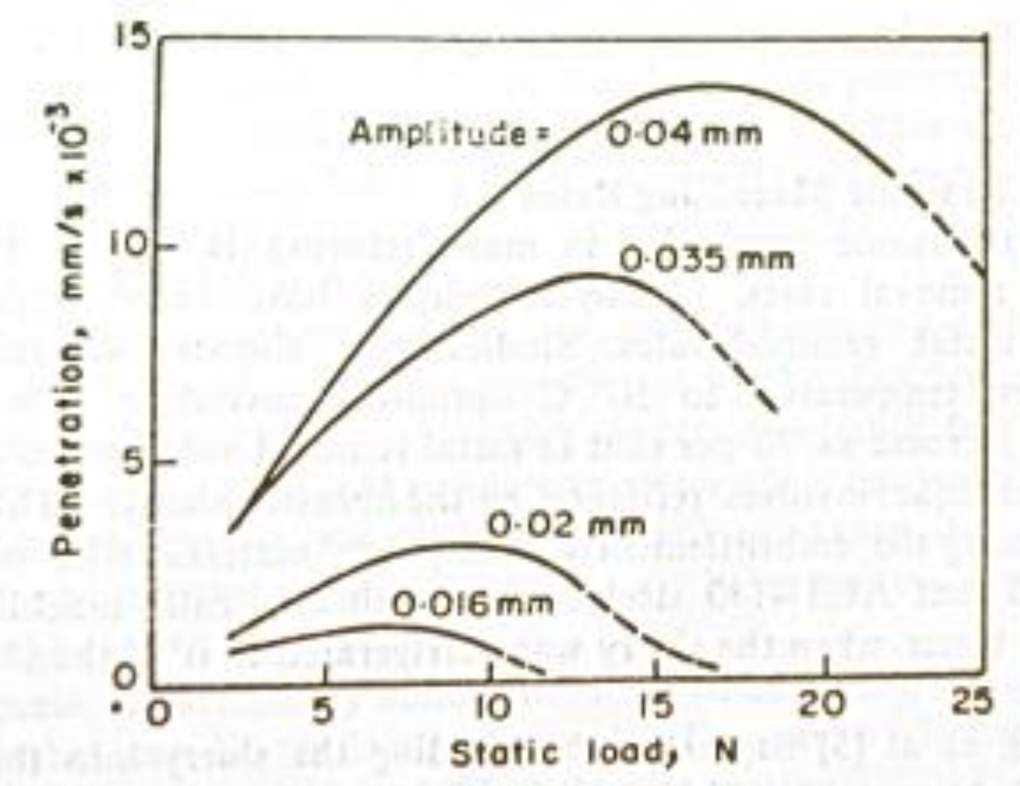
The frequency & amplitude of vibrations ranges from 15-30kHz & 25-100µm respectively.



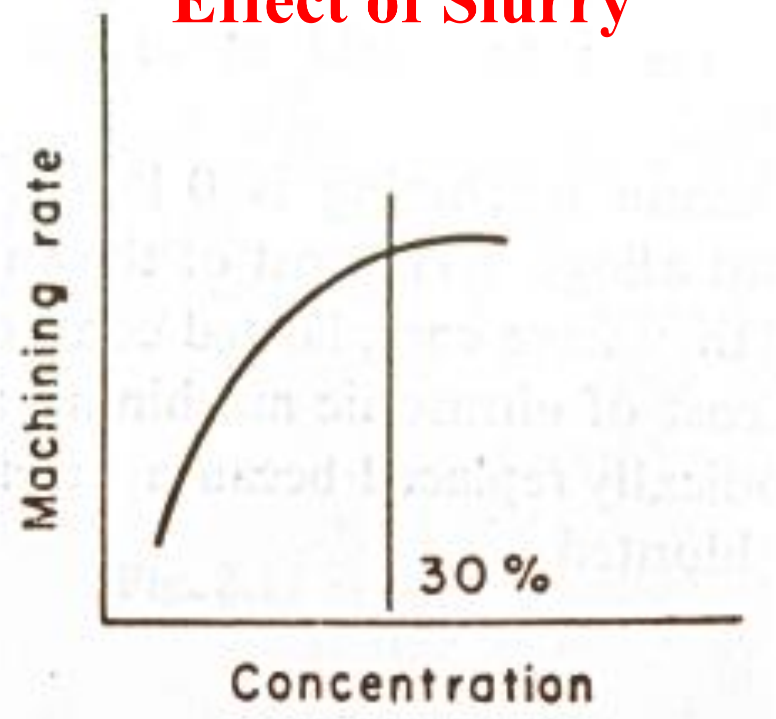
- The metal removal rate or cutting rate increases with increase in both amplitude & vibration of the tool.
- The cutting rate increases linearly with an increase in both amplitude and frequency.
- However, increasing the amplitude tends to increase the surface roughness, but the effect is minimal.

Effect of Applied Static Load

- Static load is the load or force with which the abrasive particles are initially kept pressed against the workpiece by the tool force before they are accelerated to strike against the w/p during a vibration cycle.
- The machining rate reaches a maximum as the static load on the tool is increased.
- The surface finish is found to be little affected by the applied static load .
- It is observed that higher loads, do not give a rougher finish, In fact surface finish is improved because the grains are crushed to small size with higher loads



Effect of Slurry



- Cutting rate can be increased with an increase in slurry concentration.
- It is found that a sharp drop in material removal rate with increasing viscosity.
- The pressure with which slurry is fed into the cutting zone has a remarkable effect on the material removal rate.

Effect of Tool

- The shape of the tool face also affects the cutting rate.
- A narrow rectangular tool gives a greater maximum cutting rate than a tool of the same area with a square cross section.
- A rise in cutting rate by 50% is seen by replacing a cylindrical tool with a conical cone.

Effect of Work Material

- Since the cutting forces involved in USM are not large, no mechanical stresses are set up in the work material.
- The microstructure of work material is not affected as the temperature generated at the cutting area is not that high.
- But if the flow of abrasive slurry is impaired then work material may not finished effectively

Process Characteristics of Ultrasonic machining

Process capability

1. USM can Machine work piece harder than 40 HRC to 60 HRC like carbides, ceramics, tungsten glass that cannot be machined by conventional methods
2. Tolerance range 7 micron to 25 microns
3. Holes up to 76 micron have been drilled hole depth upto 51mm have been achieved easily. Hole depth of 152mm deep is achieved by special flushing techniques.
4. Aspect ratio 40:1 has been achieved
5. Linear material removal rate - 0.025 to 25mm/min
6. Surface finish - 0.25 micron to 0.75 micron
7. Non directional surface texture is possible compared to conventional grinding
8. Radial over cut may be as low as 1.5 to 4 times the mean abrasive grain size.

Process Characteristics of Ultrasonic machining

Characteristics of USM:

Mechanics of material removal	Brittle fracture caused by impact of abrasive grains due to tool vibrating at high frequency
Medium	Slurry
Abrasives	B_4C, SiC, Al_2O_3, diamond 100–800 grit size
Vibration	
Frequency	15–30 kHz
Amplitude	25–100 μm
Tool	
Material	Soft steel
$\frac{\text{Material removal rate}}{\text{Tool wear rate}}$	1.5 for WC workpiece, 100 for glass workpiece
Gap	25–40 μm
Critical parameters	Frequency, amplitude, tool material, grit size, abrasive material, feed force, slurry concentration, slurry viscosity
Materials application	Metals and alloys (particularly hard and brittle), semiconductors, nonmetals, e.g., glass and ceramics
Shape application	Round and irregular holes, impressions
Limitations	Very low mrr, tool wear, depth of holes and cavities small

Advantages of Ultrasonic machining

- Machining any materials regardless of their conductivity
- USM apply to machining semi-conductor such as silicon, germanium etc.
- USM is suitable to precise machining brittle material.
- USM does not produce electric, thermal, chemical abnormal surface.
- USM can drill circular or non-circular holes in very hard materials
- Less stress because of its non-thermal characteristics

Limitations of Ultrasonic machining

- USM has low material removal rate. (3-15mm3/min)
- Tool wears fast in USM.
- Machining area and depth is restraint in USM

Applications of Ultrasonic machining

- Hard, brittle work materials such as ceramics, glass, and carbides
- Also successful on certain metals, such as stainless steel and titanium
- Shapes include non-round holes, holes along a curved axis
- "Coining operations" - pattern on tool is imparted to a flat work surface

Applications of Ultrasonic machining

1. Machining of cavities in electrically non-conductive ceramics

2. Used to machine fragile components in which otherwise the scrap rate is high

3. Used for multistep processing for fabricating silicon nitride (Si_3N_4) turbine blades

4. Large number of holes of small diameter. 930 holes with 0.32mm has been reported (Benedict, 1973) using hypodermic needles

5. Used for machining hard, brittle metallic alloys, semiconductors, glass, ceramics, carbides etc.

6. Used for machining round, square, irregular shaped holes and surface impressions.

7. Used in machining of dies for wire drawing, punching and blanking operations

Applications of Ultrasonic machining

8. USM can perform machining operations like drilling, grinding and milling operations on all materials which can be treated suitably with abrasives.

9. USM has been used for piercing of dies and for parting off and blanking operations.

10. USM enables a dentist to drill a hole of any shape on teeth without any pain

11. Ferrites and steel parts , precision mineral stones can be machined using USM

12. USM can be used to cut industrial diamonds

13. USM is used for grinding Quartz, Glass, ceramics

14. Cutting holes with curved or spiral centre lines and cutting threads in glass and mineral or metallic-ceramics

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Abrasive Jet Machining (AJM)

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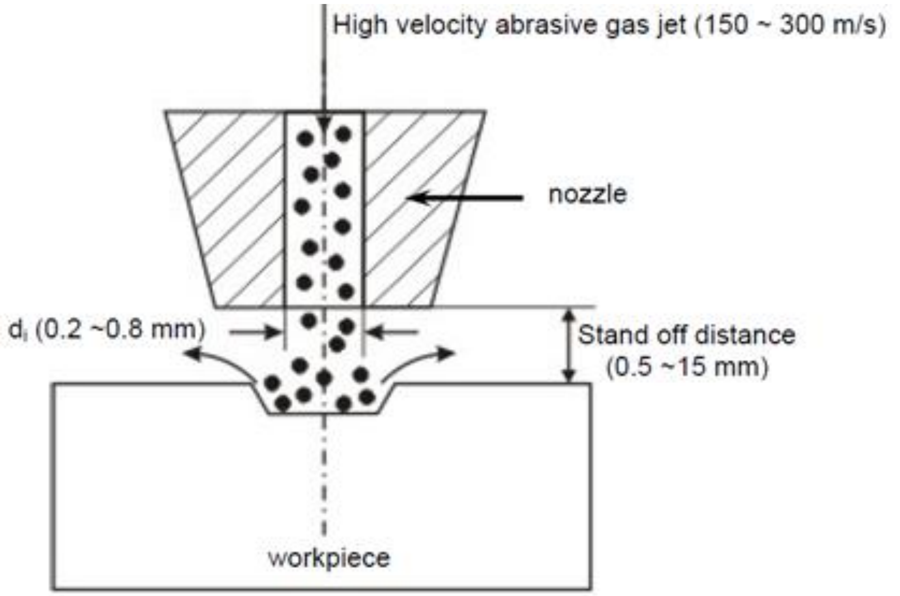
Abrasive Jet machining

DEFINITION:

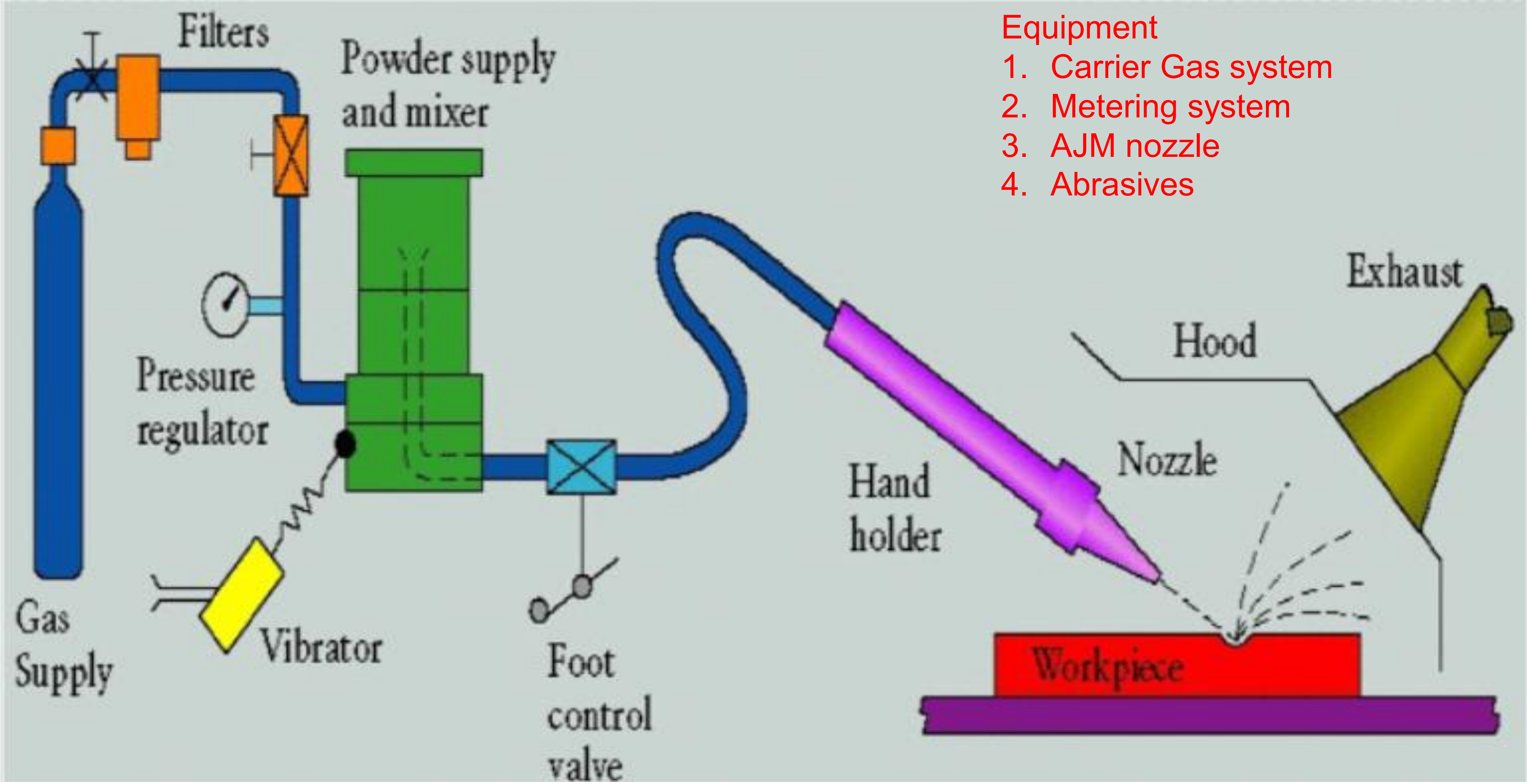
- It is the material removal process where the material is removed by high velocity stream of air/gas or water and abrasive mixture
- A focused stream of the abrasive particles, carried by high pressure air or gas is made to impinge on the work surface through a nozzle and work material is removed by erosion by high velocity abrasive particles.



AJM

Equipment of Abrasive Jet machining

Equipment
1. Carrier Gas system
2. Metering system
3. AJM nozzle
4. Abrasives



Equipment of Abrasive Jet machining

Equipment consists of following Main Parts

1. Nozzle
2. Abrasive
3. Carrier gas
4. Metering system.

a) Nozzle

- A nozzle is used to accelerate the abrasive particles onto the worksurface.
- Since the abrasive particles leave the nozzle at a very high velocity, it is subjected to abrasion wear.
- The nozzle is made from a hard material like tungsten carbide or synthetic sapphire.

b) Abrasive

ABRASIVES	GRAIN SIZE	APPLICATION
Aluminium oxide	12/20/50 microns	Cleaning, cutting and deburring (for brass and aluminium)
Silicon carbide	25,40 micron	For hard material (for SS and ceramics)
Glass beads	0.635 to 1.27mm	Light polishing and fine deburring
Dolomite	200 mesh/ 66 microns	Etching and polishing
Sodium Carbonate	27 microns	Light finish below 50'C (for nylon and tylon)

- Aluminum oxide and silicon carbide are the commonly used abrasives
- The size of the abrasive particle ranges from 10-50 µm
- Smaller size abrasives are used for polishing and cleaning, while the larger ones used for cutting and peening operations.
- It should have excellent flow characteristics.
- Re-use of abrasives is not recommended, since the cutting capacity decreases after the first application, and also the chips from the workpiece material combine with abrasives and clog the small orifice in the nozzle.
- The mass flow rate of the abrasive particles depends on the pressure and the flow rate of the gas.
- Apart from machining, there are certain abrasives like sodium bicarbonate, dolomite, glass etc., used for cleaning, etching, deburring, and polishing operations.

C) Carrier gas

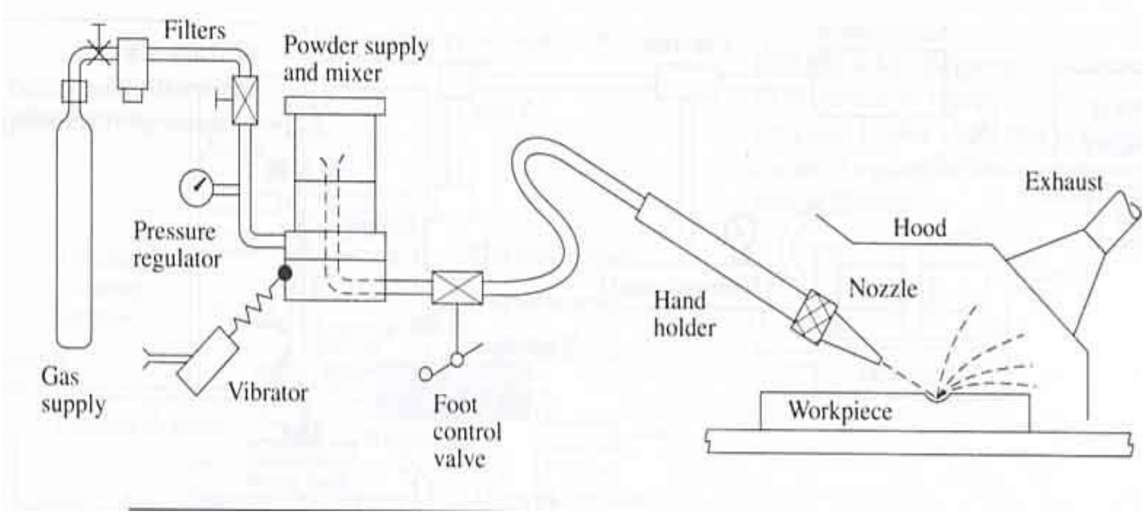
- Air, nitrogen or carbon dioxide is generally used as a carrier gas.
- Air, when used must be to remove moisture, oil and other contaminants before entering the nozzle.
- The pressure required is in the range of 2 - 8 kg/cm^2.
- Higher pressure leads to nozzle wear, while lower pressure low metal removal rate.

D) Metering system

- The metering system includes mixing chamber, regulator, valves and other devices.
- The system must inject an uniform, adjustable flow of abrasive particles into the gas stream.
- The amplitude of vibration of the chamber controls the uniform metering of the powder.

Principle of Abrasive Jet machining
(Mechanism of Material Removal)

- Abrasive particles are made to impinge on work material at high velocity.
- Abrasive particles is carried out by carrier gas/air.
- High velocity stream of the abrasives is generated by converting pressure energy of carrier gas or air to its kinetic energy and hence high velocity jet.



- Nozzles directs the abrasive jet in a controlled manner onto workpiece.
- Metal cutting action by micro-cutting as well as the brittle fracture of the work material.
- Different from conventional sand blasting/shot blasting, finer abrasive grits are used and process or machining parameters are easily controllable.

Process Parameters of Abrasive Jet machining

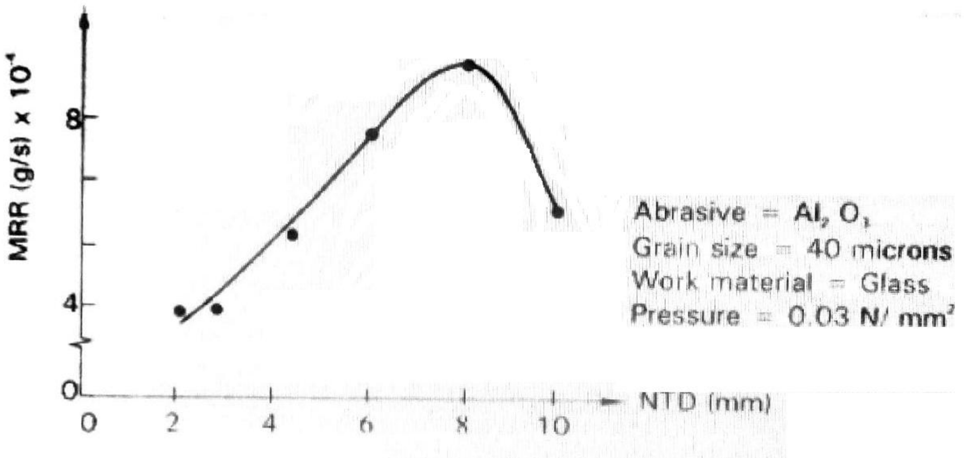
Variables of Abrasive Jet machining:

- Abrasive flow rate
- Nozzle Tip Distance (NTD) or Stand Off Distance (SOD)
- Abrasive Grain Size
- Mean Number of Abrasive Particles per Unit Volume of the Carrier Gas
- Nozzle Design

Process Parameters of Abrasive Jet machining

1) Abrasive flow rate velocity:

- Increase in the flow rate of abrasives, increases the metal removal rate, because more abrasive particles are available for cutting.
- However, when the flow rate exceeds 14 g/min, the abrasive velocity decreases, thereby reducing the metal removal rate.
- For the erosion of the worksurface by the abrasives, the minimum jet velocity is found to be 150 m/sec.
- The jet velocity is a function of the nozzle pressure, nozzle design, abrasive grain size, and the mean number of abrasives per unit volume of the carrier gas.

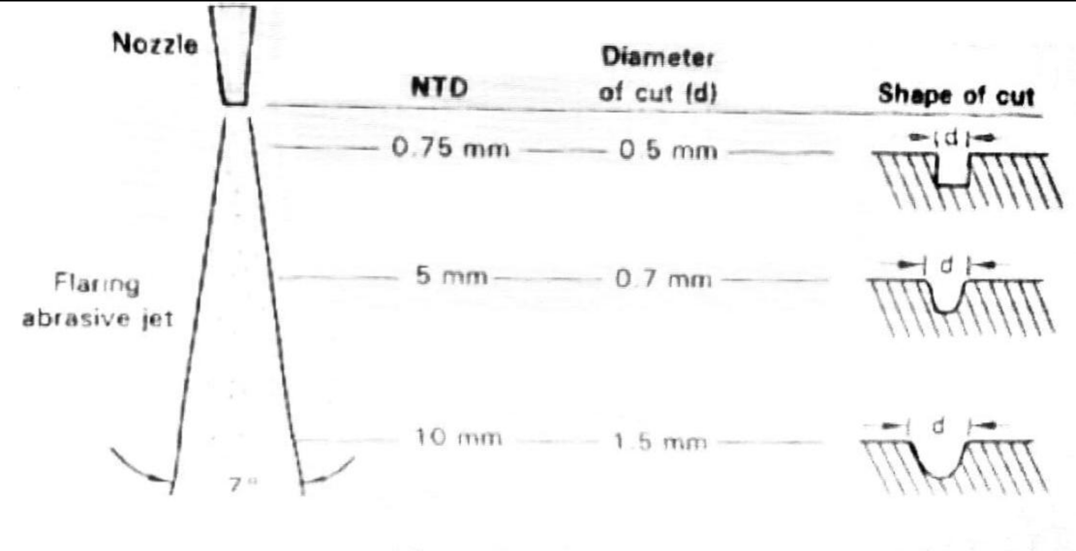


Effect of NTD on MRR

Process Parameters of Abrasive Jet machining

2) Nozzle Tip Distance (NTD) or Stand Off Distance (SOD)

- The nozzle tip distance refers to the distance between the tip of the nozzle and the worksurface.
- The increase in MRR is maximum up to a distance of about 8 mm; beyond this range, the metal removal rate decreases due to increase in machining area for the same amount of abrasives and decrease in velocity of abrasive particle stream due to drag.
- A large NTD leads to poor accuracy of the machined surface.



Effect of NTD on machining accuracy

Process Parameters of Abrasive Jet machining

3) Abrasive Grain Size

- The size of the abrasive grain ranges from 10–50 µm.
- An abrasive with larger particle size removes material faster from the worksurface than with the small particle sizes.
- Coarse grains are recommended for cutting, while fine grain abrasives for polishing, deburring, etc.

Process Parameters of Abrasive Jet machining

4) Mean Number of Abrasive Particles per Unit Volume of the Carrier Gas

- The mean number of abrasive particles per unit volume of the carrier gas can be obtained from the mixing ratio M, which is defined as, volume flow rate of the abrasive per unit time volume flow rate of the carrier gas per unit time.
- A large value of M should result in higher rates of metal removal
- However a large abrasive flow rate has been found to adversely influence jet velocity and may sometimes even clog the nozzle.
- Thus for a given condition, there is an optimum value of that gives maximum metal removal rate

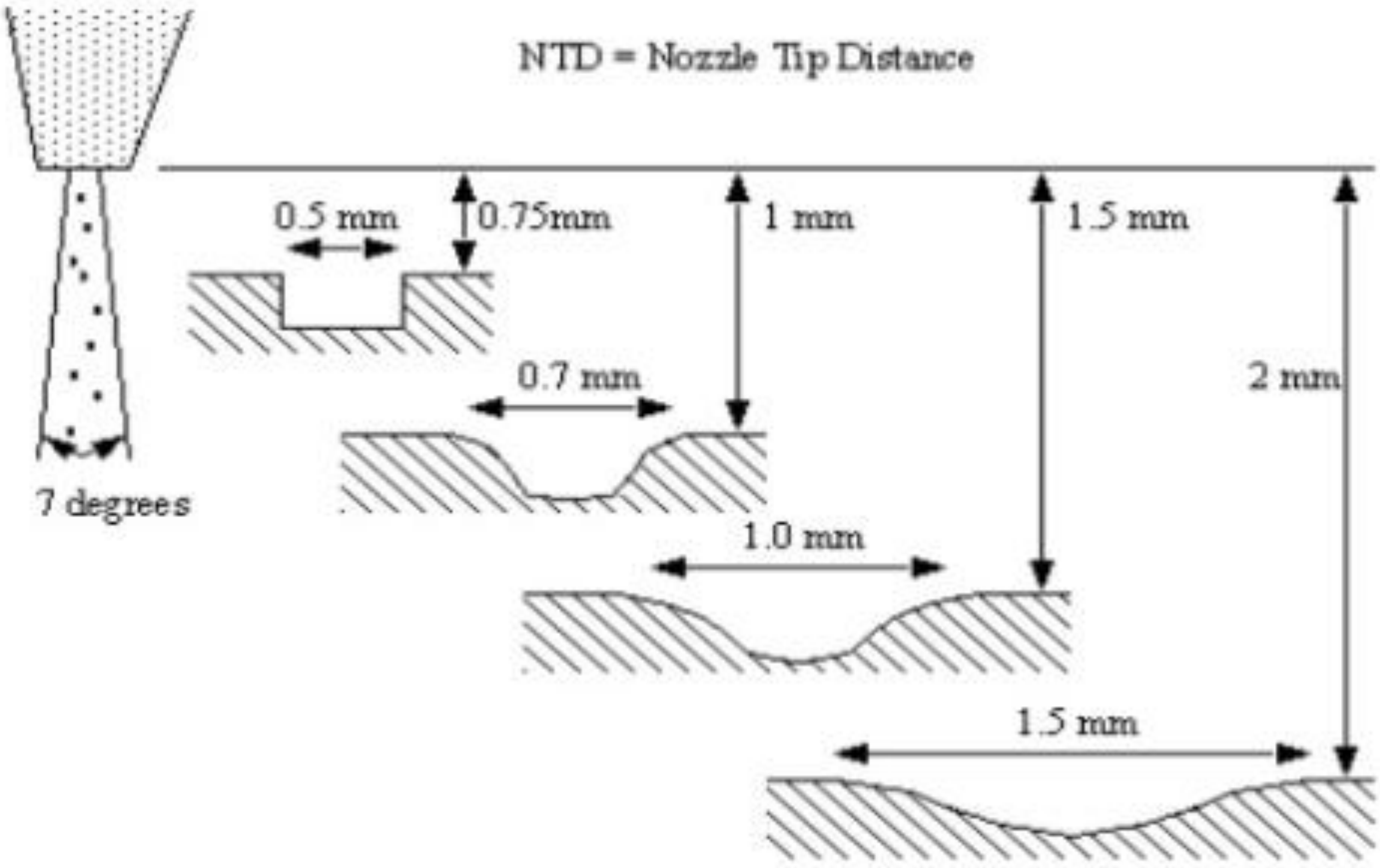
$$M = \frac{\text{volume flow rate of the abrasive per unit time}}{\text{volume flow rate of the carrier gas per unit time}}$$

Process Parameters of Abrasive Jet machining

5) Nozzle Design

- The abrasive particles leave the nozzle at a very high velocity. Thus, it is subjected to abrasion wear.
- To overcome this effect, wear resistant materials like tungsten carbide, sapphire, etc, are used for manufacturing nozzles.
- Further, the nozzle should be carefully designed so that the pressure loss due to bends, friction, etc., is minimum
- Nozzles may be either circular or rectangular in cross section with suitable dimensions

Effect of Stand of Distance (SOD/NTD)



Process Parameters of Abrasive Jet machining

Abrasives

a) Material – Al_2O_3; SiC; glass beads.
b) Shape – irregular/regular
c) Size – 10 to 50 microns
d) Mass flow – 2-20 gm/min

Carrier Gas

a) Composition – Air, CO_2, N_2
b) Density – 1.3 kg/m_3
c) Velocity - 500 to 700 m/s
d) Pressure - 2 to 10 bar
e) Flow rate - 5 to 30 microns

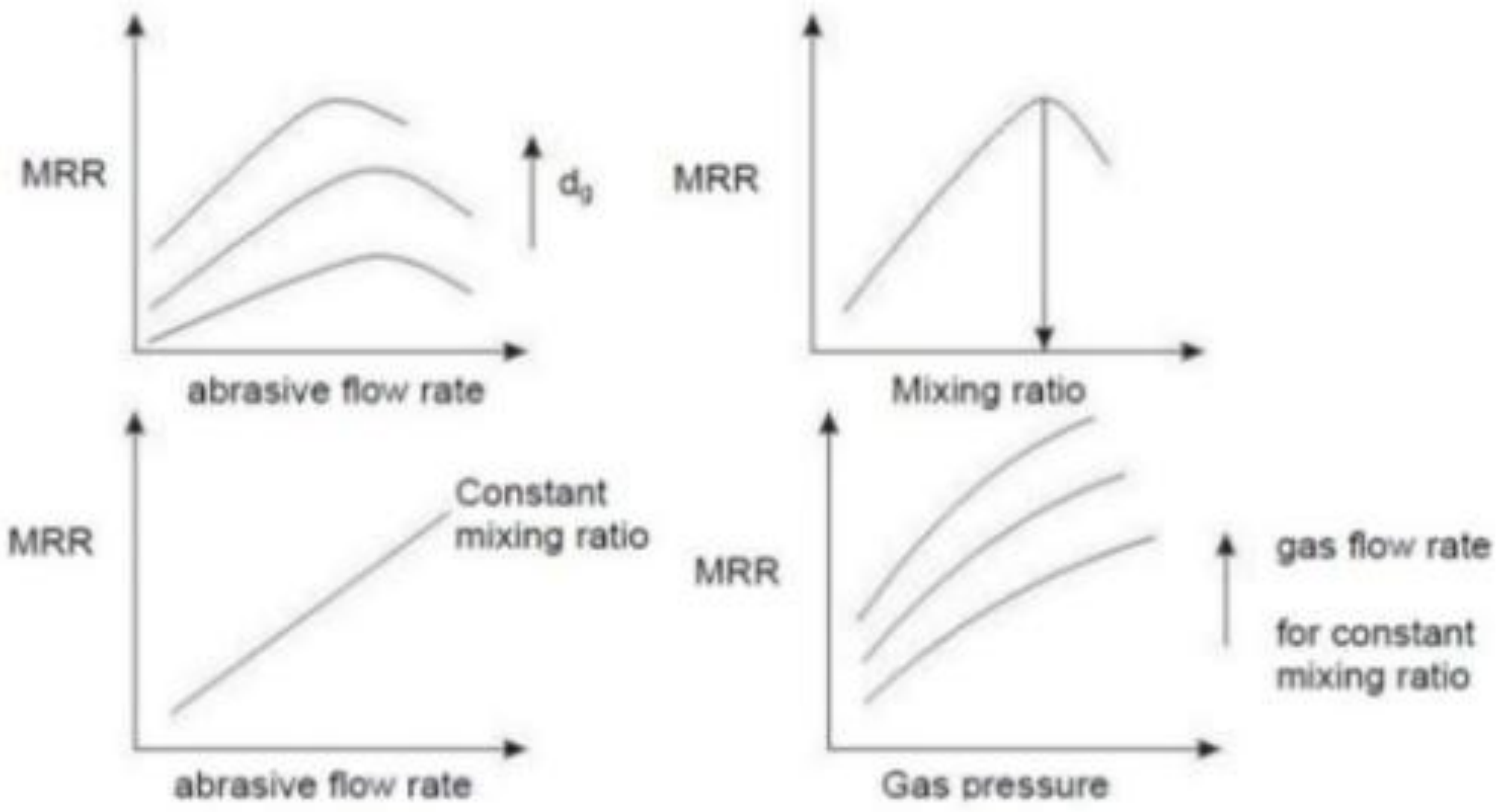
Abrasive Jet

a) Velocity - 100 to 300 m/s
b) Stand off distance (SOD)– 0.5 to 15mm.
c) Impingement angle – 60 to 90 deg.

Nozzle

a) Material – WC/Sapphire
b) Diameter – 0.2 to 0.8 mm
c) Life – 300 hours for sapphire, 20 to 30 hours for WC

Effect of process parameters on MRR



Process Capability of Abrasive Jet machining

- Material removal rate – 0.015 cm^3/min
- Narrow slots – 0.12 to 0.25mm ± 0.12mm
- Surface finish - 0.25 micron to 1.25 micron
- Sharp radius up to 0.2mm is possible
- It is possible to cut Steel upto 1.5mm, Glass upto 6.3mm
- Machining of thin sectioned hard and brittle materials is possible.

Advantages of AJM

- Low capital cost.
- Less vibration.
- Good for difficult to reach area.
- No heat is generated in work piece.
- Ability to cut intricate holes of any hardness and brittleness in the material.
- Ability to cut fragile, brittle hard and heat sensitive material without damage

Disadvantages of AJM

- Low metal removal rate.
- Due to stray, cutting accuracy is affected.
- Particles is imbedding in work piece and Abrasive powder cannot be reused.

Applications of Abrasive Jet machining

- Abrading/frosting of glass
- Cleaning of metallic smears on ceramics, oxides on metals , resistive coating etc.
- Manufacture of electronic device, drilling of glass wafers, deburring of plastics, making of nylon and Teflon parts, permanent marking on rubber utensils etc.
- Engraving registration numbers on toughened glass used for car windows.
- For cutting thin fragile components- Germanium/silicon etc.
- For drilling, cutting, deburring, etching and polishing of hard and brittle materials.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Water Jet Machining (WJM)

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Water Jet Machining (WJM)

INTRODUCTION

- Key element in WJM is a jet of water.
- Water jet travels at velocities as high as 900 m/s (approximately Mach 3).
- When the water stream strikes a work piece surface, the erosive force of water removes the material rapidly.

- The water, in this case, acts like a saw and cuts a narrow groove in the work piece material.
- True cold cutting process – no HAZ (Heat Affected Zones), mechanical stresses or operator and environmental hazards

Principle of Water Jet machining

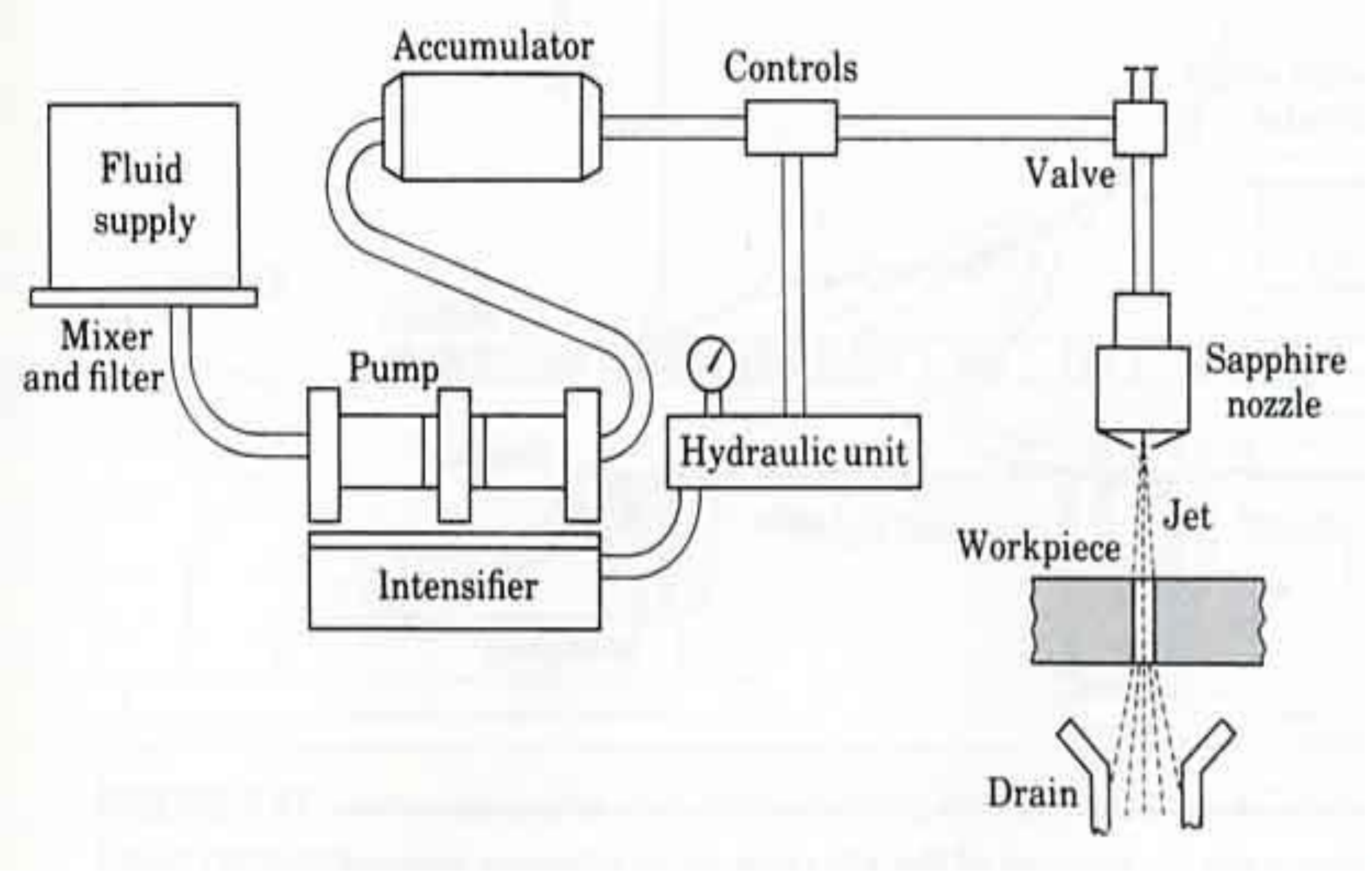
- The water jet machining involves directing a high pressure (150-1000 MPa) high velocity (540-1400 m/s) water jet (faster than the speed of sound) to the surface to be machined. The fluid flow rate is typically from 0.5 to 2.5 ltr/min
- The kinetic energy of water jet after striking the work surface is reduced to zero.
- The bulk of kinetic energy of jet is converted into pressure energy.
- If the local pressure caused by the water jet exceeds the strength of the surface being machined, the material from the surface gets eroded and a cavity is thus formed.
- Water is the most common fluid used, but additives such as alcohols, oil products and glycerol are added when they can be dissolved in water to improve the fluid characteristics.

Equipment of Water Jet machining

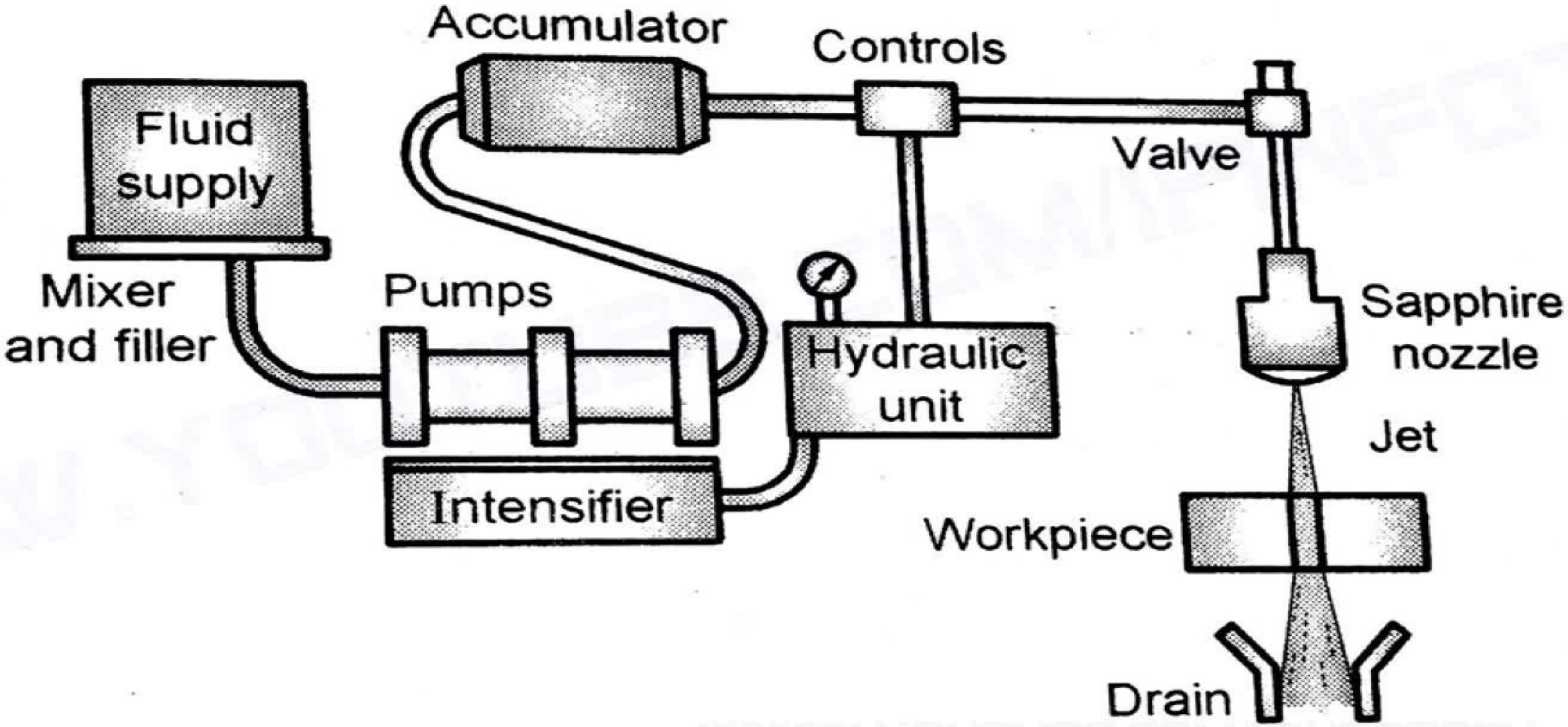
Typical work materials involve soft metals, paper, cloth, wood, leather, rubber, plastics, and frozen food. If the work material is brittle it will fracture, if it is ductile, it will cut well .

Water jet Machining consists of:

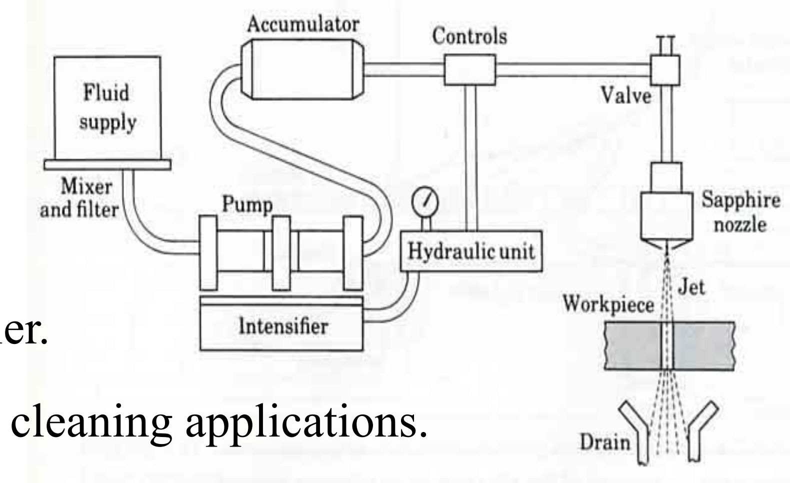
1. Hydraulic Pump
2. Accumulator
3. Intensifier
4. High Pressure Tubing
5. Catcher
6. Jet Cutting Nozzle



Water Jet Machining



Equipment of Water Jet machining



1. HYDRAULIC PUMP

- Powered from a 30 kilowatt (kW) electric motor
- Supplies oil at pressures as high as 117 bars.
- Compressed oil drives a reciprocating plunger pump termed an intensifier.
- The hydraulic pump offers complete flexibility for water jet cutting and cleaning applications.
- It also supports single or multiple cutting stations for increased machining productivity.

2. ACCUMULATOR

- Maintains the continuous flow of the high-pressure water and eliminates pressure fluctuations.
- It relies on the compressibility of water (12 percent at 3800 bar) in order to maintain a uniform discharge pressure and water jet velocity, when the intensifier piston changes its direction.

Equipment of Water Jet machining

3. ITENSIFIER

- Accepts the water at low pressure(typically 4 bar) and expels it, through an accumulator, at higher pressures of 3800 bar.
- The intensifier converts the energy from the low-pressure hydraulic fluid into ultrahigh- pressure water.
- The hydraulic system provides fluid power to a reciprocating piston in the intensifier center section.
- A limit switch, located at each end of the piston travel, signals the electronic controls to shift the directional control valve and reverses the piston direction.
- The intensifier assembly, with a plunger on each side of the piston, generates pressure in both directions.
- As one side of the intensifier is in the inlet stroke, the opposite side is generating ultrahigh-pressure output.
- During the plunger inlet stroke, filtered water enters the high-pressure cylinder through the check value assembly.
- After the plunger reverses direction, the water is compressed and exits at ultrahigh pressure.

Equipment of Water Jet machining

4. HIGH PRESSURE TUBING

- Transports pressurized water to the cutting head.
- Typical tube diameters are 6 to 14 mm.
- The equipment allows for flexible movement of the cutting head.
- The cutting action is controlled either manually or through a remote- control valve specially designed for this purpose.

5. CATCHER

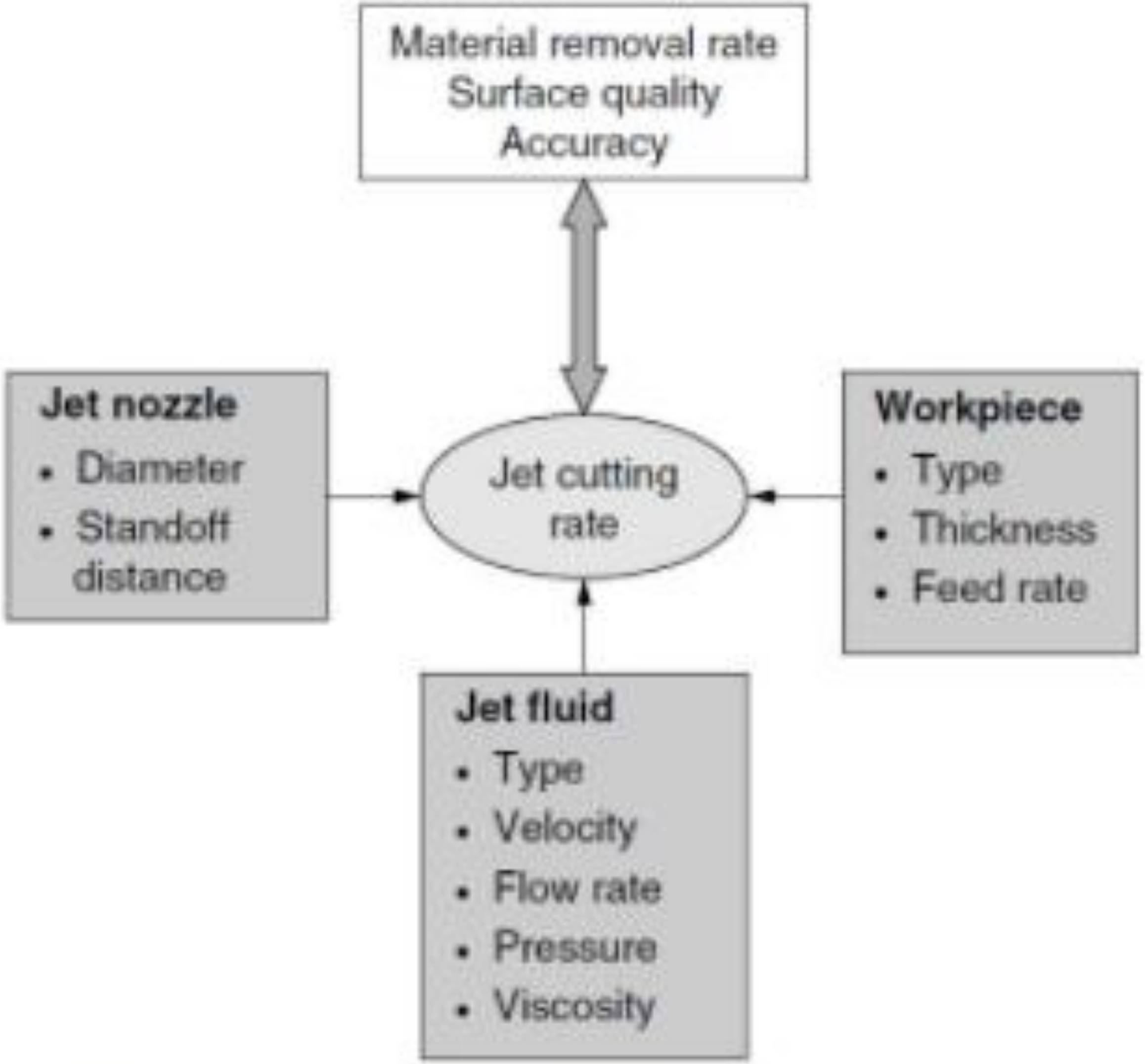
- Acts as a reservoir for collecting the machining debris entrained in the water jet.
- Moreover, it reduces the noise levels [105 decibels (dB)] associated with the reduction in the velocity of the water jet from Mach 3 to subsonic levels.

Equipment of Water Jet machining

6. JET CUTTING NOZZLE

- Nozzle provides a coherent water jet stream for optimum cutting of low- density, soft material that is considered unmachinable by conventional methods.
- Nozzles are normally made from synthetic sapphire.
- About 200 h of operation are expected from a nozzle, which becomes damaged by particles of dirt and the accumulation of mineral deposits on the orifice due to erosive water hardness.
- A longer nozzle life can be obtained through multistage filtration, which removes undesired solids of size greater than 0.45 μm.
- The compact design of the water jet cutting head promotes integration with motion control systems ranging from two-axis (XY) tables to sophisticated multiaxis robotic installations.

Process Parameters of Water Jet machining

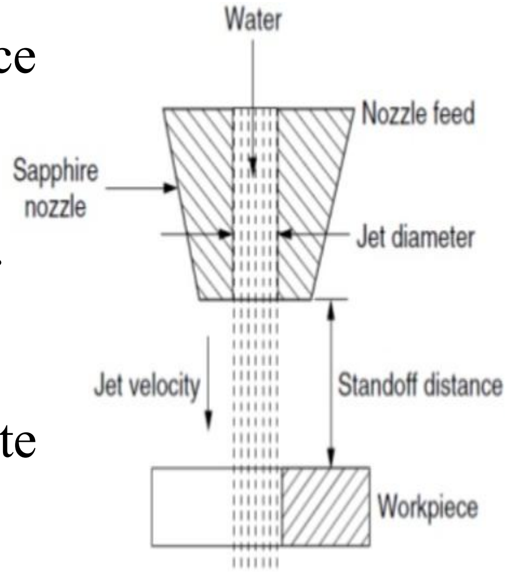


Process Parameters of Water Jet machining

1. Jet Nozzle
2. Jet Fluid
3. Work Piece

1. JET NOZZLE

1. Standoff distance - Gap between the jet nozzle (0.1–0.3 mm diameter) and the workpiece (2.5 – 6 mm).
2. However for materials used in printed circuit boards, it may be increased to 13 to 19 mm.
3. But larger the standoff distance, smaller would be the depth of cut.
4. When cutting fiber-reinforced plastics, reports showed that the increase in machining rate and use of the small nozzle diameter increased the width of the damaged layer



Process Parameters of Water Jet machining

2. JET FLUID

- Typical pressures used are 150 to 1000 MPa to provide 8 to 80 kW of power.
- For a given nozzle diameter, increase in pressure allows more power to be used in the machining process, which in turn increases the depth of the cut.
- Jet velocities range between 540 to 1400 m/s.
- The quality of cutting improves at higher pressures by widening the diameter of the jet and by lowering the traverse speed.
- Under such conditions, materials of greater thicknesses and densities can be cut.
- Moreover, the larger the pump pressure, the greater will be the depth of the cut.
- The fluid used must possess low viscosity to minimize the energy losses and be noncorrosive, nontoxic, common, and inexpensive.

Process Parameters of Water Jet machining

3. Workpiece

- Brittle materials will fracture, while ductile ones will cut well.
- Material thicknesses range from 0.8 to 25 mm or more.
- Table below shows the cutting rates for different material thicknesses

Material	Thickness, mm	Feed rate, m/min
Leather	2.2	20
Vinyl chloride	3.0	0.5
Polyester	2.0	150
Kevlar	3.0	3
Graphite	2.3	5
Gypsum board	10	6
Corrugated board	7	200
Pulp sheet	2	120
Plywood	6	1

Advantages of Water Jet machining

- It has multidirectional cutting capacity.
- No heat is produced.
- Cuts can be started at any location without the need for predrilled holes.
- Wetting of the workpiece material is minimal.
- There is no deflection to the rest of the workpiece.
- The burr produced is minimal.
- The tool does not wear and, therefore, does not need sharpening.
- The process is environmentally safe.
- Hazardous airborne dust contamination and waste disposal problems that are common when using other cleaning methods are eliminated.
- There is multiple head processing.
- Simple fixturing eliminates costly and complicated tooling, which reduces turnaround time and lowers the cost.
- Grinding and polishing are eliminated, reducing secondary operation costs.

Limitations of Water Jet machining

- The narrow kerf allows tight nesting when multiple parts are cut from a single blank.
- It is ideal for roughing out material for near net shape.
- It is ideal for laser reflective materials such as copper and aluminum.
- It allows for more accurate cutting of soft material.
- It cuts through very thick material upto 383 mm in titanium.
- Very thick parts can not be cut with water jet cutting and still hold dimensional accuracy. If the part is too thick, the jet may dissipate some, and cause it to cut on a diagonal, or to have a wider cut at the bottom of the part than the top. It can also cause a rough wave pattern on the cut surface.
- It is not suitable for mass production because of high maintenance requirements.

Applications of Water Jet machining

- WJM is used on metals, paper, cloth, leather, rubber, plastics, food, and ceramics.
- It is a versatile and cost-effective cutting process that can be used as an alternative to traditional machining methods.
- It completely eliminates heat-affected zones, toxic fumes, recast layers, work hardening and thermal stresses.
- It is the most flexible and effective cleaning solution available for a variety of industrial needs.
- In general the cut surface has a sandblast appearance. Moreover, harder materials exhibit a better edge finish.
- Typical surface finishes ranges from 1.6 μm root mean square (RMS) to very coarse depending on the application.
- Tolerances are in the range of 25 μm on thin material. Both the produced surface roughness and tolerance depend on the machining speed.

Applications of Water Jet machining


Water