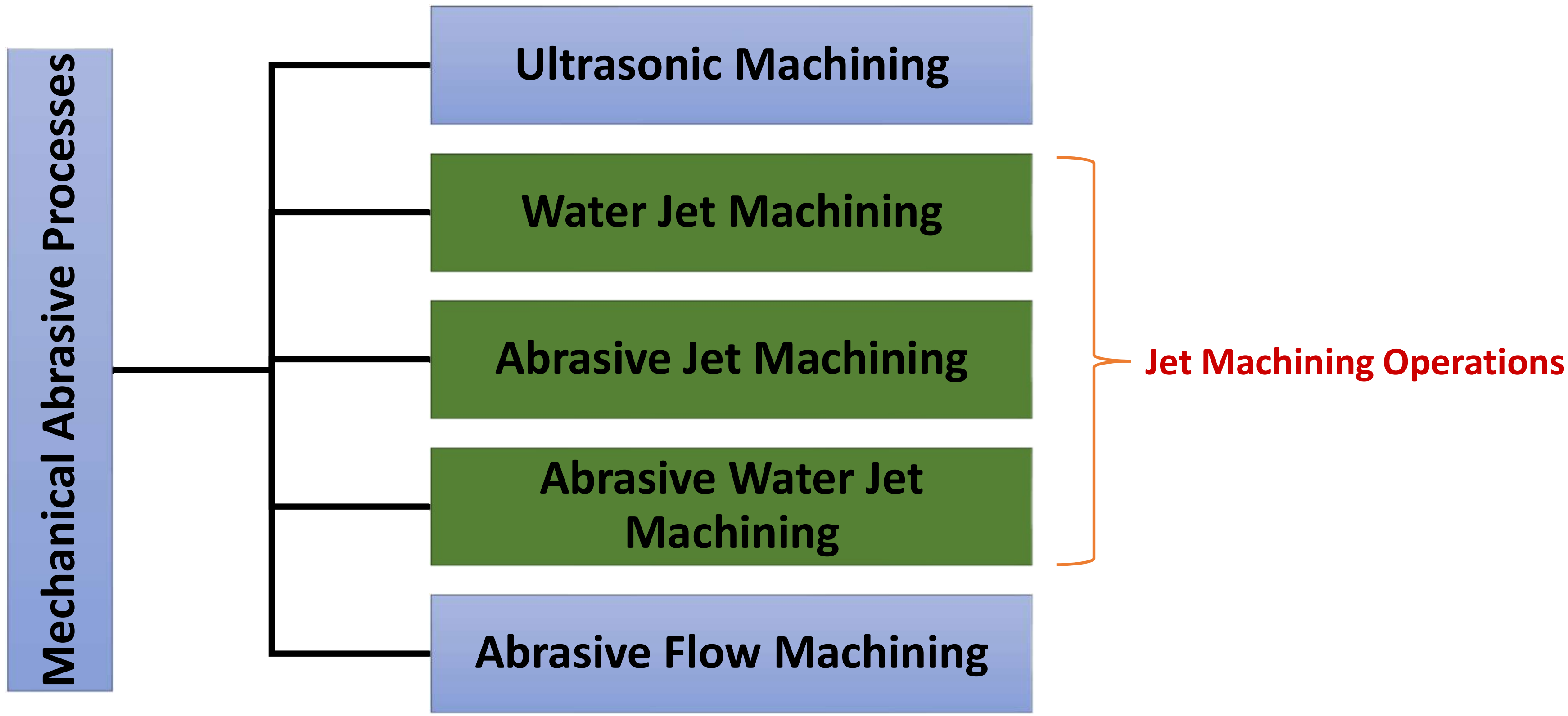
Jet Machining Operations

ME688: Advanced Machining Processes
Instructor: R K Mittal

Classification of Mechanical Abrasive Processes



Water Jet Machining (WJM)

- Removes material through the erosion effects of a high velocity, small diameter jet of water
- When the stream strikes a workpiece 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 workpiece material.

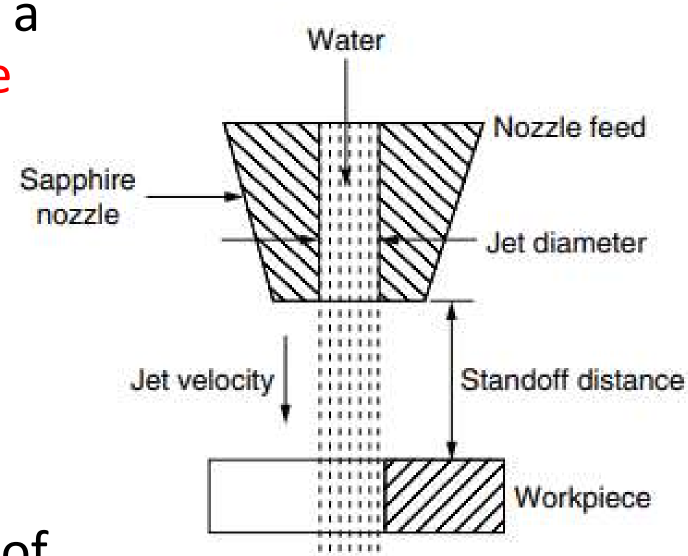


History

- The principle behind this method of cutting was first observed in the early 1900s by workers in steam plant
- No significant effort was made to apply this technology until the 1960s when Norman Franz patented the technique for producing a coherent, high-velocity stream of water
- This became the basis for today's WJM technology, was refined during the 1960s
- WJM was first introduced to industry as a new cutting tool in the early 1970s

Process Description

- Also known as Hydrodynamic Machining
- WJM is a form of micro erosion. It works by forcing a large volume of water through a small orifice in the nozzle.
- The key element in water jet machining (WJM) is a water jet, which travels at velocities as high as 900 m/s (approximately Mach 3).
- At the target, the kinetic energy of the jet is converted spontaneously to high-pressure energy, inducing high stresses exceeding the flow strength of target material, causing mechanical abrasion.

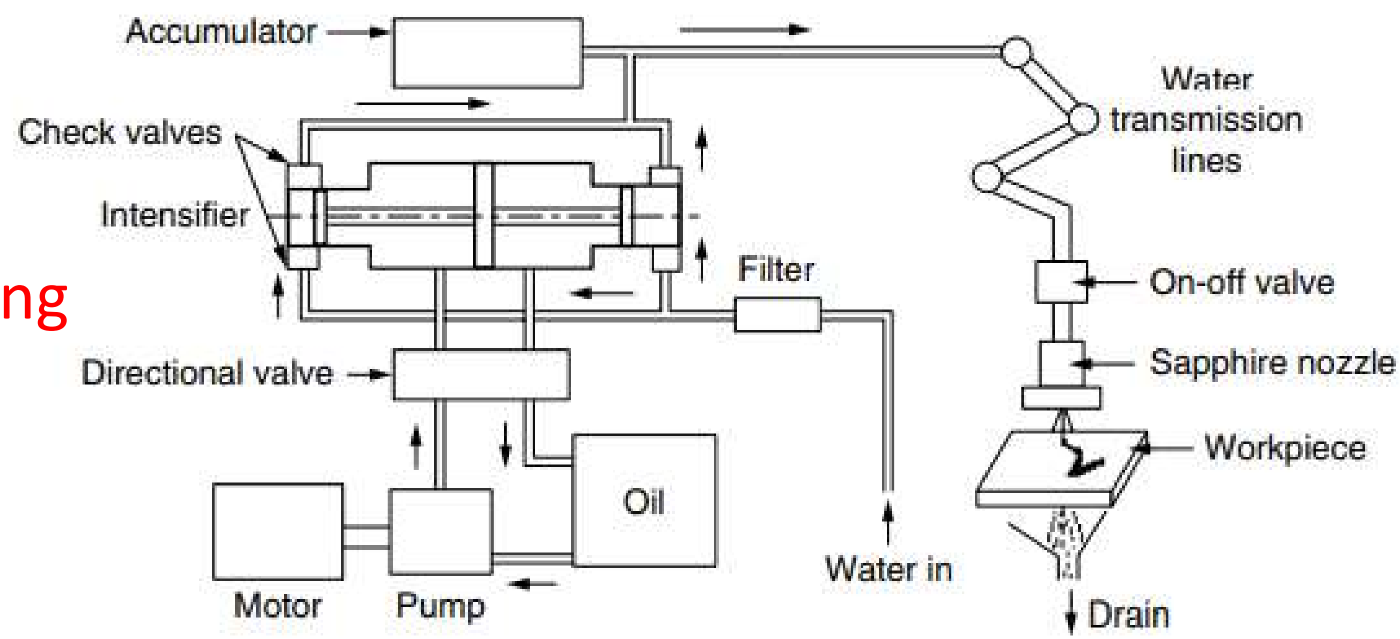


Process Description

- Water jet machining provides omnidirectional cutting capabilities at very high speeds with a resulting edge quality
- For machining softer materials such as plastics and fibers simple water jet machining is used.
- Unlike conventional processes, downtime for the replacement of worn or broken cutting tools is virtually nonexistent with WJM because the "tool" never dulls or breaks
- Additionally, the health hazards associated with cutting materials such as asbestos and fiberglass are minimized because almost no airborne dust is generated by this process

Machine Components

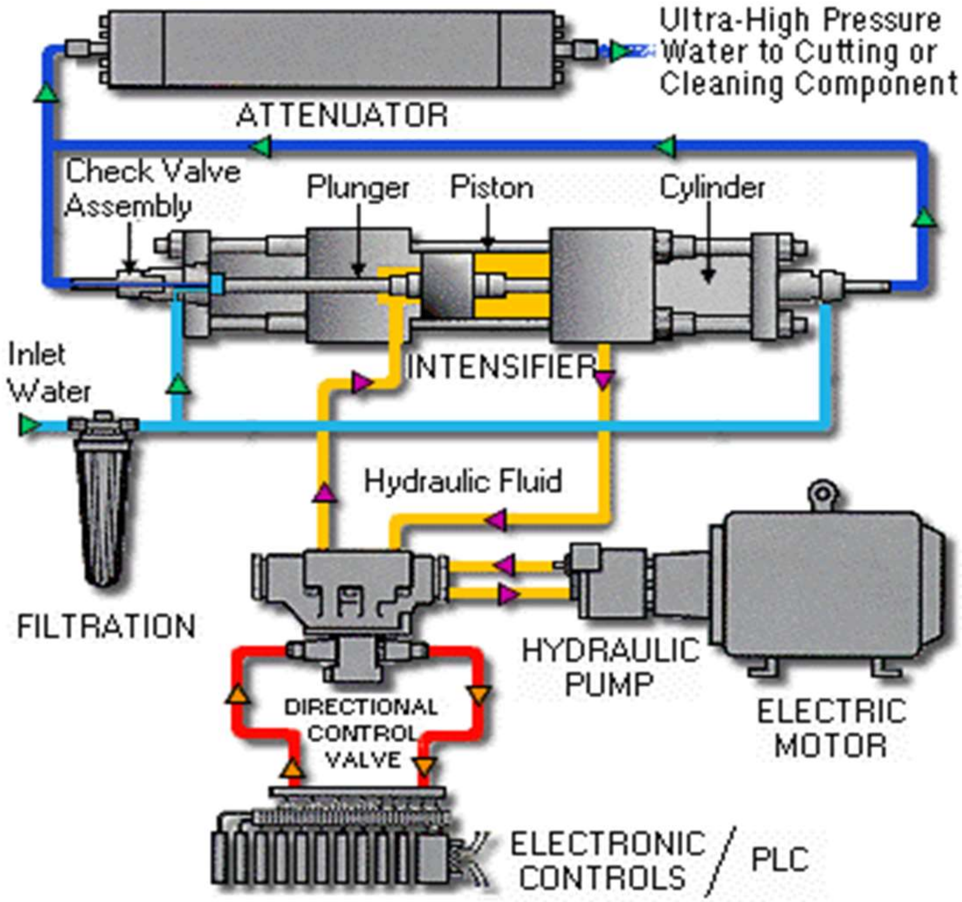
- Hydraulic Pump
- Intensifier
- Accumulator
- High Pressure Tubing
- Jet Cutting Nozzle
- Catcher



Hydraulic Pump

- Powered from a 15-37 kilowatt (kW) electric motor
- Supplies oil at pressures as high as 117 bars.
- Compressed oil drives a 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.

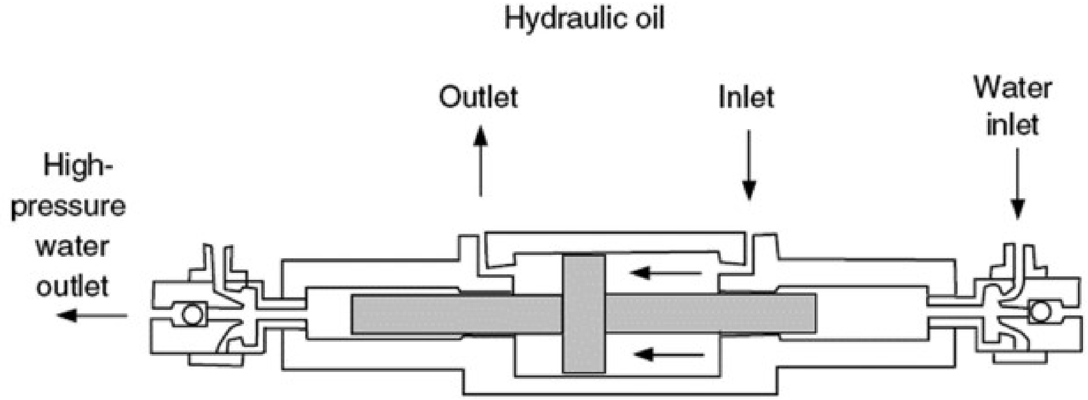
Working of WJM

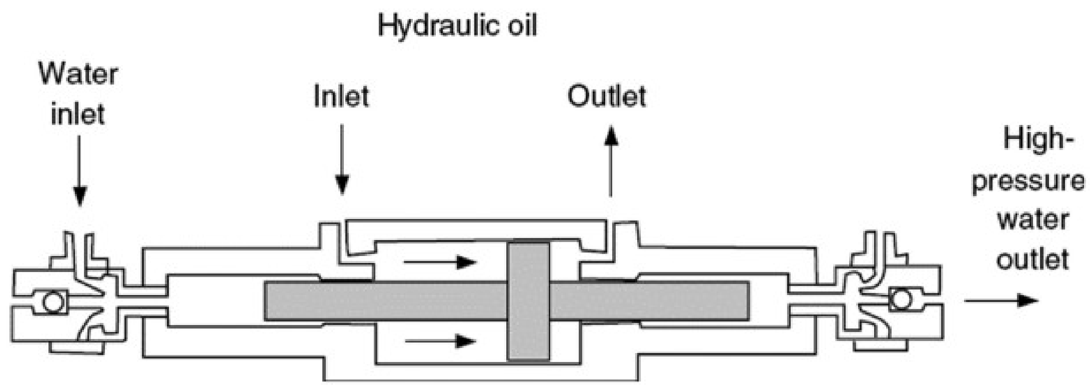


Intensifier

- The intensifier converts the energy from the low-pressure hydraulic fluid into ultrahigh-pressure water.
- The water directly supplied to the small cylinder of the intensifier at low pressure(typically 4 bar)
- It delivers water at higher pressures of 3800 bar through an accumulator
- The hydraulic system provides fluid power to 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.

Intensifier

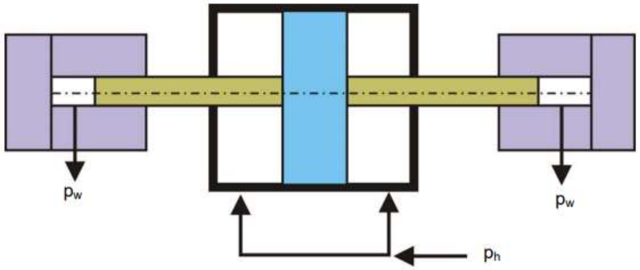




Intensifier

- 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.

$$p_h A_{large} = p_w A_{small}$$



Water pressure: $p_w = p_h \dfrac{A_{large}}{A_{small}}$

Accumulator

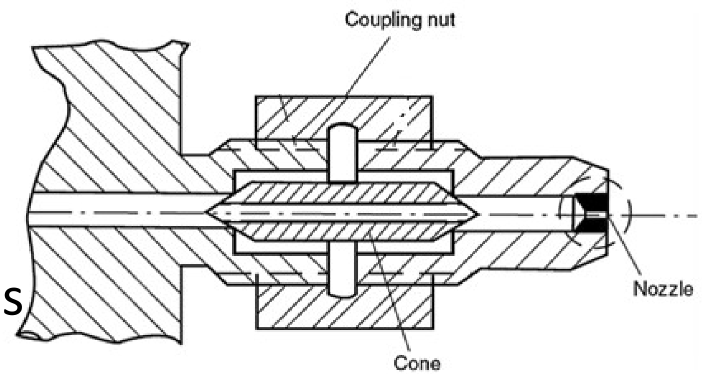
- Water compresses approximately 15% at the intensifier's output pressure causing reduced water flow at the beginning of each piston stroke.
- The accumulator is simply a pressure vessel that stores high-pressure water
- Avoids pulsations and maintains the continuous flow of the high-pressure water
- Eliminates pressure fluctuations and assures that the final output flow is smooth.
- Maintains output pressure variations of not more than ± 5%

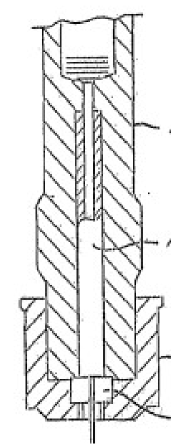
High Pressure Tubing

- Transports pressurized water to the cutting head.
- Typical tube diameters are 6 to 14 mm.
- Rigid tubing is used because no flexible tubing is currently manufactured that will handle pressures above 2000 bar
- 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.

Jet Cutting Nozzle

- The cutting nozzle converts the ultrahigh pressure (about 4000 bar) into a high speed of 400 to 1400 m/s
- Nozzle provides a coherent water jet stream for optimum cutting
- Nozzles are generally made from very hard materials such as WC, synthetic sapphire, or diamond
- Nozzle 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
- Nozzle hole diameters typically range from 0.07 to 0.5 mm and sometimes may be as large as 1.0 mm





Drain or Catcher

- Acts as a reservoir for collecting the machining debris entrained in the water jet.
- Absorbs the rest energy after cutting which is estimated to be 90% of the total jet energy.
- Water breaking up into mist and droplets at this speed and into an open area can produce sound as loud as 130 dBA
- Reduces the noise levels associated with the reduction in the velocity of the water jet from Mach 3 to subsonic levels.
- Therefore, to minimize noise, either a tube or slot-type catcher is used beneath the point of the cut.

Determination of water jet velocity

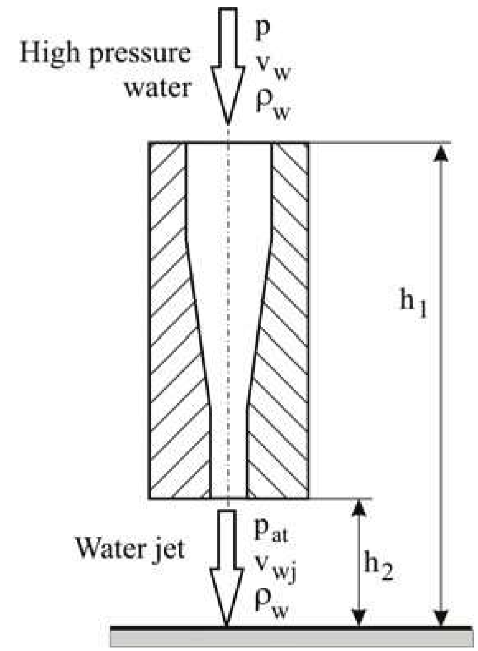
$$p_w + \frac{\rho_w V_w^2}{2} + \rho_w \mathrm{g}h = \text{constant}$$

$$p_w + \frac{\rho_w V_w^2}{2} + \rho_w \mathrm{g}h_1 = p_{at} + \frac{\rho_w V_{wj}^2}{2} + \rho_w \mathrm{g}h_2$$

$$p_w - p_{at} = \frac{1}{2}\rho_w\left(V_{wj}^2 - V_w^2\right) + \rho_w \mathrm{g}(h_1 - h_2)$$

For $p_{at} \ll p_w; V_{wj} \gg V_w; h_1 \approx h_2$

$$p_w = \frac{1}{2}\rho_w V_{wj}^2$$



Material Removal Rate

- Considering the energy loss during water jet formation at the orifice,

Water jet velocity

$$p_w = \frac{1}{2}\rho_w V_{wj}^2 \rightarrow V_{wj} = \sqrt{\frac{2p_w}{\rho_w}}$$

- MRR Depend on reactive power of the Water jet

$$MRR \propto P_{wj}$$

Reactive power is equal to pressure (p_w) multiplied by volume flow rate($\dot{Q_w}$)

$$P_{wj} = p_w \dot{Q_w}$$

P = Fv
P = (pA)v
P = p(Av)
P = pQ

Material Removal Rate

The volume flow rate of water may be expressed as

$$\dot{Q_w} = c_d V_{wj} A_{orifice}$$

$$\dot{Q_w} = c_d \frac{\pi}{4} d_0^2 \sqrt{\frac{2p_w}{\rho_w}}$$

c_d =Discharge coefficient of the orifice

Material Removal Rate

The total power of the water jet can be given as

$$P_{wj} = p_w \dot{Q}_w$$

$$P_{wj} = p_w c_d \frac{\pi}{4} d_0^2 \sqrt{\frac{2p_w}{\rho_w}}$$

$$P_{wj} = c_d \frac{\pi}{4} d_0^2 \sqrt{\frac{2{p_w}^3}{\rho_w}}$$

Material Removal Rate:

$$MRR \propto P_{wj}$$

$$MRR = \left(\frac{1}{u}\right) c_d \frac{\pi}{4} d_0^2 \sqrt{\frac{2{p_w}^3}{\rho_w}}$$

After a certain value of d, MRR will become constant or will start decreasing

u is the specific energy requirement and would be a property of the work material.

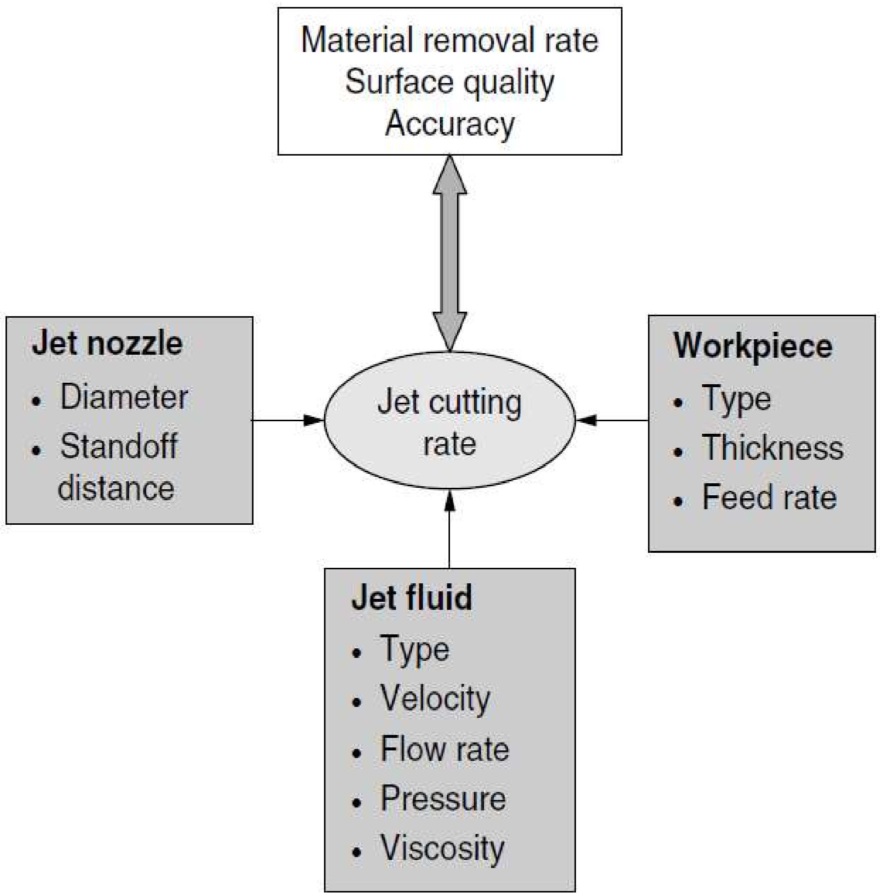
Questions

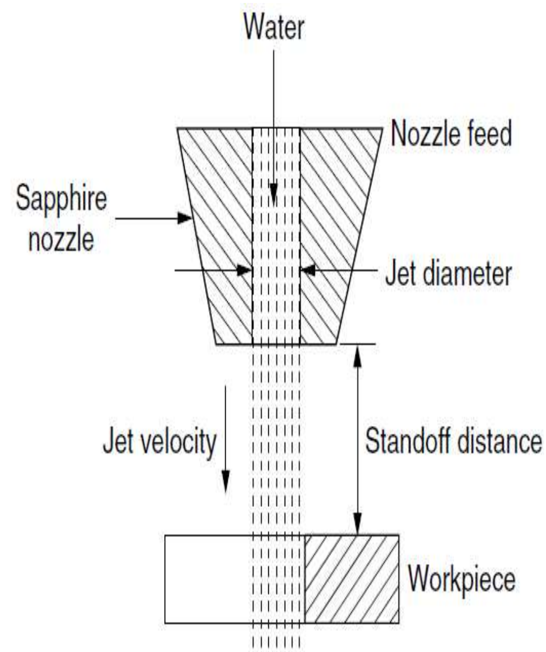
- Assuming no losses, determine water jet velocity, when the water pressure is 4000 bar, being issued from an orifice of diameter 0.3 mm

  Note: Change bar to Pascal (multiply by 10^5)

- Determine the mass flow rate of water for the given problem assuming all related coefficients to be 1.

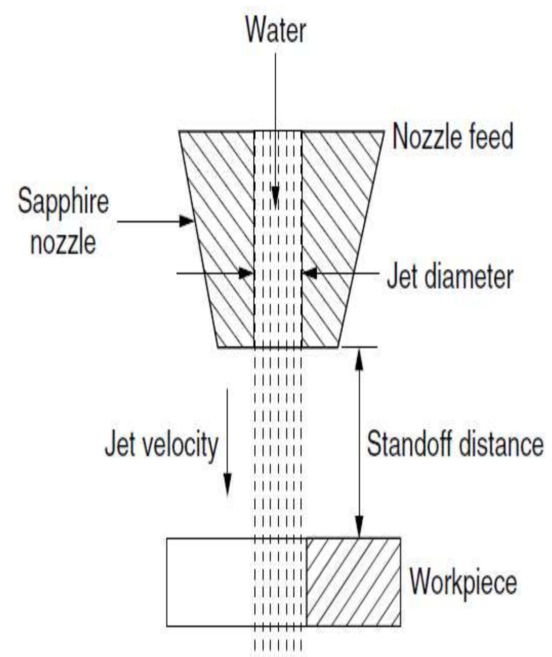
Parameters affecting the performance of WJM





Process Parameters

- Standoff distance - Gap between the jet nozzle (0.1–0.3 mm diameter) and the workpiece (2.5 – 6 mm)
- For material used in printed circuit boards, it may be increased up to 25 mm
- For larger standoff distance, the depth of cut would be smaller
- The increase in machining rate and use of the small nozzle diameter may increase the width of the damaged layer.



Water will diverge when it leaves the nozzle

Jet parameters

- Typical pressures used are 1500 to 8000 bar to provide 8 to 80 kW of power.
- 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
- The fluid used must possess low viscosity to minimize the energy losses and be noncorrosive, and nontoxic
- Water is commonly used

Workpiece

- Brittle materials will fracture, while ductile ones will cut well
- Material thicknesses range from 0.8 to 25 mm or more

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

- Water is cheap, non-toxic, and can be easily disposed and recirculated
- The process requires limited volume of water (100–200 l/hr)
- The tool (nozzle) does not wear and, therefore, does not need sharpening
- 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.
- It is ideal for cutting asbestos, glass fiber insulation, beryllium, and fiber reinforced plastics (FRP), because the process provides a dustless atmosphere
- The process provides clean and sharp cuts, free from burrs.
- It is applicable for laser reflective materials such as, glass, copper, and aluminum.

Limitations

- WJM is not safe in operation if safety precautions are not strictly followed.
- The process is characterized by a high production cost due to:
  - High capital cost of the machine
  - The need of highly qualified operators
- WJM is ~~not~~ adapted to mass production because of the high maintenance requirement.

Applications

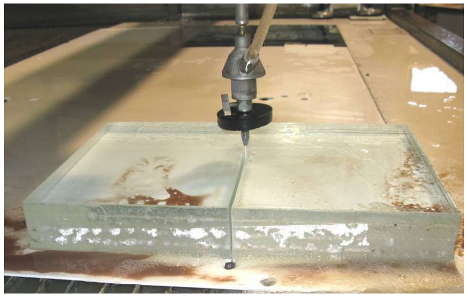
- It is ideal in cutting soft materials such as wood, paper, cloth, leather, rubber, and plastics
- Cutting of fibreglass and corrugated wood.
- Cutting of metals and composites applied in aerospace industries
- Underwater cutting and shipbuilding industries
- Cutting of rocks, granite, and marble
- Slicing and processing of frozen foods, baked foods, and meat. In such cases, alcohol, glycerin, and cooking oils are used as alternative cutting fluids
- WJM is also used in:
  - Cleaning, polishing, and degreasing of surfaces
  - Removal of nuclear contaminations
  - Cleaning of tubes and castings
  - Surface preparation for inspection purposes
  - Surface strengthening
  - Deburring

WJM Parts

Cake Cutting

Fish

PCB Cutting



Bulletproof glass

Videos

- https://www.youtube.com/watch?v=AeOXILcl0Ws
- https://www.youtube.com/watch?v=QgJ0iV9gfG4
- https://www.youtube.com/watch?v=PIJaDaSClFw
- https://www.youtube.com/watch?v=KySnPZ5SoSM
- https://www.youtube.com/watch?v=3yV-uJHla58&t=1910s

Abrasive Water Jet Machining (AWJM)

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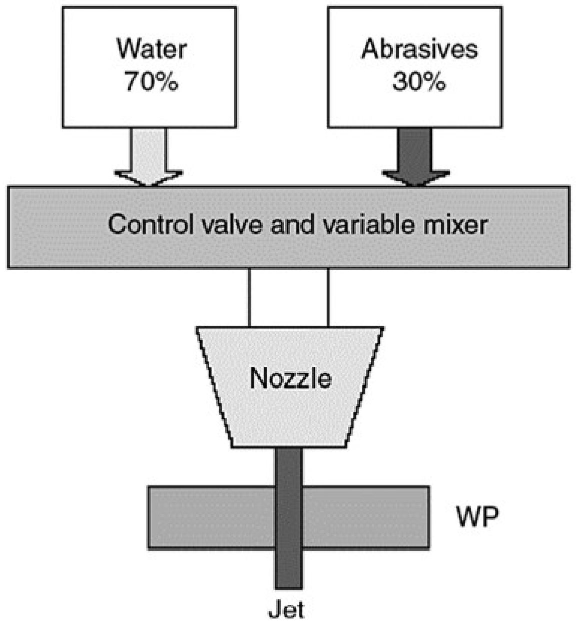
Instructor: R K Mittal

Abrasive Water Jet Machining

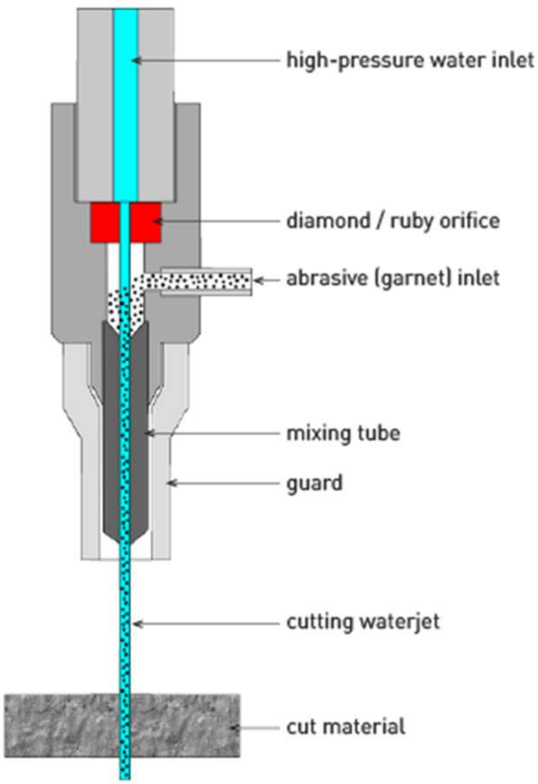
We add abrasives in water jet machining to cut hard and brittle materials of greater thickness with higher efficiency

- Water jet machines use pure water
- WJM is suitable for cutting plastics, foods, rubber insulation, automotive carpeting and headliners, and most textiles.
- Mixing of abrasives with water jet enhances the material removal rate
- AWJM cuts around 10 times faster than the conventional machining methods of composite materials.
- Cut variety of materials (thick or thin) without any thermal damages



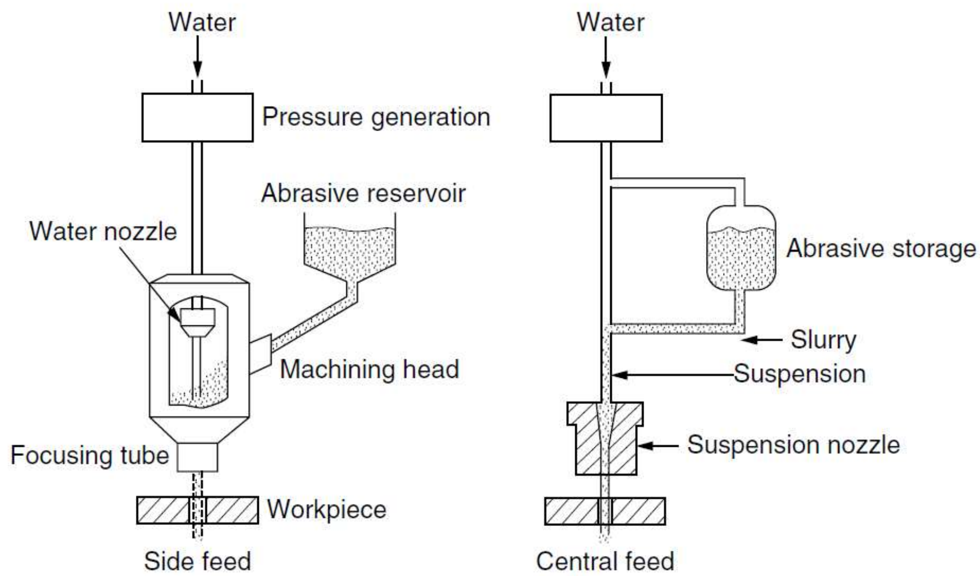
The machining system

- Water delivery
- Abrasive hopper and feeder
- Intensifier
- Filters
- Mixing chamber
- Cutting nozzles
- Catcher



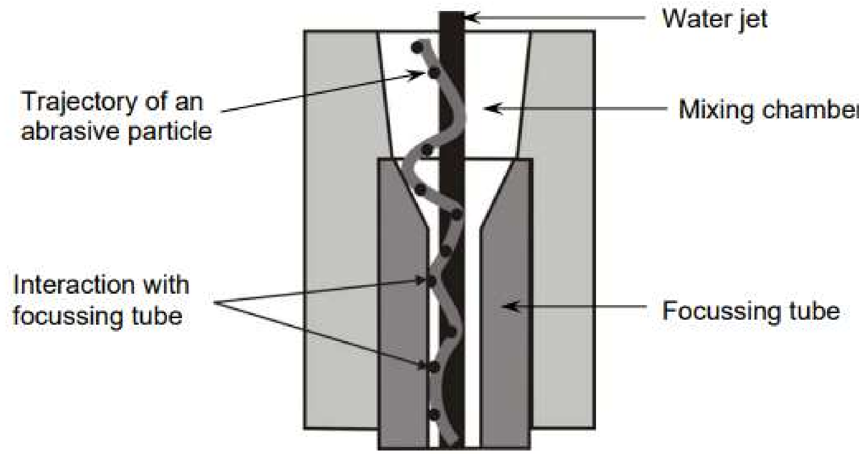
Abrasive Delivery

- After the pure water jet is created, abrasives are added using either the injection or suspension methods
- Entrained type– three phase – abrasive, water and air
- Suspended type – two phase – abrasive and water
- Abrasive particles like sand (SiO2), glass beads are used



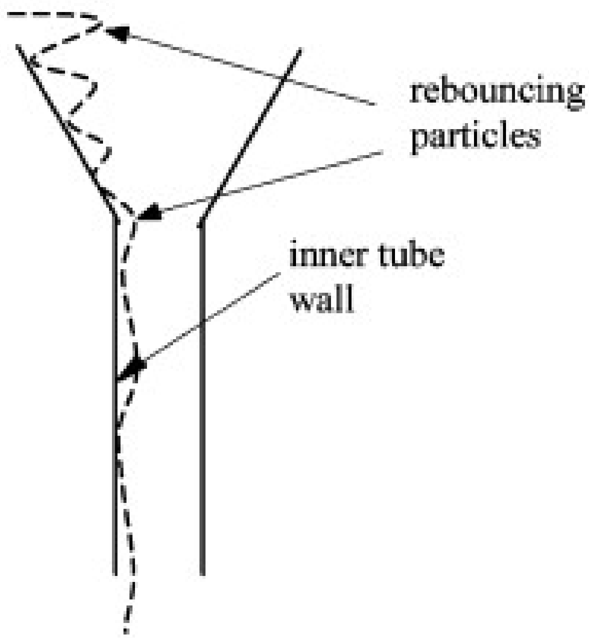
Mixing

- Gradual entrainment of abrasive particles within the water jet and finally the abrasive water jet comes out of the focusing tube or the nozzle
- The abrasive particles are gradually accelerated due to transfer of momentum from the water phase to abrasive phase
- Both phases, water and abrasive, are assumed to be at same velocity.



Mixing

- The focusing tube is generally made of tungsten carbide
- Tungsten carbide is used for its abrasive resistance
- Abrasive particles during mixing try to enter the jet, but they are reflected away due to interplay of buoyancy and drag force
- They go on interacting with the jet and the inner walls of the mixing tube, until they are accelerated using the momentum of the water jet



Mathematical model for Mixing

- During mixing process as has been discussed both momentum and energy are not conserved due to losses that occur during mixing
- But initially it would be assumed that no losses take place in momentum, i.e., momentum of the jet before and after mixing is conserved

$$\sum(\dot{m}v)_{before} = \sum(\dot{m}v)_{after}$$

$$\left(\dot{m}_{air}v_{air} + \dot{m}_{water}v_{wj} + \dot{m}_{ab}v_{ab}\right)_{before} = \left(\dot{m}_{air}v_{air} + \dot{m}_{water}\, v_{wj} + \dot{m}_{ab}v_{ab}\right)_{after}$$

Models proposed by Hashish, 1989

Mathematical model for Mixing

- The momentum of air before and after mixing will be neglected due to very low density

$$(v_{ab})_{after} = (v_{wj})_{after} = v_{awj}$$

$$\dot{m}_{water} v_{wj} = (\dot{m}_{water} + \dot{m}_{ab}) v_{awj}$$

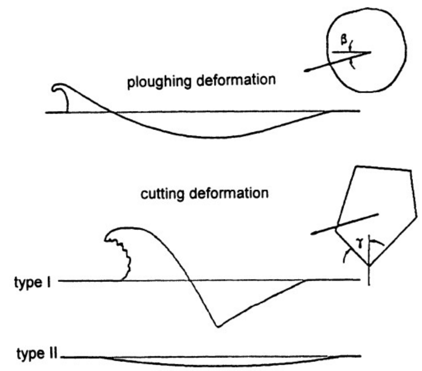
$$v_{awj} = \frac{\dot{m}_{water}}{\dot{m}_{water} + \dot{m}_{ab}} v_{wj} \rightarrow \quad v_{awj} = \frac{1}{1+R} v_{wj}$$ (R=loading factor = $\frac{\dot{m}_{ab}}{\dot{m}_{water}}$)

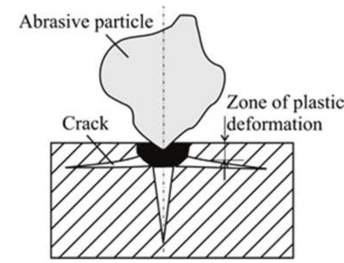
Considering momentum loss in mixing process

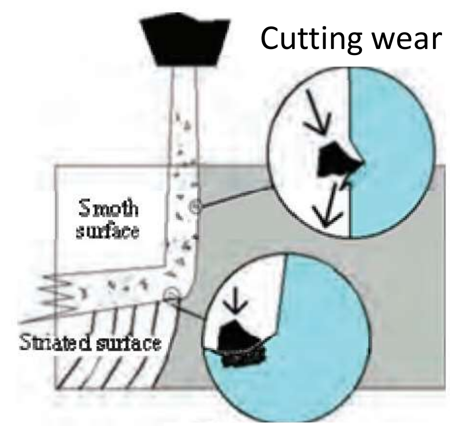
$$v_{awj} = \eta \frac{1}{1+R} v_{wj}$$ (η = momentum loss factor)

Cutting Mechanism

- Impact of solid particles is the main mechanism in the process of removing material by abrasive water jet
- For ductile material, micro-cutting and separating by material plastic deformation are the removal mechanism
- For brittle materials, mechanism of separation of materials, consisting of the phenomenon of brittle fracture and plastic deformation
- With increasing depth, the removal mechanism is changing from cutting to the separating material by plastic deformation







Material Removal Rate

Here majority of cutting is done by the abrasives (not water)

- The power of the abrasive phase of the abrasive water jet can be estimated as,

$$P_{ab} = \frac{1}{2}\dot{m}_{ab} v_{awj}^2$$

$$P_{ab} = \frac{1}{2}\dot{m}_w R \left(\frac{1}{1+R} v_{wj}\right)^2$$

$V_{wj} = \sqrt{\frac{2p_w}{\rho_w}}$ and $\dot{Q_w} = c_d \frac{\pi}{4} d_0^2 \sqrt{\frac{2p_w}{\rho_w}}$

$$P_{ab} = \rho_w c_d \frac{\pi}{8} d_0^2 R \left(\frac{1}{1+R}\right)^2 \left(\sqrt{\frac{2p_w}{\rho_w}}\right)^3$$

Material Removal Rate

$$P_{ab} = \frac{\pi}{4} c_d\, d_0^2 R \left(\frac{1}{1+R}\right)^2 {p_w}^{3/2} \left(\sqrt{\frac{2}{\rho_w}}\right)$$

Assumption: the material removal rate is proportional to the power of abrasive phase of AWJ

The water phase does not contribute to material removal in AWJM

$$MRR \propto P_{ab}$$

$$MRR = \left(\frac{1}{u}\right) \frac{\pi}{4} c_d\, d_0^2 R \left(\frac{1}{1+R}\right)^2 {p_w}^{3/2} \left(\sqrt{\frac{2}{\rho_w}}\right)$$

u is the specific energy requirement and would be a property of the work material.

Penetration Height

$$MRR = h\, w v_c$$

h = depth of penetration

w = width or diameter of the water jet

v_c = traverse speed of the AWJ or cutting speed

$$h = \left(\frac{1}{u}\right)\frac{\pi}{4} c_d\, d_0^2 R\, \left(\frac{1}{1+R}\right)^2 \frac{{p_w}^{3/2}}{w v_c}\left(\sqrt{\frac{2}{\rho_w}}\right)$$

Numerical Example

(a) Assuming no losses, determine water jet velocity, when the water pressure is 3000 bar, being issued from an orifice of diameter 0.1 mm

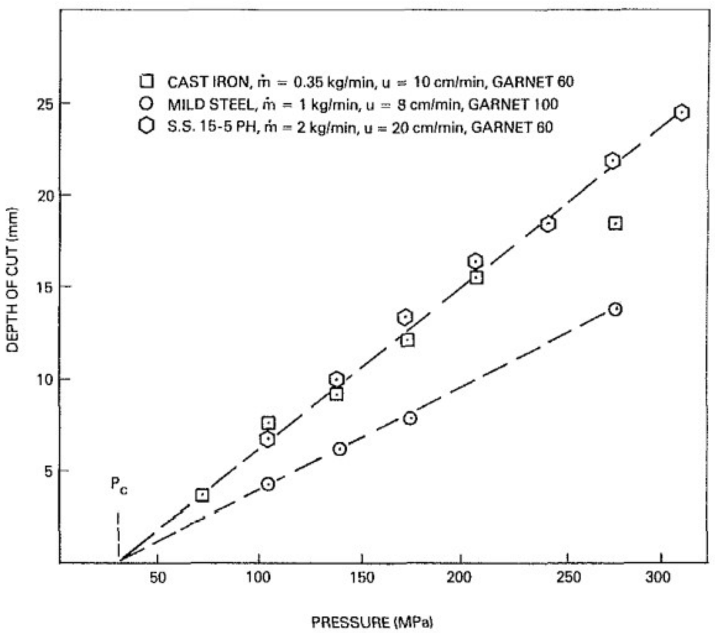
(b) Determine the mass flow rate of water for the given problem assuming all related coefficients to be 1.

(c) If the mass flow rate of abrasive is 0.8 kg/min, determine the abrasive water jet velocity assuming no loss during mixing process

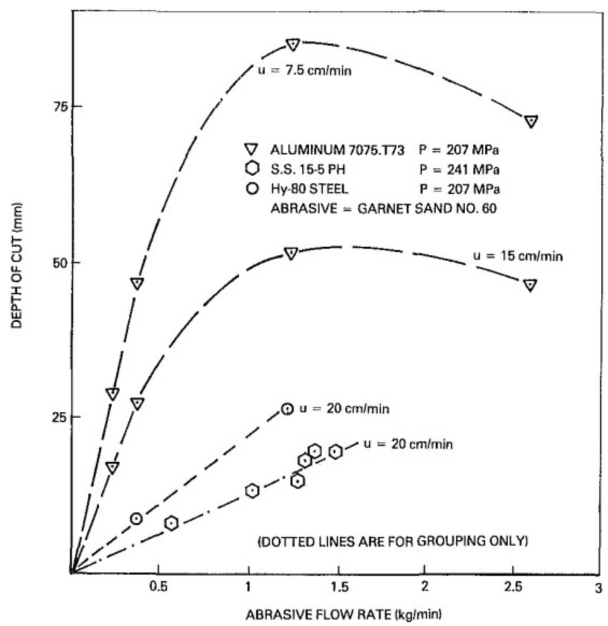
(d) Determine depth of penetration, if a steel plate is AWJ machined at a traverse speed of 100 mm/min with an insert diameter of 1 mm. The specific energy of steel is 13.4 J/mm^3 .

inset diameter is width of cut

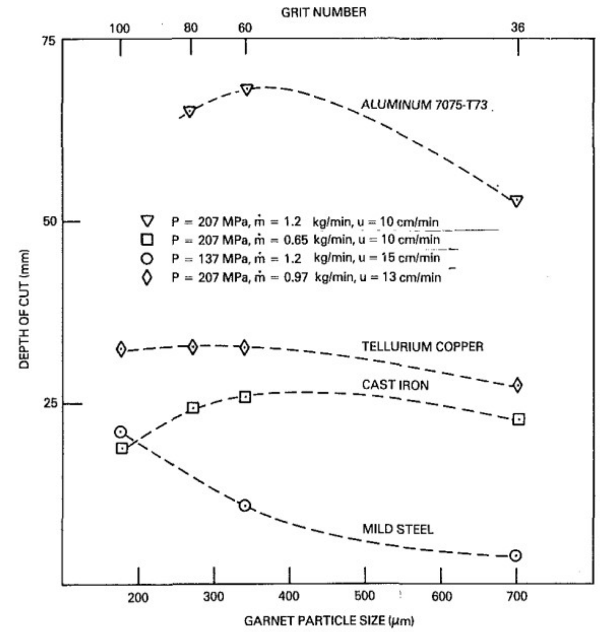
Effect of Parameters on Depth of Cut



Effect of water pressure

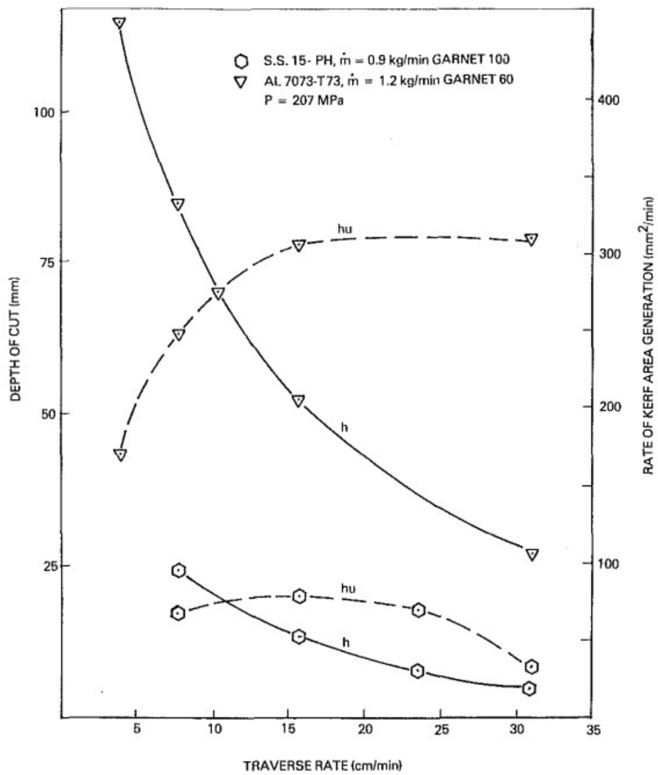


Effect of abrasive flow rate

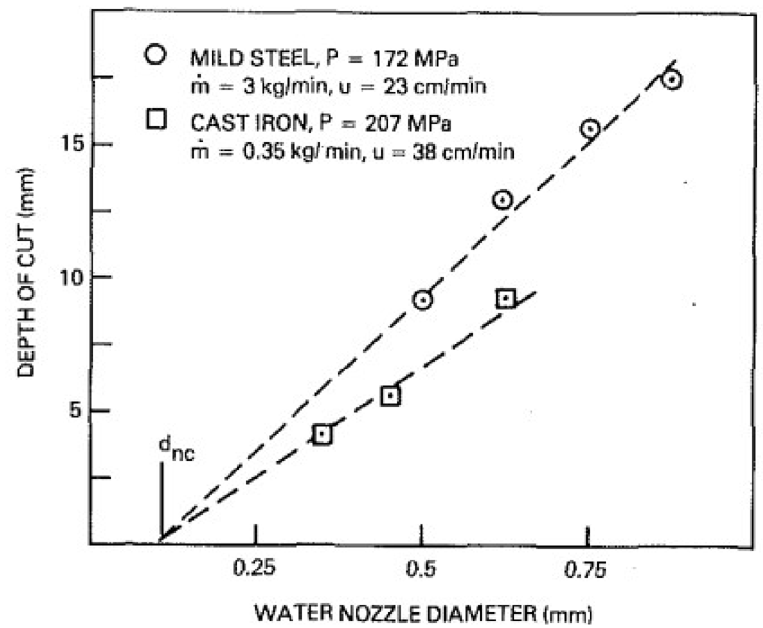


Effect of garnet particle size

Effect of Parameters on Depth of Cut

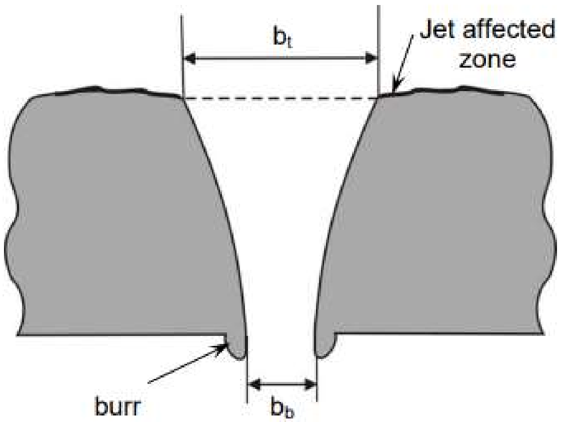


Effect of traverse rate

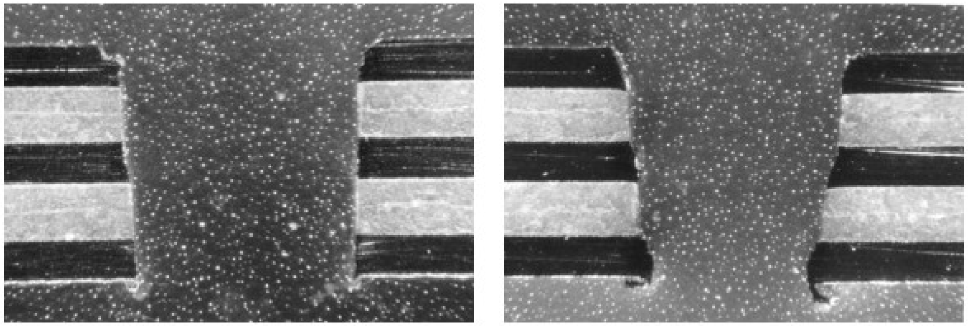


Effect of waterjet nozzle diameter

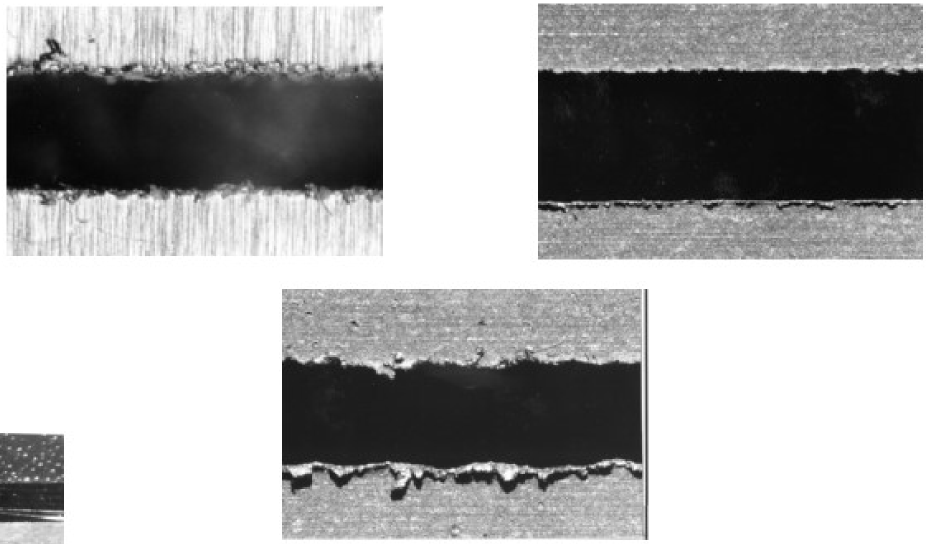
Cut /Kerf Quality



Schematic of AWJM kerf

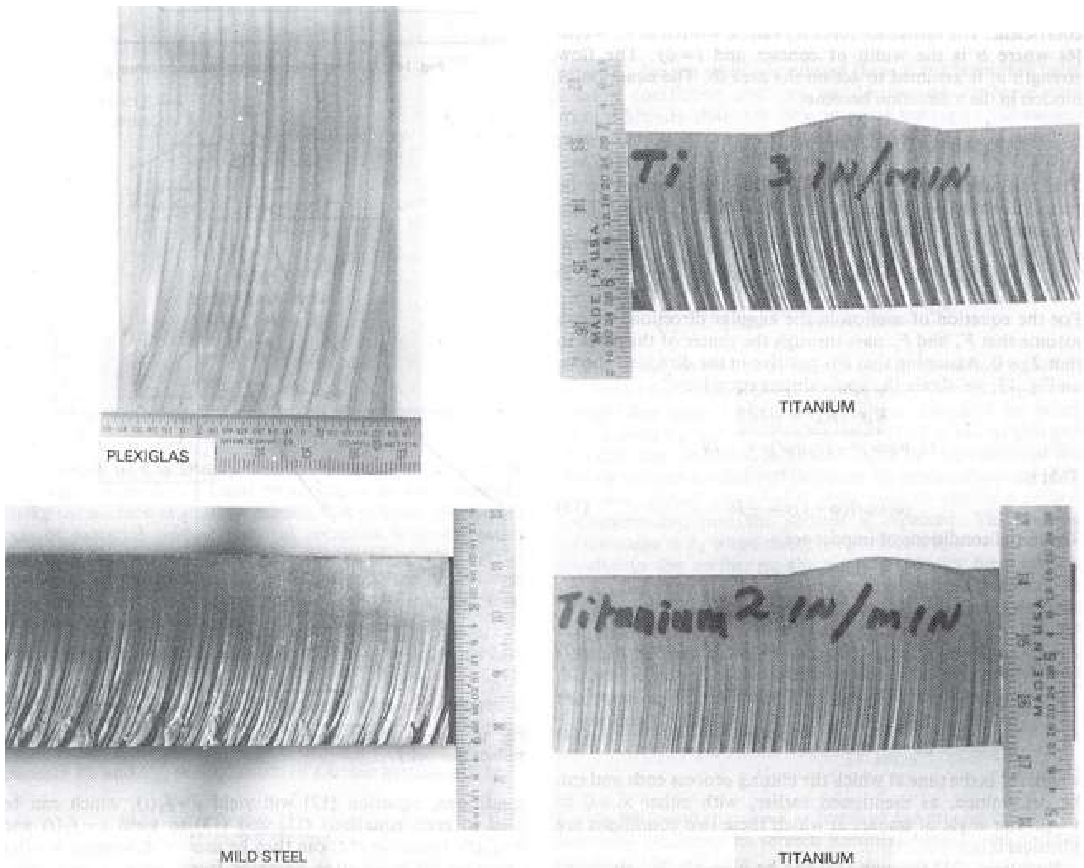


Cross section of Cut



Back Side of Cut

Surface Quality

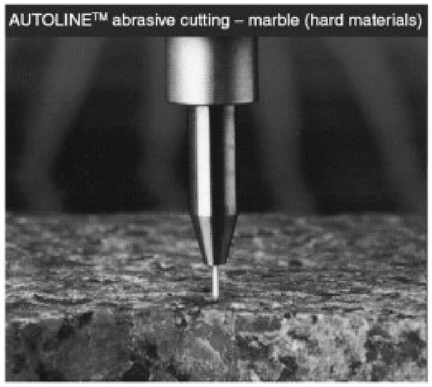


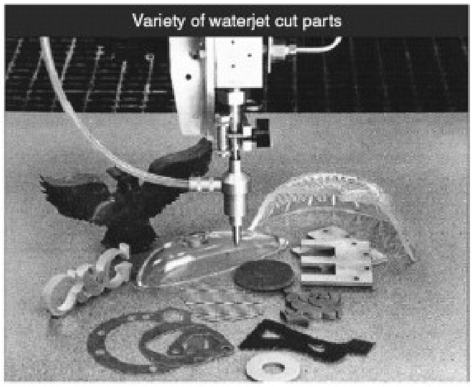
Process Parameters

- Orifice – Sapphires – 0.1 to 0.3 mm
- Focusing Tube – WC – 0.8 to 2.4 mm
- Pressure – 2500 to 4000 bar
- Abrasive – garnet and SIO_2
- Abrasive flow – 0.1 to 1.0 Kg/min
- Stand off distance – 1 to 5 mm
- Machine Impact Angle – 60^0 to 90^0
- Traverse Speed – 0.1 m/min to 5 m/min
- Depth of Cut – 1 mm to 250 mm

Advantages

- Same as Water jet machining process
- Capability to machine soft and hard materials at very high speeds
- In most of the cases, no secondary finishing required
- No cutter-induced distortion
- The burr produced is minimal.

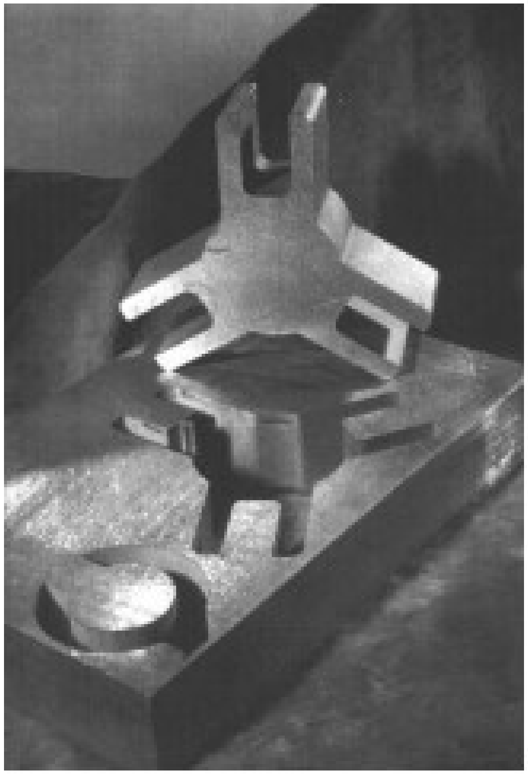




Disadvantages

- Due to the existence of the abrasives in the jet, there is an excessive wear in the machine and its elements.
- The process is not environmentally safe as compared to WJM.
- Surface finish degrades at higher cut speeds which are frequently used for rough cutting
- The major disadvantages of abrasive water jet cutting are high capital cost and high noise levels during operation

Applications



Stainless steel plate (50 mm thick)
(Omax Corporation, USA)

Different engineering components
(Omax Corporation, USA)

Abrasive Jet Machining (AJM)

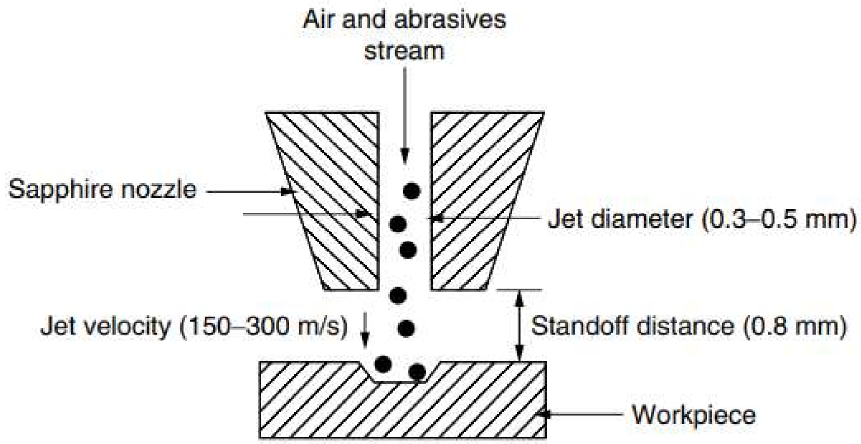
ME688: Advanced Machining Processes
Instructor: R K Mittal

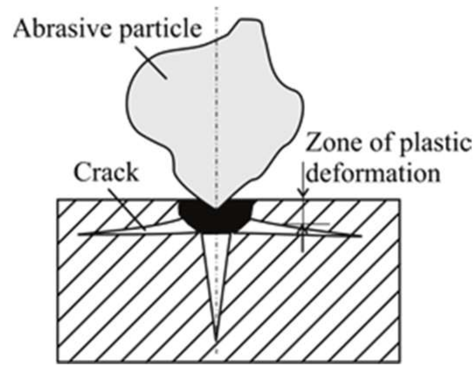
Abrasive Jet Machining

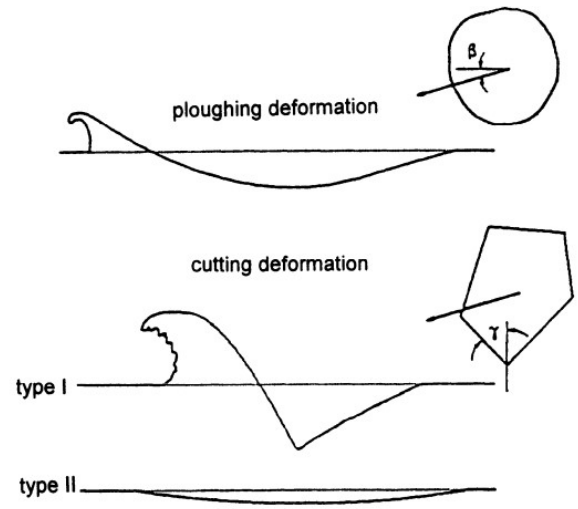
- WJM and AWJM use water jet and abrasive water jet for cutting operation
- In abrasive jet machining (AJM) high-pressure gas or air at a high velocity is used as carrier
- The material is removed by the mechanical abrasion action of the high-velocity abrasive particles
- Material removal occurs through a chipping action, which is especially effective on hard, brittle materials such as glass, Silicon, tungsten, and ceramics.
- Soft, resilient materials, such as rubber and some plastics, resist the chipping action and thus are not effectively processed by AJM

Material Removal Mechanism

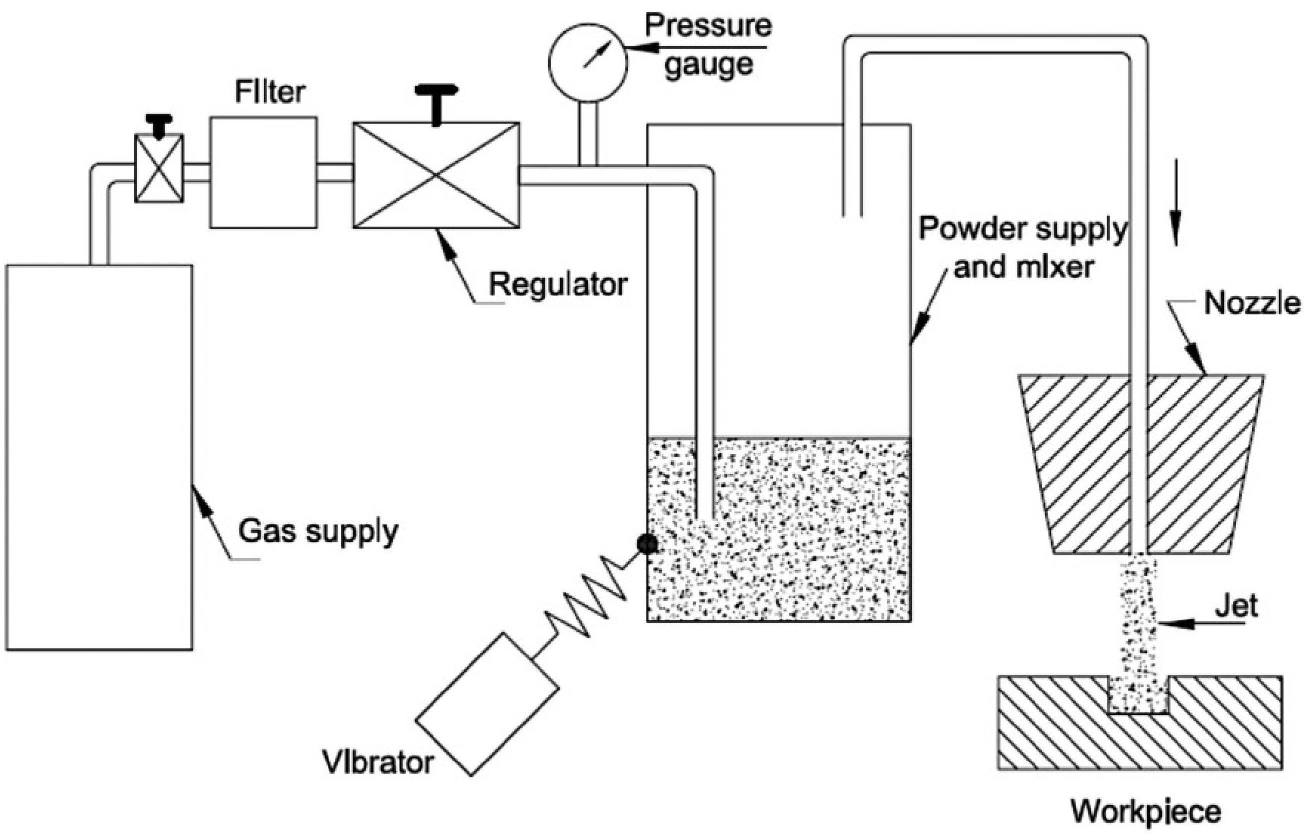
- When the sharp-edged abrasive particles hit a brittle and fragile material at high speed, tiny brittle fractures are created from which small particles dislodge
- The lodged out particles are carried away by the air or gas.







Machining system



Machining system

- Gas (Nitrogen, CO_2, or air) is supplied under a pressure of 2 to 8 kg/cm^2
- After filtration and regulation, the gas is passed through a mixing chamber that contains abrasive particles and vibrates at 50 Hz
- Al_2O_3 or SiC abrasives, of grain size ranging from 10 to 80 μm, are used
- The nozzles are generally made of sintered carbides (WC) or synthetic sapphire of diameters 0.2 to 2 mm
- To limit the jet flaring, nozzles may have rectangular orifice
- The abrasives attain a high speed ranging from 150 to 350 m/min
- The abrasive powder feed rate is controlled by the amplitude of vibrations in the mixing chamber

Machining system

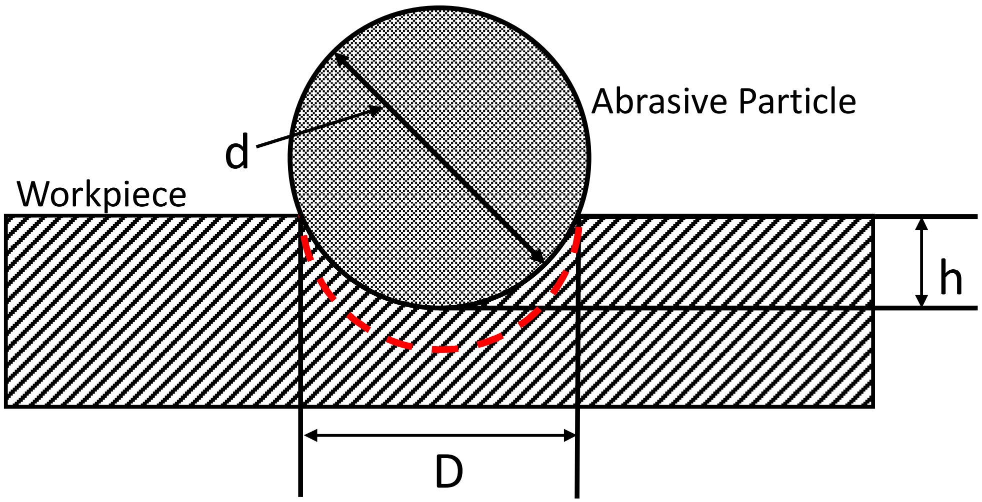
- As the particles impact the surface of workpiece, it causes a small fracture and wear, which is carried away by the gas along with the abrasive particles
- The abrasive particles once used, cannot be re-used as its shape changes partially
- The workpiece material is also clogged with the abrasive particles during impingement and subsequent flushing by the carrier gas
- Oxygen should never be used because it causes a violent chemical reaction with workpiece chips or abrasives
- Dust removal equipment is incorporated to protect the environment

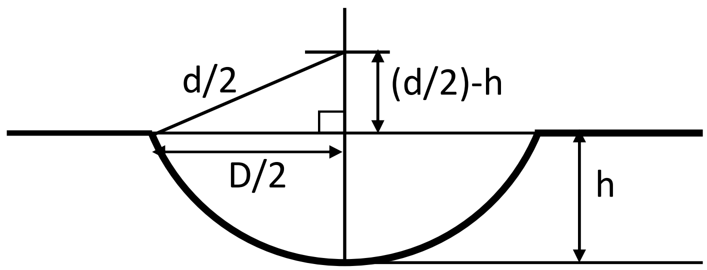
Material Removal Rate

Assumptions:

- Abrasives are rigid and spherical in shape having diameter d (grit diameter)
- Kinetic energy of particle is used to cut the material
- For brittle materials, volume of material removal is considered to be hemispherical in shape having diameter D
- For ductile materials, volume of material removal is assumed to be equal to the indentation volume due to abrasive particle impact.

Volume of Material Removed/Particle





$$\left(\frac{d}{2}\right)^2 = \left(\frac{d}{2} - h\right)^2 + \left(\frac{D}{2}\right)^2 \longrightarrow D \approx 2\sqrt{dh}$$

Energy Balance

- The Kinetic Energy

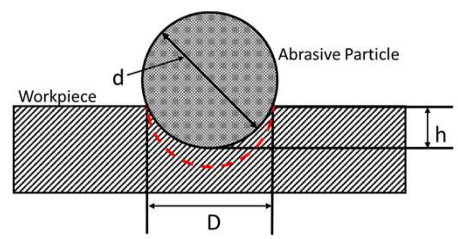
$$KE = \frac{1}{2}\,\mathrm{m}\,(V)^2$$

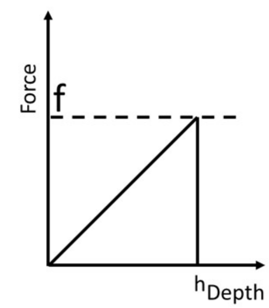
m= mass of abrasive particle

V= velocity of abrasive particle

- An abrasive particle penetrates to the depth equal to 'h' into the workpiece. Then the work done by a particle is given by

$$W_p = \frac{1}{2}\,fh$$





Energy Balance

- Force in terms of mean stress of workpiece (σ_w)

$$f = \sigma_w A_w = \sigma_w \pi h d$$

- Energy balance

$$\frac{1}{2}\left(\frac{4\pi}{3}\left(\frac{d}{2}\right)^3 \rho_p\right)(V)^2 = \frac{1}{2}\sigma_w \pi h^2 d$$

$$h = \sqrt{\frac{\rho_p}{6\sigma_w}} dV$$

$\sigma_w \approx H$

H= hardness of workpiece material

Material Removal Rate (Brittle Materials)

- MRR will be equal to MRR due to one impact multiplied by number of impacts per second
- Number of impact per second will be ratio of mass flow rate of abrasives and mass of one abrasive

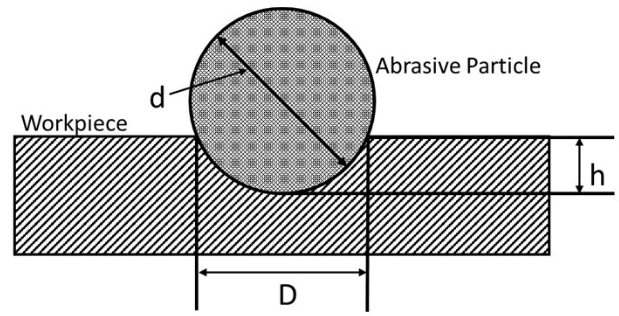
$$N = \frac{\dot{m}_{ab}}{\left(\frac{\pi d^3 \rho_p}{6}\right)}$$

- Material Removal Rate:

$$MRR = \frac{\pi D^3}{12} \frac{\dot{m}_{ab}}{\left(\frac{\pi d^3 \rho_p}{6}\right)} = \frac{\pi \left(2\sqrt{dh}\right)^3}{12} \frac{\dot{m}_{ab}}{\left(\frac{\pi d^3 \rho_p}{6}\right)} = \frac{4\dot{m}_{ab} V^{3/2}}{\rho_p{}^{1/4} (6\sigma_w)^{3/4}}$$

Material Removal Rate (Ductile Materials)

- Volume removal per particle= $\frac{\pi h^2 (3(\frac{d}{2}) - h)}{3} = \frac{\pi h^2 d}{2}$



$$MRR = \frac{\pi h^2 d}{2} \frac{\dot{m}_{ab}}{\left(\frac{\pi d^3 \rho_p}{6}\right)} = \frac{\pi d \left(\sqrt{\frac{\rho_p}{6\sigma_w}} dV\right)^2}{2} \frac{\dot{m}_{ab}}{\left(\frac{\pi d^3 \rho_p}{6}\right)}$$

$$\mathrm{MRR} = \frac{\dot{m}_{ab} V^2}{2\sigma_w}$$

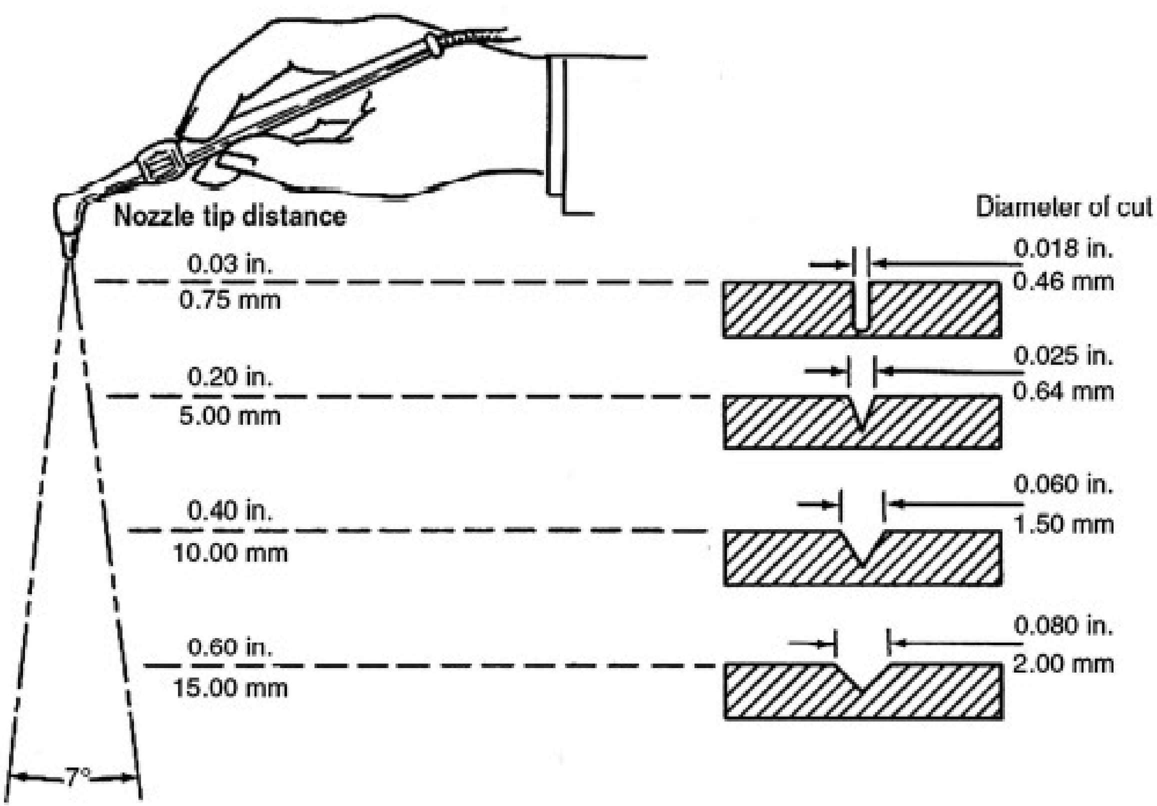
Numerical Example

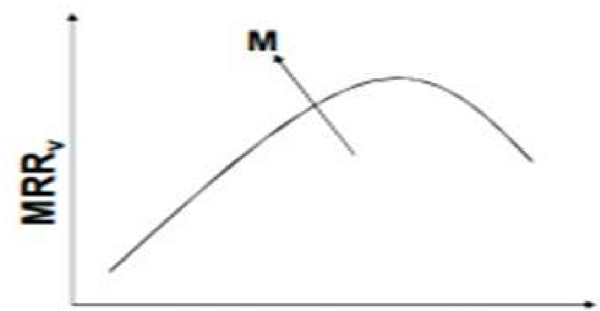
- Estimate the MRR in AJM of a material with flow strength of 3 GPA. The abrasive flow rate is 2.5 gm/min, velocity is 205m/s, density of abrasive is 3 gm/cc. dia of abrasive is 100 micron

(a) Consider brittle material MRR=80 mm^3/min

(b) Consider ductile material MRR=17.5 mm^3/min

Effect of Stand-Off Distance

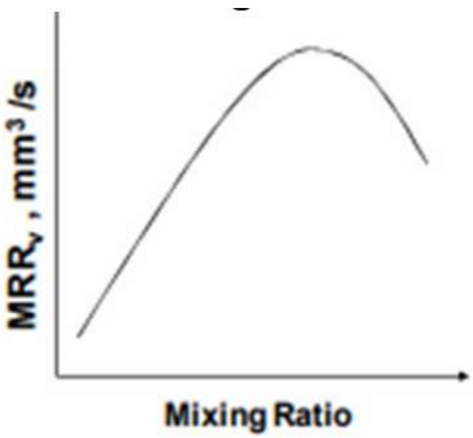


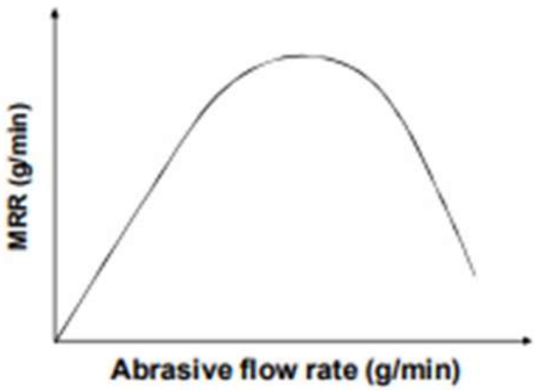


Effect of Mixing Ratio

$$\text{Mixing ratio} = \frac{\text{Volume flow rate of abrasive particles}}{\text{Volume flow rate of carrier gas}}$$

$$\text{Mass ratio} = \frac{\text{Mass flow rate of abrasive particles}}{\text{Mass flow rate of carrier gas and abrasive}} = \frac{\dot{m}_{ab}}{\dot{m}_{ab} + \dot{m}_{gas}}$$





Process parameters and Capabilities

- Abrasives – Al_2O_3 ,SiC, Glass beads – 10 to 50 microns – 2-20 gm/min
- Carrier Gas – Air, CO_2, N_2 – 500 to 700 m/s – 2 to 10 bar
- Abrasive Jet – Velocity - 100 to 300 m/s – Stand off distance 0.5 to 15mm – Impingement angle – 60 to 90 deg
- Nozzle – Material – WC/Sapphire – Diameter – 0.2 to 0.8 mm
- Material removal rate – 0.015 cm3 /min 2
- Narrow slots – 0.12 to 0.25mm
- Surface finish -0.25 micron to 1.25 micron
- Sharp radius up to 0.2mm is possible
- Steel up to 1.5mm ,Glass up to 6.3mm is possible to cut

Advantages

- Best suited for machining brittle and heat-sensitive materials like glass, quartz
- Used for machining superalloys and refractory materials
- Not reactive with any workpiece material
- No tool changes are required
- Intricate parts of sharp corners can be machined
- The machined materials do not experience hardening
- No initial hole is required for starting the operation
- Material utilization is high
- Characterized by low capital investment and low power consumption

Disadvantages/ Limitations

- The removal rate is slow
- Stray cutting can't be avoided (low accuracy of ± 0.1 mm)
- The tapering effect may occur especially when drilling in metals
- The abrasive may get impeded in the work surface
- Suitable dust-collecting systems should be provided
- Soft materials can't be machined by the process
- Silica dust may be a health hazard
- Ordinary shop air should be filtered to remove moisture and oil

Applications

- Drilling holes, cutting slots, cleaning hard surfaces, deburring, polishing, and radiusing
- Machining intricate shapes or holes in sensitive, brittle, thin, or difficult-to-machine materials
- Insulation stripping and wire cleaning without affecting the conductor
- Micro-deburring of hypodermic needles
- Frosting glass and trimming of circuit boards
- Removal of films and delicate cleaning of irregular surfaces because the abrasive stream is able to follow contours

Applications

sugino.com

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