UNIt-I

UCMP - Introduction & USM (1)

Manufacturing :- Conversion of raw materials into finished products.

Manufacturing processes can be broadly divided into two groups :

(1) primary manufacturing process (welding, casting, Rolling) - provide basic shape & size.

(2) secondary " " — provide final shape & size with tighter control on dimension, surface characteristics.

→ Material removal processes once again can be divided into two groups.

(1) conventional machining process.

(2) Non Traditional manufacturing process. (or) Non conventional manufacturing process.

Traditional machining :-

Traditional, also termed as conventional machining processes remove material in the form of chips by applying forces on work material with a wedge shaped cutting tool that is harder than the work material under machining condition.

Characteristics :-

→ generally macroscopic chip formation by shear deformation.

→ material removal takes place due to application of cutting forces.

→ cutting tool is harder than work piece at room temperature as well as under machining conditions.

Demerits :-

1) In CMP, metal is removed by chip formation which is an expensive & difficult process.

(2) chips produced during this process are unwanted by products.

(3) Removal of these chips & their disposal and recycling is a very tedious procedure, involving energy & money.

(4) Very large cutting forces are involved in this process, so proper holding of w/p is most important.

(5) due to large cutting forces & large amount of heat generated, b/w tool & w/p interface, undesirable deformation & residual stresses are developed into w/p.

(6) It is not possible to produce chips by conventional machining process for delicate components like semi conductors.

Non Traditional machining :- (NTM) :-

NTM also termed as unconvetional machining process.

→ It is defined as a group of process that remove excess material by various techniques. involving mechanical, Thermal, electrical or chemical energy or combinations of these energies but do not use a sharp cutting tools as it needs to be used for TMP.

→ extremely hard & brittle materials are difficult to m/c by TMP such as Turning, drilling, shaping & milling.

— NTMP also called as advanced manufacturing process

Differences b/w Conventional & Non Conventional process:-

Conventional process	Non Conventional process
(1) The cutting tool & work piece are always in physical contact with relative motion with each other, which results in friction & tool wear.	(1) There is no physical contact b/w tool & work piece, in some non traditional process tool wear exists. (→ does not)
(2) material removal rate is limited by mechanical properties of work material.	(2) It can m/c difficult to cut & hard to cut materials like titanium, ceramics, composites, semi conducting materials.
(3) Relative motion b/w tool & work is typically rotary or reciprocating. Thus the shape of work is limited to circular or flat shapes.	(3) Many NTM are capable of producing complex 3D shapes & cavities.
→ machining of small cavities, slits (a long, narrow cut), blind holes or through holes are difficult.	→ machining of small cavities, slits & production of non circular, micro sized, large aspect ratio, shall entry angle holes are using NTM.
→ use relative simple & inexpensive machinery & readily available cutting tools.	→ Non Traditional processes require expensive tools & equipment as well as skilled labour, which increase the production cost.
→ Capital cost & maintenance cost is low.	→ Capital cost & maintenance cost is high.

→ Traditional processes are well established & physics of process is well understood.	→ mechanics of material removal of some of NTM process are still under research.
→ Conventional process mostly uses mechanical energy.	→ Most NTM uses energy in direct form. ex: laser, electron beam in its direct forms are used in LBM & EBM.
→ surface finish & Tolerances are limited by machining inaccuracies.	→ high surface finish (up to 0.1 micron) & Tolerances (2.5 micron) can be achieved.
→ high MMR	→ Low MMR.

UCMP :- uncoventional machining process

It is defined as a group of processes that remove excess material by various techniques involving mechanical, thermal, electrical or chemical energy or combinations of these energies but do not use a sharp cutting tools as it needs to be used for traditional machining processes.

Advantages :-

It has good Accuracy.
It provides a good surface.
Complex shapes can be made easily.
It has longer tool life.
The rate of metal removal is high.

Importance :-

To machine high steel alloys
To generate desired complex surfaces.
To achieve high accuracy & surface finish.

Limitations :-

high initial or setup cost.
high skilled labor is required.
lower metal removal rate.
more power required for machining.
It is not economical for bulk production.

Conventional machining process :- lower Accuracy & surface finish.

It involves the direct contact of tool & w/p.
Where as UCmp does not require direct contact of tool & workpiece.

Types of Machining processes :-

Turning, milling & drilling.

Basic machining process :-

Conventional machining processes

Abrasive process

Non Traditional processes.

Need for UCMP :-

1) Extremely hard & brittle materials (or) difficult to machine material are difficult to machine by traditional machining processes.

2) when the work piece is too flexible or slender to support the cutting or grinding forces

3) when shape of part is too complex.

Materials :- by UCMP

Titanium

Stainless steel

Nimonics & other similar HSTR alloys.

Fiber Reinforced Composites

~~Ste~~ Ceramics

other difficult to machine alloys

Composite :- It is made up of two or more different elements or substances (matrix & reinforcement)

ex :- Concrete – small rocks & cement, Reinforced plastic – fiber reinforced polymer or fiberglass

Ceramic matrix composites – composite ceramic & metal matrices.

alloy :- It is a combining 2 or more metals elements, to give higher strength. brass (Cu, Zn), bronze (Cu, Tin), steel, stainless steel, red gold (gold, Cu), white gold (gold, silver)

Need for development of NCP :-

1) production & processing parts of complicated shapes in high strength Temperature resistant (HSTR) & other hard to machine alloys is difficult time consuming an uneconomical

2) Innovative geometric design of products & components.

3) Difficult to machine materials like titanium, SST, nimonics, ceramics & semiconductors.

4) examples :- Intricate shaped blind hole.
difficult to m/c material.
low stress grinding
deep hole with small hole diameter
machining of composites.

Classification of NTMp :- Depending on the nature of energy used for material removal.

Mechanical process	Electro Chemical process	Electro thermal process	Chemical process
1) AJM	1) ECM	1) EDM	1) CHM
2) USM	2) ECG	2) LJM	2) PEM → photo chemical machining
3) WJM	3) ECD	3) EBM	
4) AWJM		~~4) PAM~~ 4) PAM - plasma Arc machining	

Considerations in process selections :- (Selection of process)

The correct selection of NTMp must be based on the following aspects.

(i) physical parameters of the process :-

Parameters	Non Traditional process							
	USM	AJM	CHM	ECM	EDM	EBM	LBM	PAM
potential (volts)	220	220	—	10-30	100-300	150 KV	4.5 KV	100
Current (amps)	12	1	—	10,000	50	0.001	2	500
power (Kw)	2.4	0.22	—	100	2.70	0.15	—	50
Gap (mm)	0.25	0.75	—	0.20	0.025	100	150	7.5
medium	Abrasives in water	Abrasive in gas	liquid Chemical	electrolyte	di electric oil	Vaccum	Air	Argon

The physical parameters of different NTM are given in above table; which indicates that PAM & ECM require high power for fast machining.

EBM & LBM require high voltages & require Careful handling of equipment.

EDM & USM require more power.

EBM Can be used in Vaccum

PAM uses oxygen & hydrogen gas.

(2) Shapes cutting capability :-

The different shapes Can be machined by NTM.

EBM & LBM are used for micro drilling & cutting. (→ diameters used in mm & Mm.)

USM & EDM are useful for Cavity sinking & standard hole drilling. (↓ used for molding plastics for hot & cold forging)

Tungsten Carbide fine hole (0.065mm)

ECM, LBM, EBM is useful for fine hole drilling & Contour machining. (4)

PAM Cannot be used for cutting

AJM is useful for shallow pocketing.

(3) process capability :-

It achieves higher accuracy has the lowest specific power requirement.

ECM Can m/c faster & has a low thermal surface damage depth.

USM & AJM have very material removal rates combined with high tool wear & are used non metal cutting.

LBM, EBM are due to their high penetration depth Can be used for micro drilling, sheet cutting, welding.

— used for manufacture of PCM & other shallow components.

· Importance of Smart HSTR.

→ ultimate Tensile strength (or) Just Tensile strength for short is an important property of materials to determine their mechanical performance.

→ It is the ability of a material to resist tearing due to tension.

It is applicable to all types of materials such as wires, ropes, metal beams etc.

Shallow pocketing — Small assets / big liabilities

↓

hole that is only an inch deep

process selection :-

selection of processes for different materials :-

All methods are not suitable for all materials.
depending on the material to be machined, following methods can be used as shown in table.

Materials	Method of machining
1) Non metals like ceramics, plastics & glass	USM, AJM, EBM, LBM
2) Refractories	USM, AJM, EDM, EBM
3) Titanium	EDM
4) Super alloys	AJM, ECM, EDM, PAM
5) steel	ECM, CHM, EDM, PAM

selection of processes ~~for application considerations~~ :-

4) economics of the process. — does not include salary, wages & benefits

It means any payments, fees, reimbursement for expenses.

USM :- ultrasonic machining

Introduction :- Abrasive material — (silicon carbide & boron carbide) suspended in water or oil → to remove MRR.

It is a mechanical material removal process or an abrasive process used to erode holes or cavities on hard & brittle workpiece by using shaped tools, high frequency, abrasive slurry. (cleaning & polishing)

→ Machining brittle materials such as single crystals, glasses & polycrystalline ceramics & increasing complex operations to provide intricate shapes & w/p profiles.

→ USM is a NTP, in which abrasives contained in a slurry are driven against a w/p by a tool oscillating at low amplitude (25-100 μm) & high frequency (15-30 KHz)

→ The process was first developed in 1950s & was originally used for finishing EDM surfaces.

→ The gap b/w tool & w/p is (25-40 μm) to circulate abrasives & carry way chips.

→ The cutting action comes from an ultrasonic force applied.

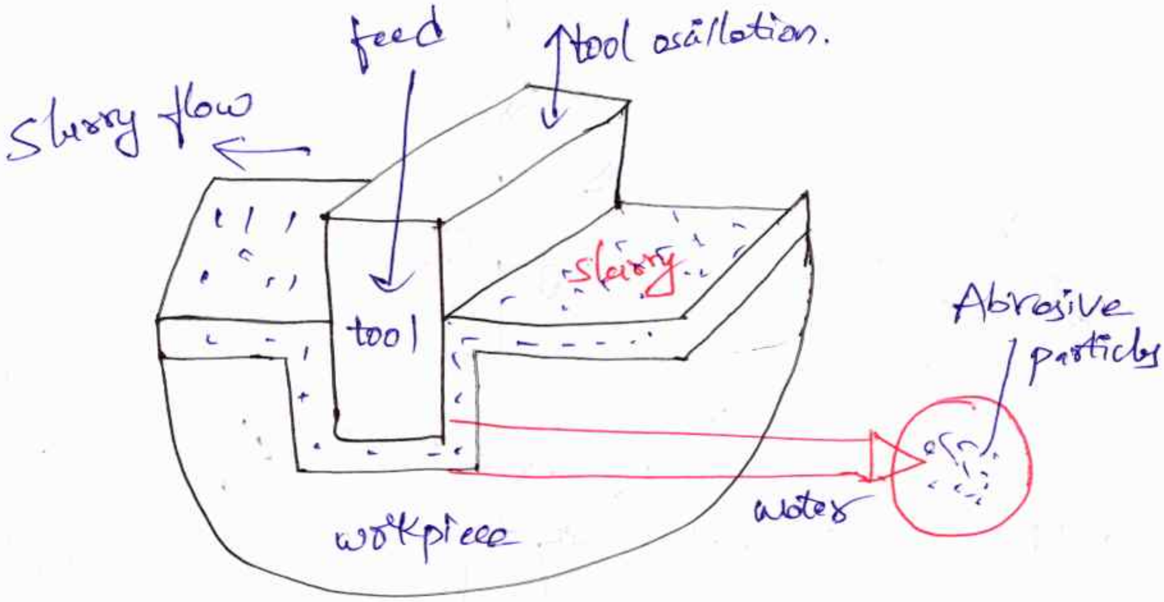
→ Components to the cutting action are

1) brittle fracture caused by impact of abrasive grains due to tool vibration.
2) Cavitation induced erosion. [After MRR, how damage occurs at several locations]
3) Chemical erosion caused by slurry.

It is therefore used extensively in machining hard & brittle materials that are difficult to machine by traditional manufacturing processes.

The hard particles in slurry are accelerated towards the surface of the w/p by a tool oscillating at a frequency of upto 100kHz - through repeated abrasions, the tool machines a cavity of c/s identical to its own.

USM working principle :-



→ material removal primarily occurs due to the indentation of abrasive grits on brittle work material.

→ Some MRR may occur due to free flowing impact of abrasives against the work material & related solid - solid impact erosion.

→ Tool's vibration — due to tools vibrate, fracture will takes place.

→ during indentations, due to contact stresses, cracks develop, and the cracks would propogate due to increase in stress & lead to brittle fracture

→ The tool material should be such that indentations by abrasive grits does not lead to brittle failure.

→ Thus the tools are made of tough, strong & ductile materials like steel, stainless steel & other ductile alloys.

USM Machine :-

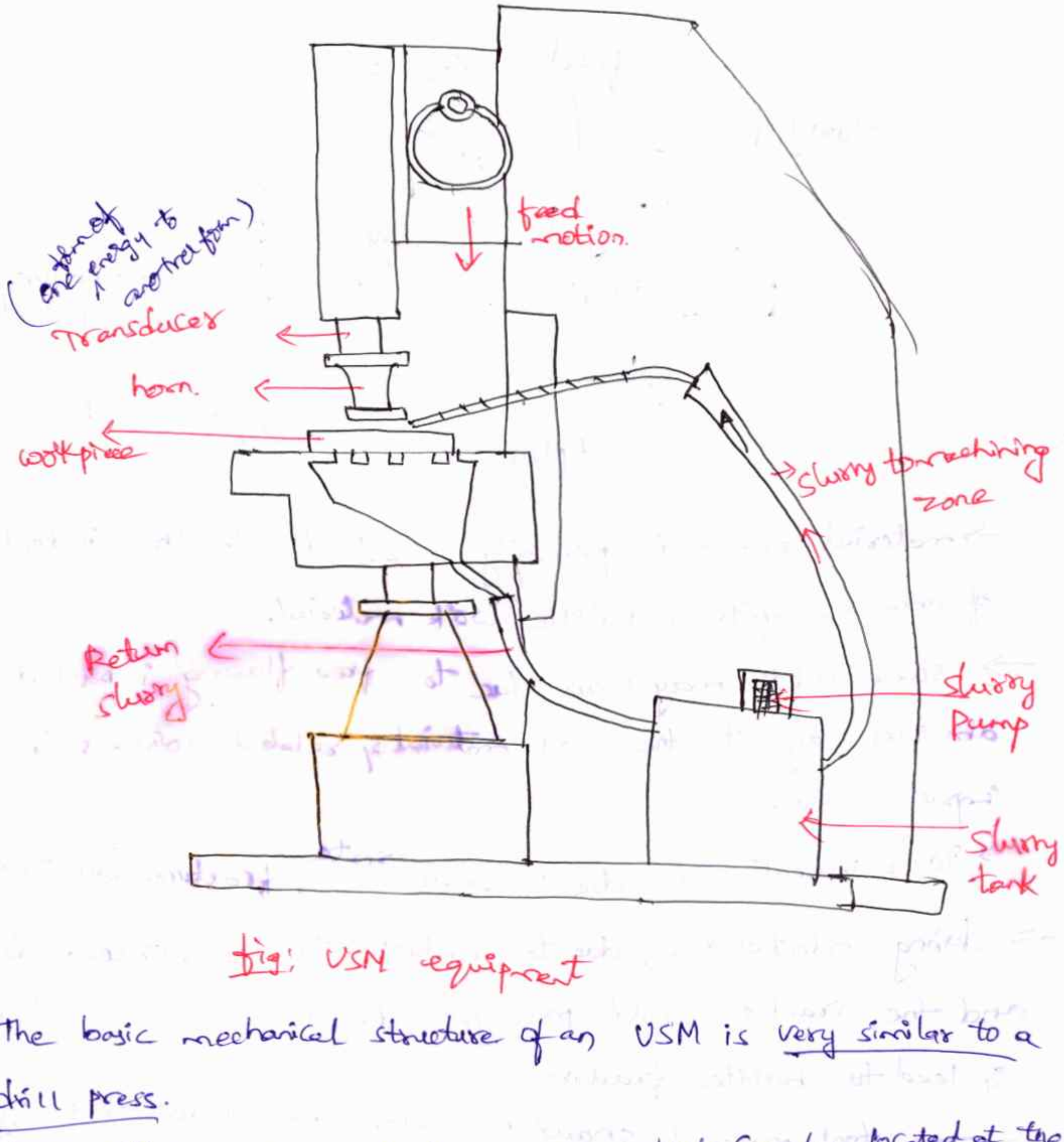


fig: USM equipment

The basic mechanical structure of an USM is very similar to a drill press.

The work piece is mounted on a vice, which can be located at the desired position under the tool using a 2 axis table.

The table can further be lowered or raised ~~which can be located at the desired position under~~ t to accomodate work of different thickness.

The typical elements of an USM are

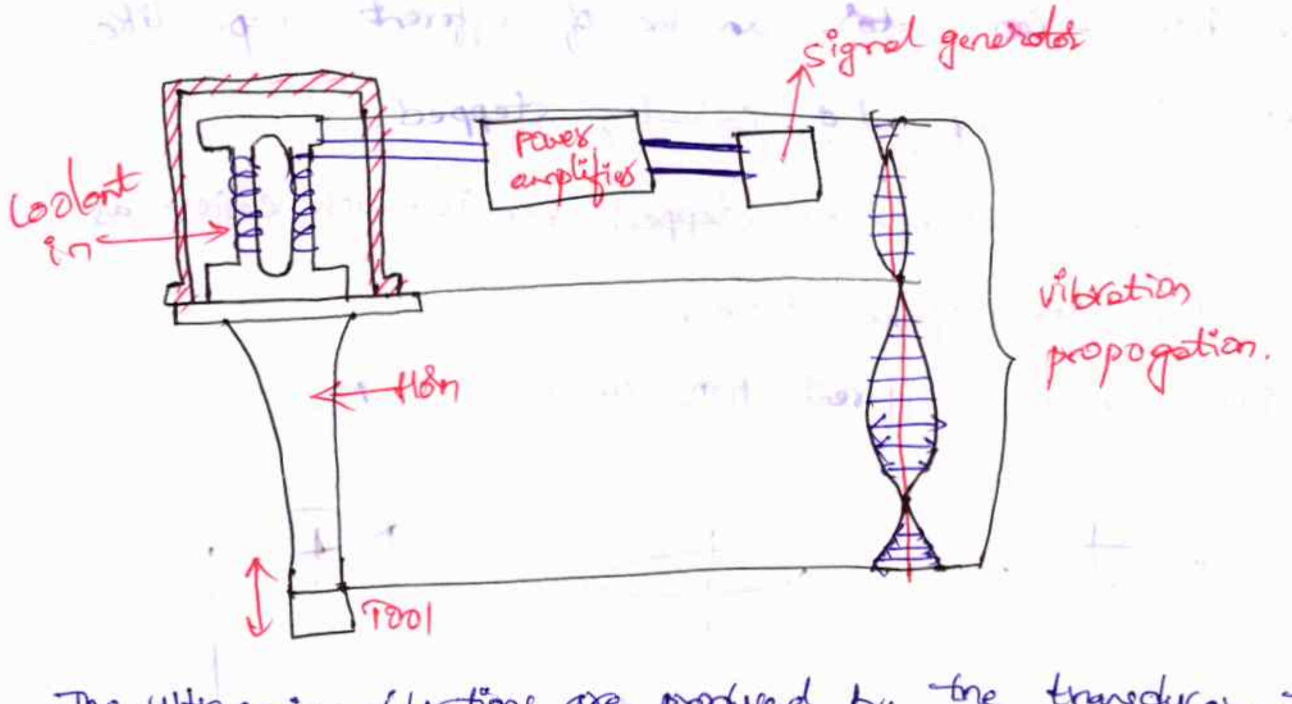
→ slurry delivery & return system.

→ Feed mechanism to provide a downward feed force on the tool during machining.

→ The transducer, which generates the ultrasonic vibration.

→ The horn or concentrator which mechanically amplifies the vibration to the required amplitude of 15–50 μm & the tool at its tip.

Working of horn as mechanical amplifier of amplitude of vibration :-



The ultrasonic vibrations are produced by the transducer. The transducer is driven by suitable signal generator followed by power amplifier.

→ The transducer for USM works on the following principle.

1) piezoelectric effect

2) Magnetostrictive "

3) Electrostrictive "

The Transducer for USM works on the following principle.

1) piezoelectric effect

2) magnetostrictive "

3) Electrostrictive "

→ magnetostrictive transducers are most popular & robust amongst all.

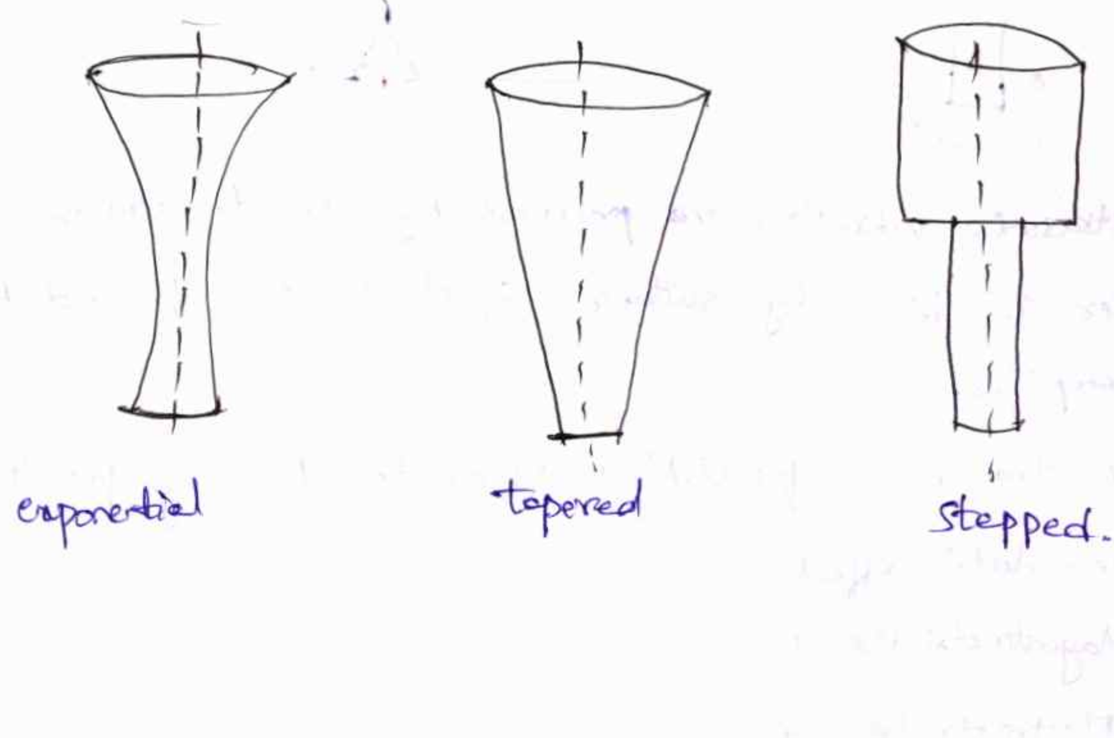
Figure shows a typical magentostrictive transducer along with horn.

The horn or concentrator is a wave guide, which amplifies & concentrates the vibration of tool from the transducer.

→ The horn or concentrator can be of different shapes like Exponential; Tapered or conical; stepped.

→ Machining of tapered or stepped horn is much easier as compared to the exponential one.

→ Figure shows different horns used in USM.



Process Variables :-

1) Amplitude of Vibration (a_0) — 15-50 μm.
2) frequency of Vibration (f) — 19-25 KHz
3) Feed force (F) — related to tool dimensions.
4) feed pressure (P)
5) Abrasive size — 15-150 μm.
6) Abrasive materials — Al_2O_3; SiC; B_4C; diamond; Boronsilicarbide.
7) Flow strength of work material
8) Flow " tool "
9) Contact area of tool — A
10) Volume concentration of abrasive in water slurry — C

Advantages

1) used for machining hard & brittle metallic alloys, Semiconductors, glass, Ceramics, Carbides etc.
2) used for machining round, square, irregular shaped holes & surface impressions.
3) machining, wire drawing; punching or small blanking dies.
4) USM process is a non-thermal; non chemical; creates no changes in microstructures, chemical or physical properties of the workpiece & offers virtually stress free machined surfaces.

→ Any materials can be machined regardless of their electrical conductivity.

→ especially suitable for machining of brittle materials.

→ machined parts by USM posses better surface finish & higher structural integrity.

→ It does not produce thermal, electrical & chemical abnormal surface.

Dis Advantages :-

It has higher power consumption & lower material removal rates than traditional fabrication process.

~~Tool wear fast in USM.~~

machining area & depth is restraint in USM

Applications :-

drilling → piercing of dies

grinding → welding operations on all materials

profiling (complex profiles) → wire drawing

coining

Elements of process :-

1) work material 2) Tool cone & tool tip

3) Abrasive slurry 4) ultrasonic machine

1) work material :-

In this process only by brittle fracture, the material is removed & so only brittle materials were machined by this process.

→ soft & ductile materials are usually cut more economically by other methods.

2) Tool cone & Tool Tip :-

The tool cone (horn) amplifies & focuses the mechanical energy produced by the transducer and imparts this to the w/p so that the energy utilisation is optimum.

→ The tool-tip is attached to the base of the cone by silver brasing, soft soldering & by means of screws.

→ The area of tool does not exceed the area of the small section of the cone by more than 10-15%.

→ The area of tip influences the rate of penetration.

→ The choice of the material for tool is very vital because the cost of making the tool & time required to change tools are critical factors in the economics of USM.

(3) Abrasive slurry :-

It is a mixture of abrasive particles & liquid commonly used abrasives are

a) Aluminium oxide (Alumina)

b) Boron Carbide

c) Silicon "

d) diamond dust

- Boron is the most expensive but is best suited for cutting tungsten Carbide, tool steel & precious stones.

-> silicon finds max app.

-> The problem with alumina is that it wears fast & soon loses its cutting power.

-> Alumina is best for cutting glass, germanium & Ceramics.

-> diamond & rubies are nicely cut by using diamond powder which ensures good accuracy, surface finish & cutting rates.

-> Boron Carbide is a new promising abrasive which has an abrasive power 8-12% greater than that of boron Carbide.

-> The size of abrasives Varies from 200 to 2000 grits.

-> Coarse grades are good for roughing, where as finer grades are used for finishing.

Liquid media:-

The abrasive is suspended in liquid. The liquid performs many functions.

a) Acts as an Acoustic bond b/w w/p & vibrating tool.

b) helps efficient transfer of energy b/w w/p & tool.

c) acts as a coolant.

d) provides a medium to Carry the abrasive to the cutting zone.

e) Helps to carry away the worn abrasive & swarf.

Characteristics of a good suspension media are :-

a) density, approximately equal to that of abrasives.

b) good wetting properties to wet the tool, work & abrasive.

c) High Thermal Conductivity & Specific heat for efficient removal of heat from the cutting zone.

d) low viscosity to carry the abrasive down the sides of hole b/w tool & w/p.

e) Non Corrosive

4) Ultrasonic machine :-

The main parts are a) Acoustic head

b) Tool feed mechanism

c) Abrasive feed system

d) generator

(a) Acoustic Head :- (Sound & vibration) It causes energy loss due to frictional heating in susceptible ferro magnetic cores.

The magnetostriction type of transducers which utilise the effect of longitudinal magnetostriction are now very common.

These may be made of Nickel, iron - Cobalt or iron - Al.

→ Nickel finds max app because of high strength & good insulating properties of Ni oxide film.

→ when an object is made of ferromagnetic (metallic alloys & rare earth magnets) material is placed in continuously changing magnetic field, a change in its length takes place.

Piezo electric crystals (Quartz) generates a small electric current when they are compressed.

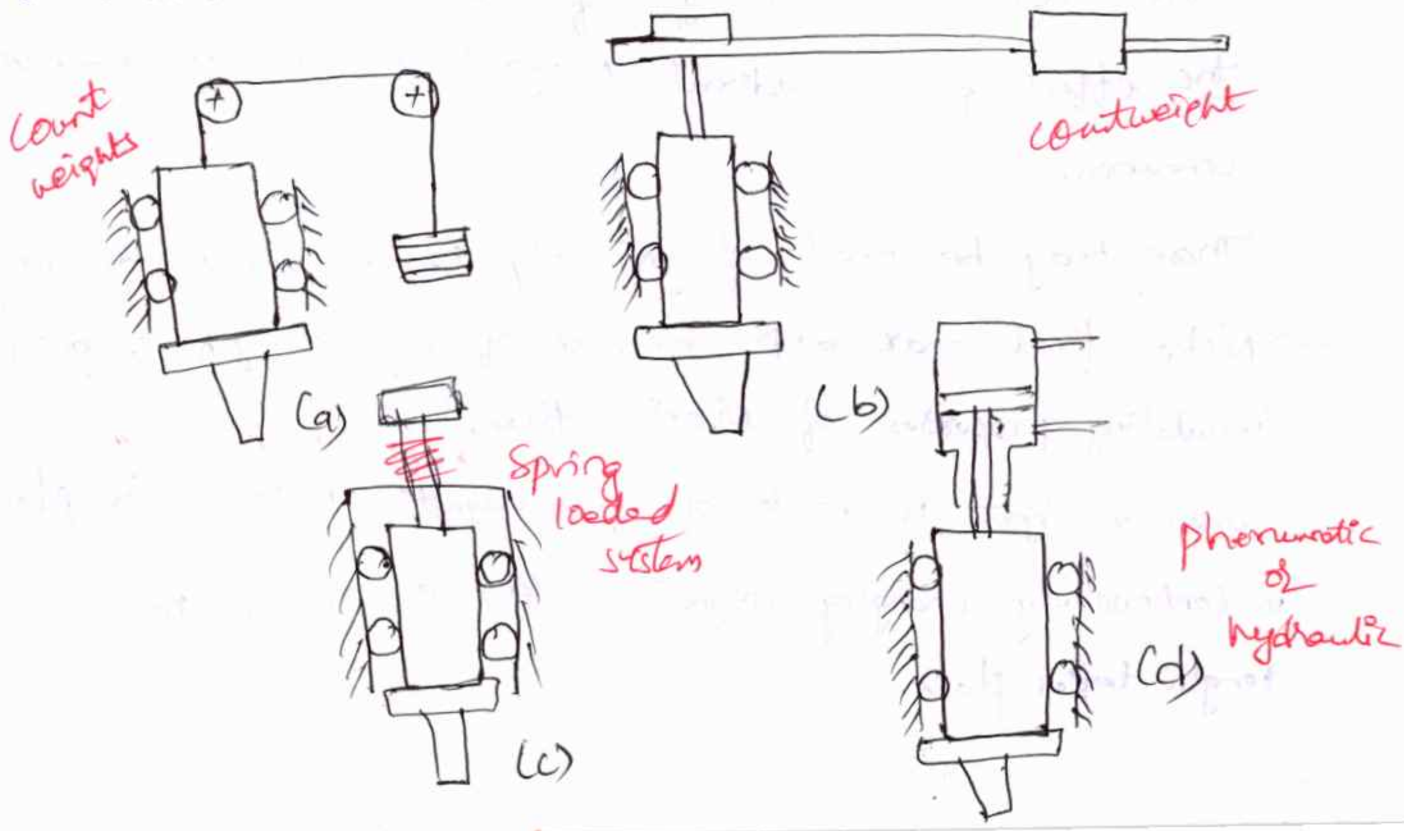
→ when an electric current is passed through the crystal, it expands.

→ when the current is removed the crystal attains its original size.

This is known as piezoelectric effect. Such transducers are available upto a power capacity of 900W.

(b) Tool feed mechanism :-

1) bring the tool very slowly close to the w/p.
2) provide adequate cutting force & sustain this during cutting.
3) decrease the force at a specified depth.
4) over run a small distance to ensure the required hole size at the exit.
5) Return the tool.



11 (2)

The figures a, b counter weights are used, the force being the difference b/w weight of head & that of the counter weight attached through a pulley or lever system.

Fig (c) shows a compact spring loaded system which is quite sensitive.

for high rating m/cs are peneumatic or hydraulic systems fig(d) may be used.

Abrasive Feed system:-

The abrasive slurry can be supplied by hand in a small m/c but for m/c's of higher power, a pump (usually centrifugal type) is used to supply the slurry through a Nozzle.

→ A good method is to keep the slurry in a bath in cutting zone.

→ Another effective method of supplying the slurry to the cutting zone is via a hollow tool or holes in w/p.

Generator:-

The requirements of a generator are reliability, efficiency, simplicity in design & low cost.

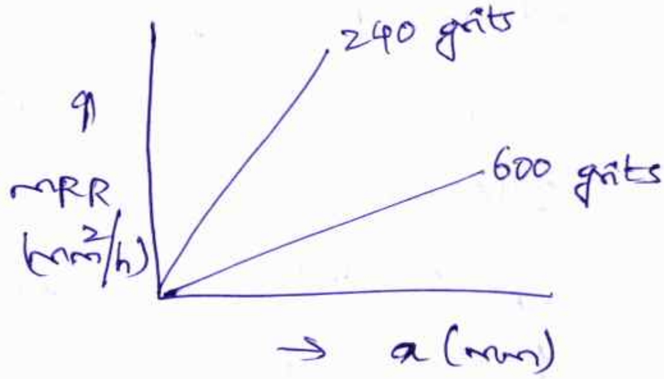
→ It is a device that converts motive power in to the electric power for use in an external circuit.

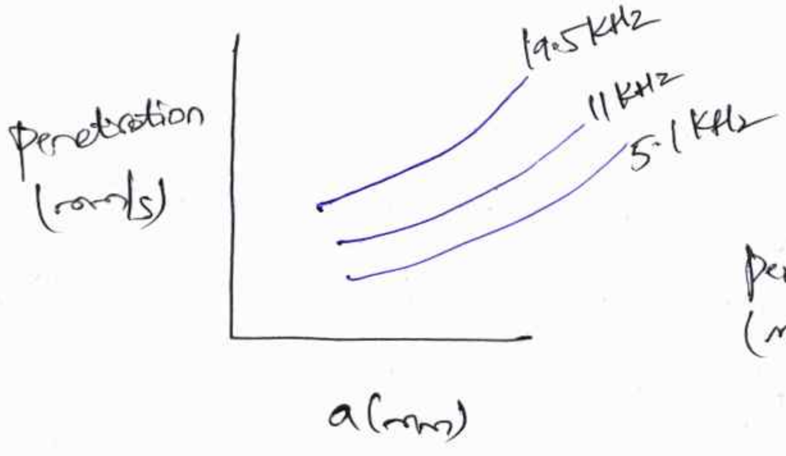
— Sources of mechanical energy include steam turbines, gas turbines, IC Engines.

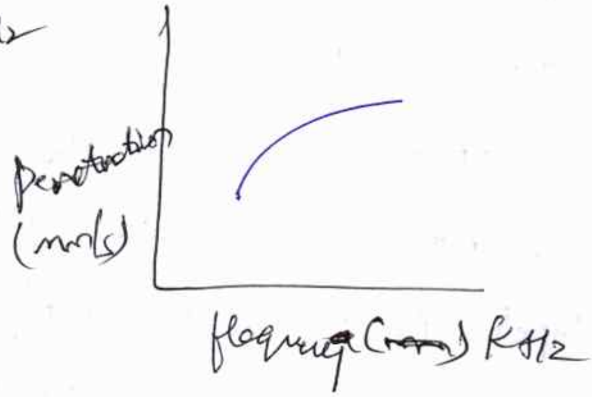
Effect of parameters :-

1) Amplitude & frequency of vibrations :-

Miller found that for a given material, MRR bears a linear relationship with amplitude.







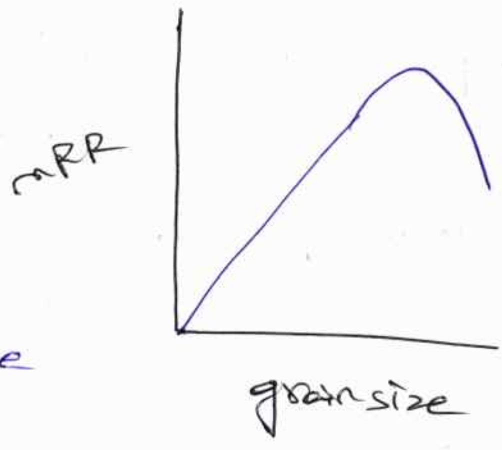
The results of Neppiras & Foskett indicated non-linear relationships b/w MRR & frequency as well as Amplitude.

→ Increasing the amplitude tends to increase the surface finish but the effect is minimal.

2) Grain Diameter :-

According to Goetze theory ; the cutting Rate (R) increases linearly with grain size.

→ Neppiras & Foskett indicated a Non linear effect of grain size on MRR.



→ There is a limit to the effect of grain size on rate as a very coarse (ముతక పొడి) powder may even cause a fall in rate as shown in fig.

The optimum size is governed by the amplitude of tool vibration.

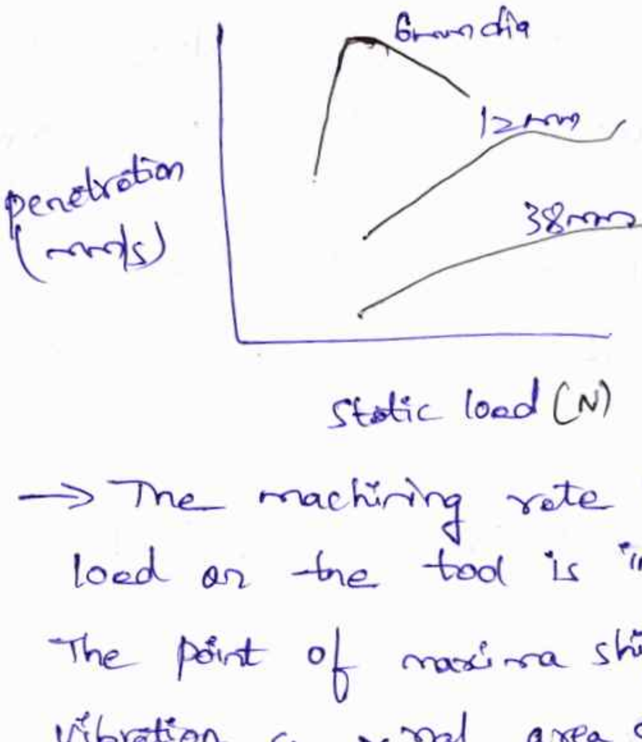
Surface finish is greatly influenced by grain size.

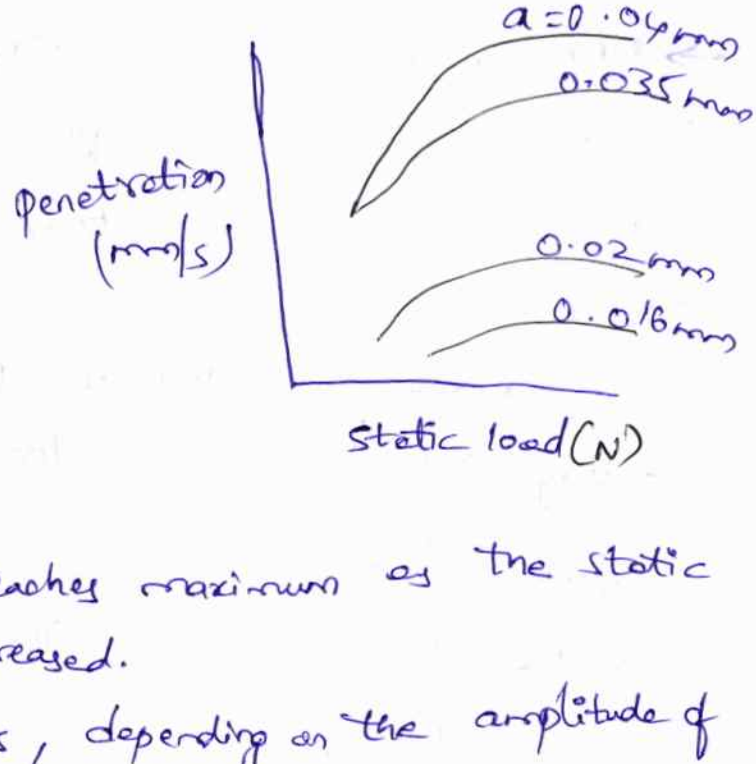
→ grain size determines the accuracy of cavity configuration in USM.

→ The hole cut is larger than the tool owing to the flow of abrasive along the sides of the hole to the bottom face of tool.

→ For accuracy & good surface finish, it is better to use a set of tools & more than one size of abrasive grits eg

3) Applied static load :-





→ The machining rate reaches maximum as the static load on the tool is increased.

The point of maxima shifts, depending on the amplitude of vibration & X-nal area of the tool.

→ Surface finish is found to be little affected by the applied static load.

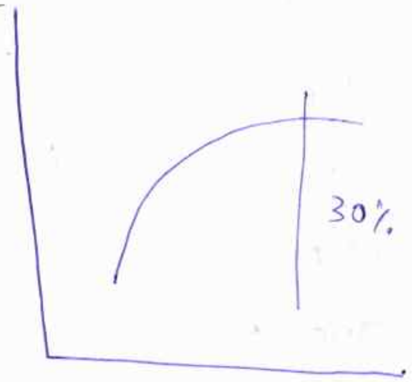
→ At higher loads, the grains are crushed to small size, ∴ Surface finish improves.

4) Slurry, tool & work material :-

→ a water mixture of insoluble water (sand, lime, plaster of paris)

The cutting rate increases with increase in slurry concentration saturation occurs when the volume of slurry is 30-40% abrasive/water mixture.
→ to finish & shape of w/p.

MRR



Concentration

→ The experimental results have shown a sharp drop in MRR with increasing viscosity.

→ The pressure of slurry fed in to the cutting zone has a remarkable effect on MRR.

→ MRR improves by improving slurry concentration.

→ The shape of tool face also affects the cutting rate.

→ ~~A narrow rectangular tool face also affects the cutting rate.~~

→ A narrow rectangular tool gives a greater cutting rate than a tool of same area with a square X^n.

→ The cutting rate is increased by 50% by replacing cylindrical tool with a conical one.

→ The brittle behaviour of the work material is important in determining the cutting rate.

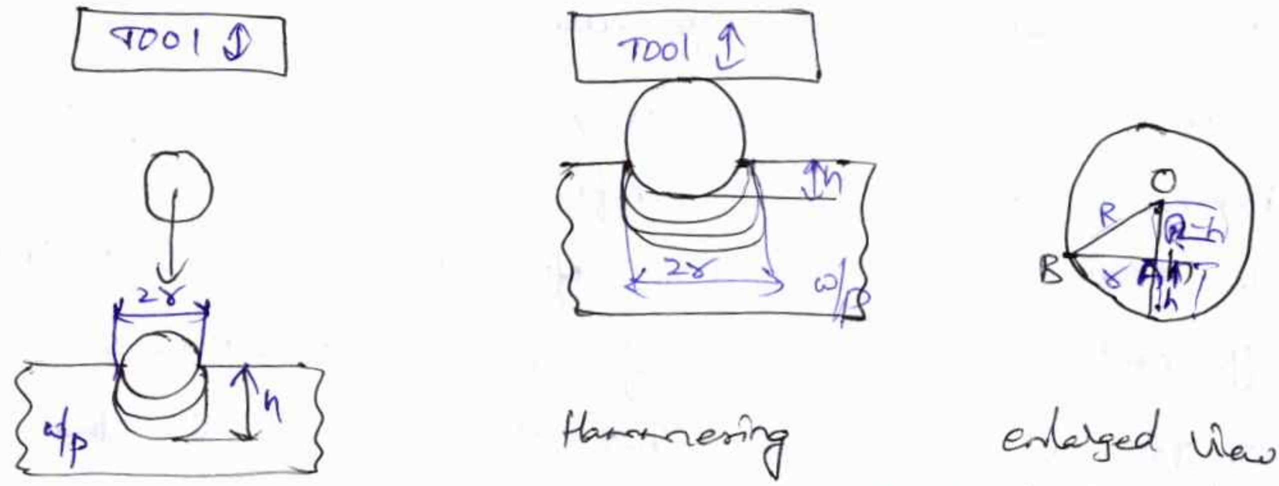
→ brittle non-metallic materials can be cut at higher rates than ductile materials.

MRR

$\frac{\text{w/p hardness}}{\text{tool hardness}}$

Mechanics of cutting :- (MRR) :-

Shaw model :-



Throwing — Hammering — enlarged view of Pentrated abrasive

Material removal during USM due to erosion (that removes soil, rock or dissolved material.) & cavitation (formation of vapour bubbles within a liquid at low pr regions) under tool & chemical corrosion due to slurry media are considered insignificant.

→ hence material removal Rate due to these two factors has been ignored.

→ Contributions to the material removal by abrasive particles due to throwing & hammering actions have been analyzed.

→ Abrasive particles are assumed to be spherical in shape having diameter as 'd' units.

→ Abrasive particles move under the high frequency of vibrating tool.

→ There are two possibilities when the tool hits on abrasive particle.

→ If the size of the particle is small & gap b/w the bottom of the tool & work surface is large enough, then the particle will be thrown by the tool to hit the work surface (throwing model).

→ under reverse conditions, the particle will be hammered over the work surface.

In both cases, a particle after hitting the work surface generates, a crater (large bowl shaped cavity in ground) of depth 'h' & radius 'r'.

→ It is also assumed that the volume of the particle removed is approximately proportional to the diameter of indentation (2R).

→ The volume of material removed due to fracture per grit per cycle (assuming hemi-spherical crater) is given by $V_g = \frac{1}{2}\left(\frac{4}{3}\pi r^3\right)$

$hyp^2 = adj^2 + opp^2$

$R^2 = r^2 + (R-h)^2$

$r^2 = R^2 - (R-h)^2$

from $\triangle OAB$, $r^2 = R^2 - (R-h)^2$

$= R^2 - R^2 - h^2 + 2Rh$

$= 2Rh - h^2$

$= 2Rh$ (or) Neglecting h^2, $h << D$.

Dh.

$\therefore V_g = \frac{1}{2}\left(\frac{4}{3}\pi r^3\right)$

$= \frac{1}{2}\left(\frac{4}{3}\pi r^2 \cdot r\right)$

$= \frac{2}{3}\pi\left(\sqrt{Dh}\right)^3$

$V_g = K_1 (Dh)^{3/2}$ $\quad K_1 = \frac{2}{3}\pi = \text{constant}$

No of impacts (N) on the workpiece by the grits each cycle will depend upon the no of grits beneath the tool at any time.

This is inversely proportional to the dia of grit.

$$N = K_2 \cdot \frac{1}{D^2} \qquad K_2 \rightarrow \text{Cons of proportionali}$$

let K_3 be the probability of an abrasive particles under tool being effective.

Volume of material removed/sec $V = f \times \text{vol of m/c/sec}$

~~$V = K_1 K_2 K_3 \frac{D^3}{6} \sqrt{\frac{h^3}{D}} \times f$~~

$$V = K_1 K_2 K_3 (Dh)^{3/2} \cdot \frac{1}{D^2} \times f$$

$$\boxed{V = K_1 K_2 K_3 \sqrt{\frac{h^3}{D}} \times f}$$

Model I (Grain Throwing model) :-

Assuming sinusoidal vibration;

t = time period ; $\frac{a}{2}$ = amplitude of oscillation.

displacement of tool $y = \frac{a}{2} \sin(2\pi f t)$

velocity of tool $\dot{y} = \frac{a}{2} \times 2\pi f \cdot \cos(2\pi f t)$

$$= \pi a f \cos(2\pi f t)$$

max vel of tool $\dot{y}_{max} = \pi a f \quad (\because \cos(2\pi f t) = 1)$

Assume that the grits also leave the tool with the same maximum velocity.

Then KE of a grit $= \frac{1}{2} m (\pi^2 a^2 f^2)$ $= \frac{1}{2} m v^2$

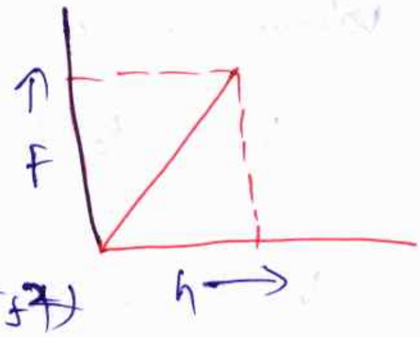
$\rho = m/v \Rightarrow m = \rho \cdot V$ $= \frac{1}{2}\left(\rho_a \times \frac{4}{3}\pi R^3\right)(\pi^2 a^2 f^2)$

$R = D/2$ $= \frac{1}{2}\left(\rho_a \times \frac{\pi D^3}{6}\right)(\pi^2 a^2 f^2)$

The KE of grit is absorbed by w/p before it comes to rest.

workdone by grit = KE of the particle.

Assuming triangular variation of force (F) with the depth of penetration.



$\therefore W = \frac{1}{2} \cdot F \cdot h$

$\frac{1}{2} \cdot F h = \frac{1}{2}\left(\frac{\pi}{6} D^3 \cdot \rho_a\right)(\pi^2 a^2 f^2)$

$h = \frac{\pi^3}{6} \frac{a^2 f^2 D^3 \rho_a}{F}$

mean stress acting on w/p $\sigma_\omega = F/A = \frac{F}{\pi r^2}$

(or) $\sigma_\omega = \frac{F}{\pi D h}$

$F = \sigma_\omega \cdot \pi D h$

$h = \frac{\pi^2}{6} \times \frac{a^2 f^2 D^2 \rho_a}{\sigma_\omega \cdot h}$

$h^2 = \pi^2 a^2 f^2 D^2 \cdot \frac{\rho_a}{6\sigma_\omega}$

(or)

$h = \pi a f D \sqrt{\frac{\rho_a}{6\sigma_\omega}}$

Volumetric material removal rate due to throwing mechanism,

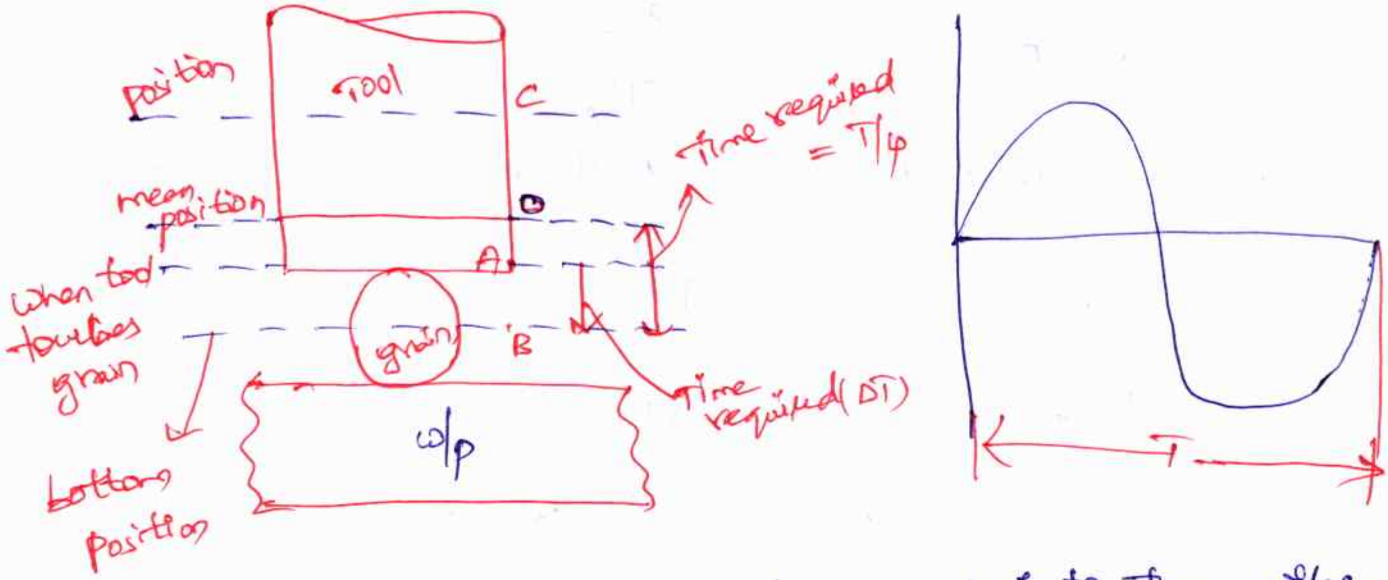
$$V_{th} = K_1 K_2 K_3 \sqrt{\frac{\left[\pi a f \cdot D \left(\frac{\rho_a}{6\sigma_w}\right)^{1/2}\right]^3}{D}} \times f$$

$$= K_1 K_2 K_3 \sqrt{\pi^3 a^3 f^3 D^2 \left(\frac{\rho_a}{6\sigma_w}\right)^{3/2}} \times f$$

$$= K_1 K_2 K_3 \; \pi^{3/2} a^{3/2} f^{3/2} D \left(\frac{\rho_a}{6\sigma_w}\right)^{3/4} \times f$$

$$V_{th} = K_1 K_2 K_3 \left(\frac{\pi^2 a^2 \rho_a}{6\sigma_w}\right)^{3/4} D \times f^{5/2}$$

Model-2 (Grain Hammering model)



Assume that the grains are hammered into the workpiece surface.

Force F applied to the abrasive grain acts for only a short time (ΔT) in one complete cycle of duration T.

The mean static force Favg can be written as

$$F_{avg} = \frac{1}{T}\int_0^T F(t)\,dt$$

F(t) = force at any instant of time (t)

Force on grit by tool starts increasing as soon as the grit gets in contact with both tool & w/p at the same time.

It attains max value & then starts decreasing until attains zero value.

∴ hence momentum eq can be written as

$$\int_0^T F(t)\,dt \cong \left(\frac{F}{2}\right) \times \Delta T$$

Total penetration due to hammering $h_n = h_w + h_t$

a/2 = amplitude of oscillation of the tool.

The mean velocity of tool during quarter cycle (from 6 to B) $= \frac{a/2}{T/4}$.

Time required to travel A to B; $= \Delta T = \frac{h_n}{\frac{a/2}{T/4}}$

$$\Delta T = \frac{h_n}{a}\cdot\left(T/2\right)$$

$$F_{avg} = \frac{1}{T} \times \frac{F}{2} \times \Delta T$$

$$= \frac{1}{T} \times \frac{F}{2} \times \frac{h_n}{a} \times T/2$$

$$F_{avg} = \frac{F}{4} \times \frac{h_n}{a}$$

$$F = F_{avg} \times \frac{4a}{h_n}$$

let N be the No of grains under tool stress acting on w/p, $\sigma_\omega = \frac{F}{N(\pi r^2)}$

$$\sigma_\omega = \frac{F}{N(\pi \times D h_\omega)}$$

$$\sigma_t = \frac{F}{N(\pi D h_t)}$$

$$\sigma_t \cdot N(\pi D h_t) = \sigma_\omega \times N(\pi D h_\omega)$$

$$\sigma_t = \sigma_\omega \times \frac{h_\omega}{h_t}$$

$$\sigma_\omega = \frac{F_{avg} \times \frac{4a}{h_n}}{N(\pi D h_\omega)} = \frac{F_{avg} \cdot \frac{4a}{h_n}}{\frac{K_2}{D^2}(\pi D h_\omega)}$$

$$= F_{avg} \times \frac{4aD^2}{h_n K_2 (\pi D h_\omega)}$$

$$= F_{avg} \times \frac{4aD}{\pi K_2 h_\omega (h_\omega + h_t)}$$

$$= \frac{4 F_{avg} a D}{\pi K_2 h_\omega^2 \left(\frac{h_t}{h_\omega} + 1\right)}$$

$$h_\omega = \sqrt{\frac{4 F_{avg} a \cdot D}{\sigma_\omega \cdot \pi K_2 (j+1)}} \qquad j = \frac{\sigma_\omega}{\sigma_t}$$

volumetric material removal rate from the w/p

$$V_h = K_1 K_2 K_3 \left[\frac{4a F_{avg}}{\sigma_w \pi K_2 (j+1)}\right]^{3/4} \times D^{\frac{1}{4}} \times f$$

$V_h >> V_{th}.$

→ find out the approximate time required to machine a hole of diameter equal to 6mm in a tungsten Carbide plate (fracture hardness = 6900 N/mm² = 6.9×10⁹ N/m²) of thickness equal to one & half times of hole diameter. The mean abrasive grain size is 0.015mm diameter. The feed force is ~~required~~ equal to 3.5N. The amplitude of tool oscillation is 25μm & frequency is equal to 25kHz. The tool material used is copper having fracture hardness equal to 1.5×10³ N/mm². The slurry contains one part abrasive to one part of water. Take $K_1 = 0.3$ $K_2 = 1.8$ mm² & $K_3 = 0.6$ abrasive density = 3.8 gm/cm³. Also calculate the ratio of volume removed by throwing mechanism to the volume removed by hammering mechanism.

$h_{th} = 1.78 \times 10^{-5}$ mm

$h_w = 2.192 \times 10^{-4}$ mm

$V_{th} = 4.97 \times 10^{-3}$ mm³/s

$V_h = 0.2146$ mm³/s

$V_{hn} >> V_{th}$

$V_h = 40 V_{th}$

$$T = \frac{\text{vol of hole}}{(V_{tn} + V_h)} = 19.289 \text{ min}$$

$$\text{Ratio} = \frac{V_{tn}}{V_h} = 0.023$$

Recent developments :-

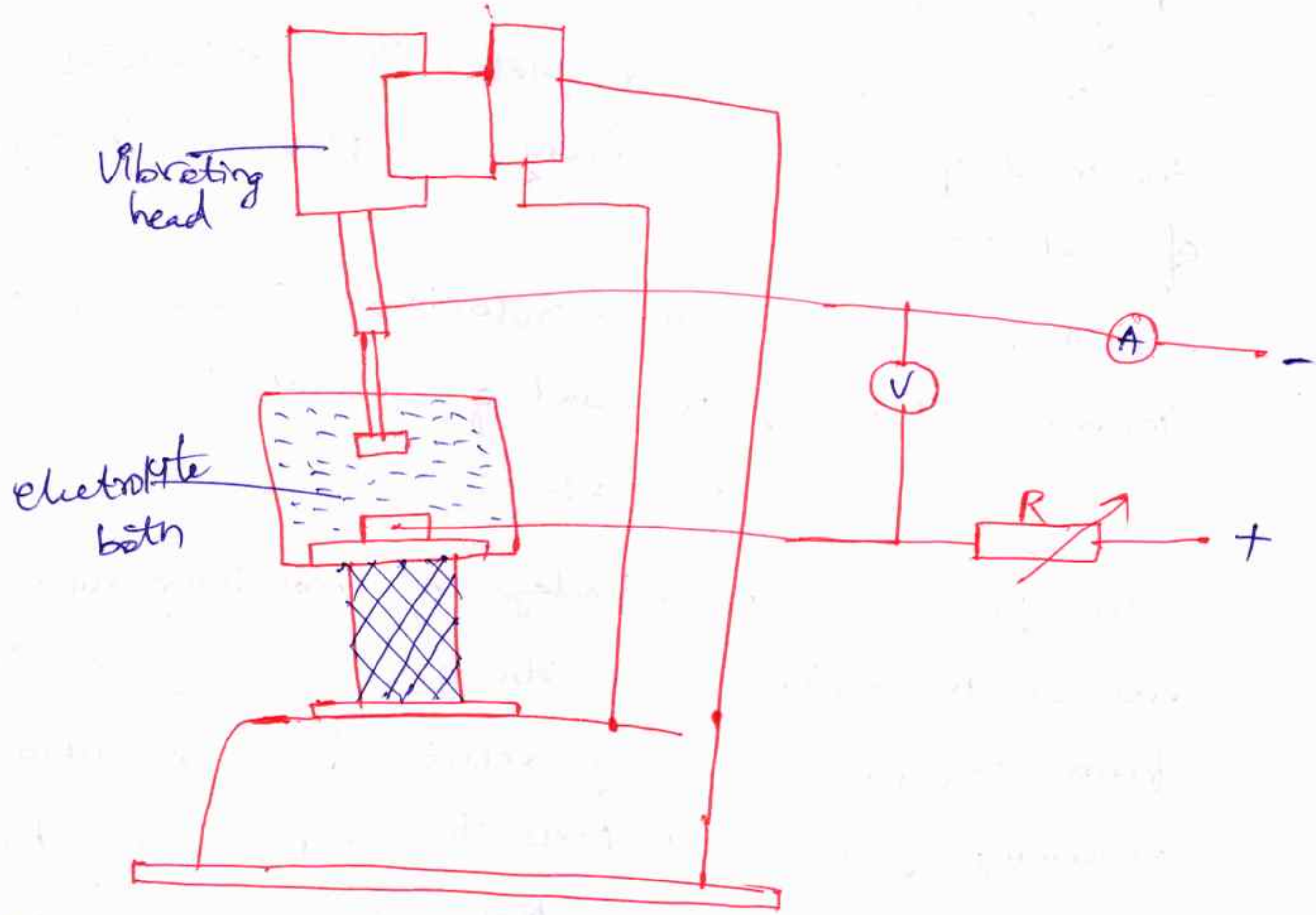


Fig:- Electrochemical reaction with ultrasonic abrasives.

Mullard Research Laboratories, USA, have developed a process that combines electrochemical reaction with ultrasonic abrasion.

Using a 60W ultrasonic drill & abrasive suspended in an alkaline electrolyte

Mullard researchers have reported that tool steel can be machined nine times faster than by ultrasonics alone.

→ Eng's limited of england has developed the disonic die ripper in which the diamond plate tool oscillates at ultrasonic speed as well as rotates at high speed (5000 rpm) in a liquid to rapidly remove material from tungsten carbide dies.

→ The use of diamond plated tool eliminates the need of abrasive slurry & frequent re-grinding of steel tools.

→ The oscillating - cum - rotational system is claimed to increase the m/l removal of several times.

Economic (cost) Considerations :-

The process has the advantage of machining hard & brittle materials to complex shapes with good accuracy & surface finish considerable economy results from the ultrasonic machining of hard alloy press tools, dies & wire drawing equipment on account of high wear resistance of tools made of these alloys.

The m/c's have no high speed moving parts. working on machines is not hazardous, provided care is taken to shield ultrasonic radiation, from falling on the body.

The power consumption of ultrasonic machining is 0.1 wh/mm³ for glass & about 5 w-h/mm³ for hard alloys.

The cost of manufacture & use of tools, particularly if they have complicated contours is very high.

→ another item adding to the cost of ultrasonic machining is abrasive.

→ The abrasive slurry has to be periodically replaced because during using the particles are eventually broken & blunted.

Ultrasonic m/c's are not yet completely reliable, failure sometimes occurs on account of faults in acoustic head, pump or generator.

It is probable that with more research in the near future on techniques & m/c's the process will have more economic advantages.

Abrasive Jet Machining (AJM)

Abrasive water Jet cutting is an extended version of water Jet cutting, in which water jet contains abrasive particles such as Silicon Carbide or aluminum oxide in order to increase the MRR above that of water Jet machining.

→ Almost any type of material ranging from hard brittle materials such as ceramics, metals & glass to extremely soft materials such as foam & rubbers can be cut by abrasive water jet cutting.

→ The narrow cutting stream & computer controlled movement enables this process to produce parts accurately & efficiently.

→ This machining process is especially ideal for cutting materials that Cannot be cut by laser or thermal cut.

→ Metallic, Non-metallic & advanced composite materials of Various thickness can be cut by this process.

→ This process is particularly suitable for heat sensitive materials that cannot be machined by process that produce heat while machining.

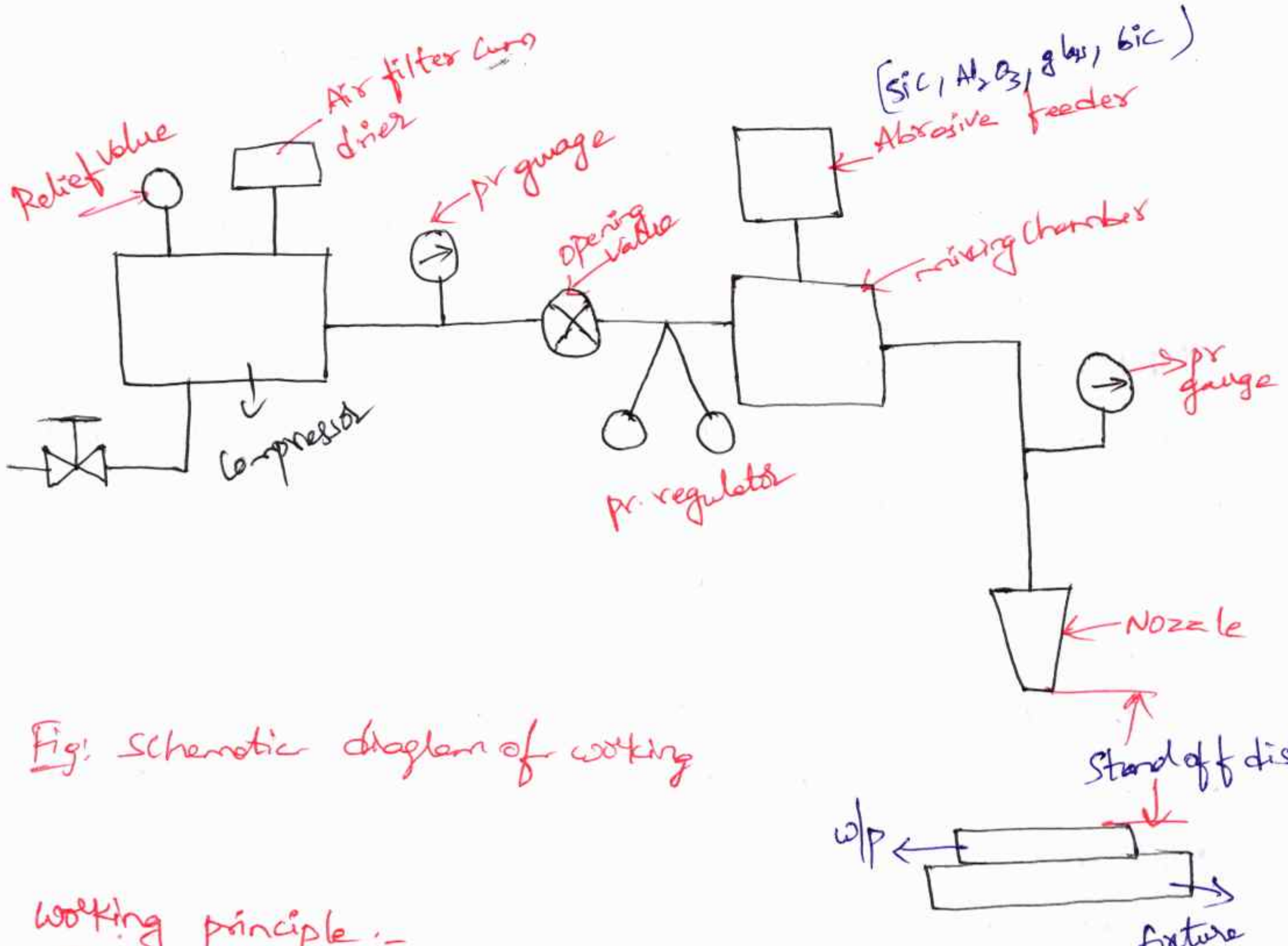
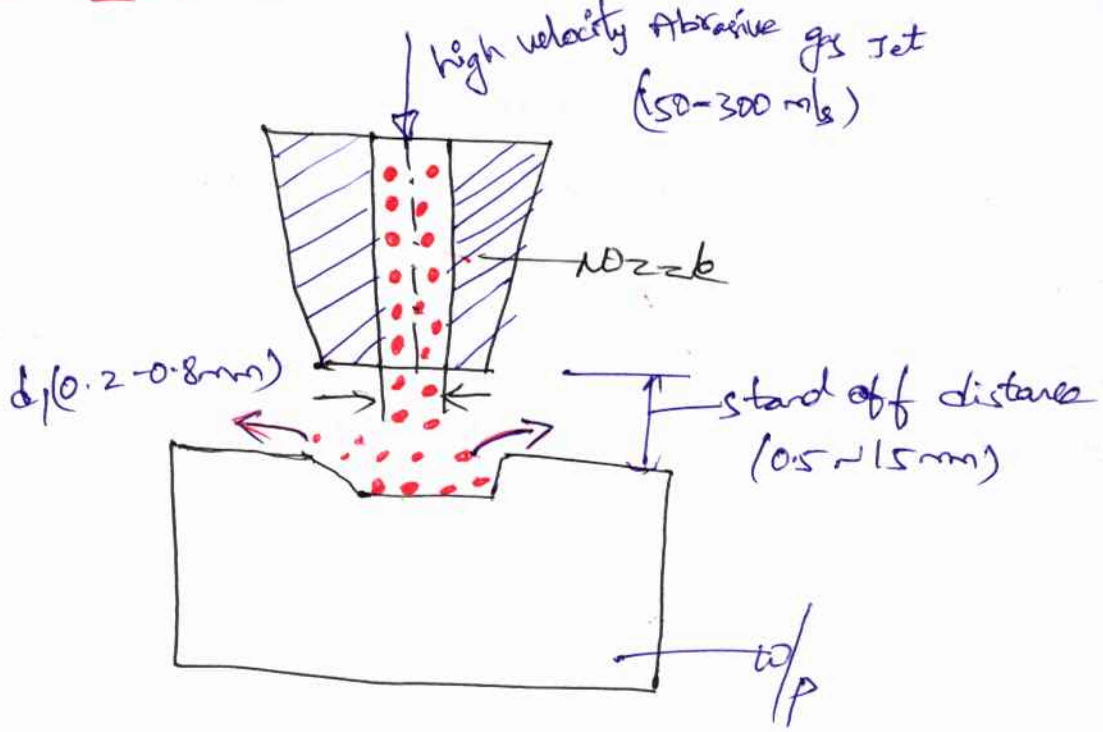


Fig: Schematic diagram of working

Working principle :-



A JM uses a stream of fine grained abrasive mixed with air or some other carrier gas at high pressure.

This stream is directed by means of a suitably designed Nozzle on the work surface to be machined.

→ Metal removal occurs due to erosion caused by the abrasive particles impacting the work surface at high speed.

→ The gas propulsion system supplies clean & dry gas (air, N_2 or CO_2) to propel the abrasive particles.

→ The gas may be supplied either by a compressor or a cylinder.

Elements :-

(1) Compressor :- The main function of a compressor is to provide clean & high pressure gas.

→ Air filter cum drier should be used to avoid water or oil contamination of the abrasive powder.

The gas should be non toxic, cheap & easily available.

It should not excessively spread when discharged from Nozzle into atmosphere.

2) Abrasive Feeder :-

Required quantity of Abrasive particles supplied by abrasive feeder.

In this particular sets abrasive quantity is controlled by inducing vibrations to the feeder.

The particles are propelled by carrier gas to a mixing chamber.

The Air Abrasive mixture moves further to Nozzle.

→ The Nozzle imparts high velocity to the mixture which is directed at the w/p surface material removal occurs due to erosive action of the jet of air-abrasive mixture impinging on the surface.

(3) Mixing chamber :-

The mixing chamber is well closed so that the concentration of the abrasive particles around working chamber does not reach to the harmful limits.

→ machining chamber is equipped with a vaccum dust collector.

→ speical consideration should be given to the dust collection system if the toxic materials (say beryllium) are being machined.

(4) Nozzle :-

The AJM Nozzle is usually made of tungsten Carbide or sapphire (usual life = 300 hr) which has high resistance to wear.

The Nozzle is made of either circular or rectangular c/s.

→ It is so design that a loss of pr due to bends, friction etc is minimum possible.

→ Its value depends upon the m/l of w/p & the desired charateristics of the machined surface (accuracy etc)

→ with an increase in the wear of a Nozzle, the divergence of jet stream increases resulting in more stray cutting & high inaccuracy.

→ The stray cutting can be controlled by the use of masks made of soft materials like rubber (for less accurate work or pool edge definition) or metals (for more accurate works or sharp edge definition).

mask covers only that part of the job where machining is not desirable.

5) Abrasives :-

Al_2O_3, SiC, glass beads, crushed glass & sodium bi carbonate are some of the abrasives used in AJM.

Selection of Abrasive depends upon the type of work material, MRR & machining accuracy desired.

Al_2O_3 is good for cleaning, cutting & deburring while SiC is also used for the similar applications but for harder work m/ls.

for obtaining matte finish, glass beads are good while Crushed glass performs better for giving sharp edges.

However cleaning, deburring & cutting of soft materials are better performed by sodium bicarbonate.

→ Small abrasive particles are used for cleaning & polishing.

→ while large particles perform better during cutting.

→ Fine grains are less irregular in shape.

hence their cutting ability is poor.

Reuse of abrasives is not recommended because of the two reasons.

→ Firstly abrasives get contaminated with metallic chips which may block the nozzle passage.

→ Secondly, cutting ability of used abrasive particles goes down.

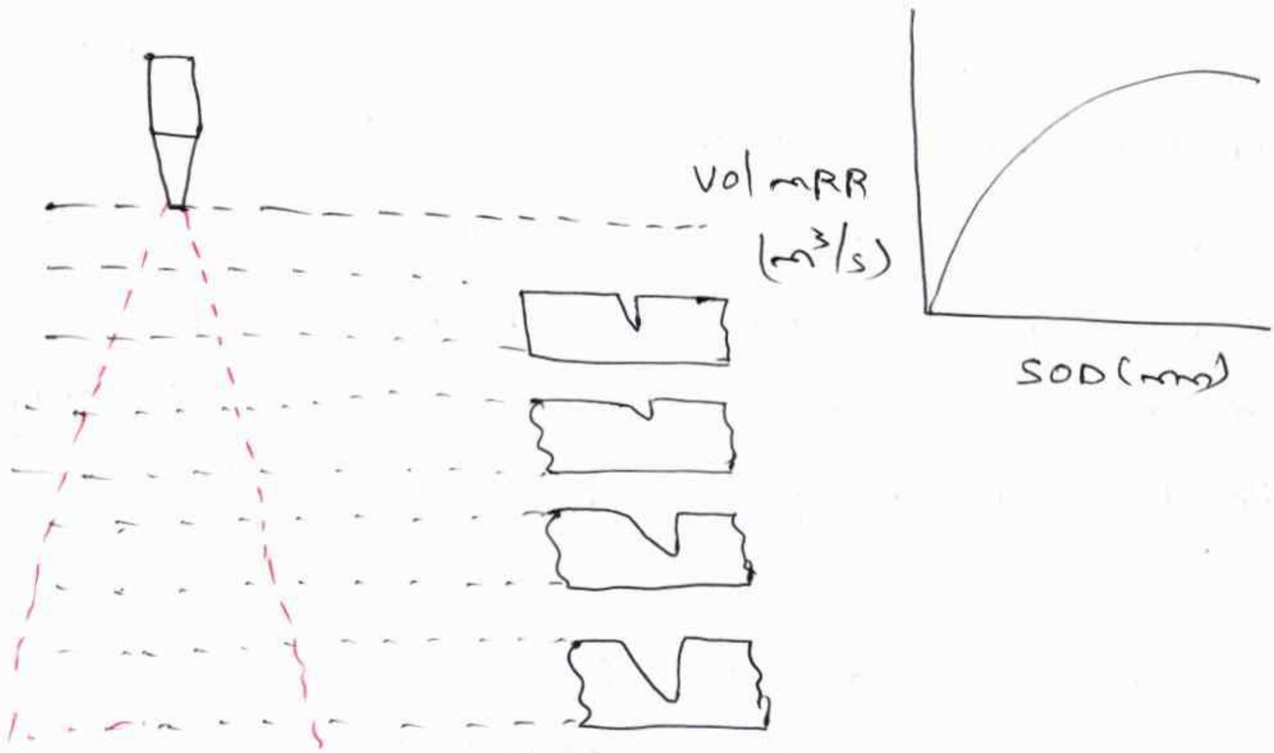
→ Further cost of abrasives is also low.

Process Variables :-

The variables that influence the rate of metal removal & accuracy of machining are :-

1) stand off distance
2) Type & size of abrasive particles
3) Jet Velocity
4) work material
5) Mixing Ratio.

1) stand off distance :-



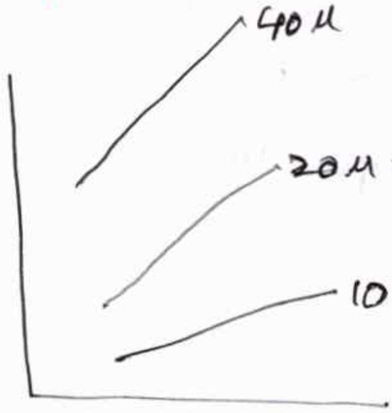
Effect of change in SOD on volumetric MRR is shown in fig. Cross sections of the actually machined profiles in the above figure show the shape of the machined cavity changes with a change in SOD.

The MRR is maximum when SOD is in b/w 0.75 to 1mm.

→ A decrease in SOD improves accuracy & reduces tapper in the machined groove.

However, light operations like cleaning, conducted with a large SOD (say 12.5–75mm)

(2) Type and size of abrasive particle:-



The choice of abrasive depends on the type of machining operation.

→ For example; roughing finishing, etc, work material & cost.

→ The rate of metal removal depends on size of abrasive grains.

→ Finer grains are less irregular in shape & hence posses lesser cutting ability.

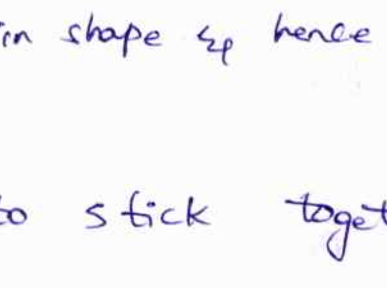
→ More over; finer grains tend to stick together & choke the nozzle.

→ The most favourable grain size range from 10 to 50 µ.

→ Coarse grains are recommended for cutting whereas finer grains are usefull in polishing, deburring etc.

The effect of grain size on MRR is shown in fig.

(3) Jet velocity:-



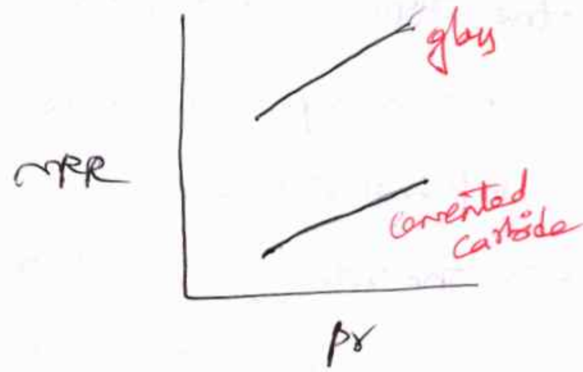
The jet velocity is a function of nozzle pressure, abrasive grain size & mean no of abrasives per unit volume of Carrier gas (mixing Ratio)

4) Work Material :-

AJM is recommended for the processing of brittle materials, such as glass, ceramics, refractories etc.

→ most of ductile materials are partically unmachinable.

→ The rate of metal removal has been found to depend upon the mohr's hardness of w/p to be machined.



5) Mixing Ratio :-

$$M = \frac{\text{volume flow rate of abrasive particles}}{\text{volume flow rate of Carrier gas}}$$

An increase in the value of 'm' increases, MRR but a large value of M, May decrease jet velocity & sometimes may block the nozzle.

Thus an optimum value of mixing Ratio has been observed that gives Max MRR.

Advantages of AJM :-

1) High surface finish can be obtained depending upon the grain sizes.

particle size (microns)	surface roughness (μm)
10	0.152 to 0.203
25-27	0.355 – 0.675
50	0.965 – 1.27

(2) Depth of damage is low (around 2.5 μm) [w/p damage].

(3) It provides cool cutting action, so it can machine delicate & heat sensitive material.

(4) process is free from chatter (sudden (thin sheets)) & vibration as there is no contact b/w tool & workpiece. (absorbs)

(5) Capital cost is low & it is easy to operate & maintain AJM.

(6) Thin sections of hard brittle m/ls like germanium, mica, silicon, glass & ceramics can be machined.

(7) It has the capability of cutting holes of intricate shape in hard materials.

Dis Advantages :-

(1) limited capacity due to low MRR. MRR for glass is 40 gm/min.

(2) Abrasives may get embedded (fixed firmly) in the w/p surface, especially while machining soft m/l like elastomers or soft plastics.

(3) The accuracy of cutting is hampered by tapering of hole due to unavoidable flaring (gas) of abrasive jet.

(4) over cutting is difficult to avoid.

(5) A dust collection system is a basic requirement to prevent atmospheric pollution & health hazards.

(6) Nozzle life is limited (300 hrs)

(7) Abrasive powders cannot be reused as the sharp edges are worn & smaller particles can clog (block) the Nozzle.

(8) short stand off distances when used for cutting the damages the Nozzle.

Applications :-

(1) This is used for abrading (wear again by friction) & frosting glass more economically as compared to etching or grinding.

(2) cleaning metallic means on ceramics, oxides on metals, resistive coatings etc.

(3) It is useful in manufacture of electronic devices, drilling of glass wafers, deburring of plastics, making of Nylon & Teflon parts, permanent marking on rubber stencils, cutting titanium.

(4) Deflashing small castings, engraving registration numbers on toughened glass used for carwind.

(5) used for cutting thin fragile components like silicon, germanium etc.

(6) micro module fabrication for electrical conduct, semi conductor processing can also be done effective.

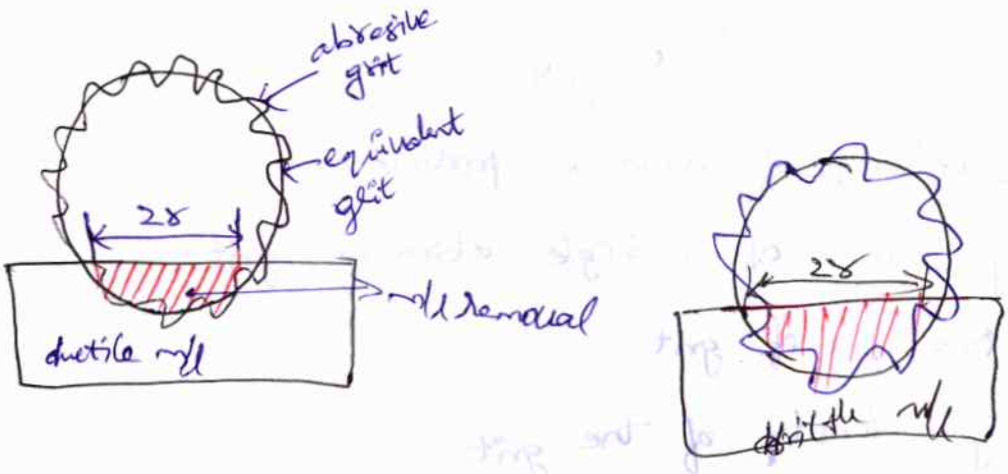
Mechanics Material Removal :-

Material removal in AJM takes place due to brittle fracture of work material due to impact of high velocity abrasive particles.

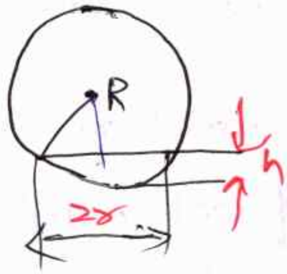
Assumptions :-

1) Abrasives are spherical in shape and rigid. The particles are characterised by the mean grit diameter.
2) The KE of the abrasives is fully utilised in removing material.
3) Brittle materials are considered to fail due to brittle failure & fracture volume is considered to be hemispherical with diameter equal to chordal length of the indentation. (M) 2r dist from center
4) For ductile material; removal volume is assumed to be equal to the indentation volume due to particulate impact.

→ The following schematic diagram shows the interaction of the abrasive particle & work m/l.



From the geometry of Identation;



$$r^2 = R^2 - (R-h)^2$$

Neglecting small terms; $r^2 = 2Rh$

$$r = \sqrt{2Rh}$$

∴ volume of material removal in brittle materials is the volume of the hemispherical impact crater;

$$V_B = \frac{2}{3}\pi r^3 = \frac{2\pi}{3} (Dh)^{3/2}$$

brittle

For ductile material; volume of material removal in single impact is equal to the volume of indentation & is expressed as $V_D = \pi h^2 \left(R - \frac{h}{3}\right)$

ductile $V_D = \pi h^2 R$.

K.E of a single abrasive particle is given by

$$KE = \frac{1}{2} m_g V^2$$

$$= \frac{1}{2} \left[\rho_g \times \frac{4}{3}\pi R^3\right] v^2$$

$R = \frac{D}{2}$

$$= \frac{1}{2}\left[\frac{\pi D^3}{6} \rho_g\right] v^2$$

$$= \frac{\pi}{12} D^3 \rho_g v^2$$

where V = velocity of abrasive particle

m_g = mass of a single abrasive grit

D = dia of grit

ρ_g = density of the grit

on impact, the work material would be subjected to a maximum force F which would lead to an indentation of 'h'. (7)

Thus work done during such indentation is given by

$$W.D = \frac{1}{2} F h$$

Now considering 'σ' as the stress or hardness of the work material, the impact force;

F = indentation area × hardness

$$F = \pi r^2 \times \sigma$$

Now as it is assumed that the KE of the abrasive is fully used for material removal; then work done is equated to the K.E.

$$\frac{1}{2} F h = \frac{1}{2} \pi r^2 h . \sigma$$

$$\frac{1}{2} \pi r^2 h \sigma = \frac{\pi}{12} D^3 e_g v^2$$

$$r^2 h \sigma = \frac{1}{6} D^3 e_g v^2$$

$$h = \frac{D^3 e_g v^2}{6 r^2 h . \sigma} \qquad r = \frac{D}{2}$$

$$h^2 = \frac{D^2 e_g v^2}{6 \sigma}$$

$$\boxed{h = D.V \sqrt{\frac{e_g}{6\sigma}}}$$

MRR in AJM of brittle materials;

$MRR_B = V_B \times$ No of impacts by abrasive grits per sec(N)

$= V_B \times \frac{m_a}{\text{mass of a grit}}$

where m_a = mass flow rate of abrasive (kg/min)

$$MRR_B = V_B \times \frac{m_a}{\pi/6 \, D^3 \, e_g}$$

$$= \frac{2\pi}{3} (Dh)^{3/2} \cdot \frac{m_a}{\frac{\pi}{6} D^3 \cdot e_g}$$

$$= \frac{4 m_a}{e_g} \left(\frac{h}{D}\right)^{3/2} \qquad \because h = DV\sqrt{\left(\frac{e_g}{6\sigma}\right)}$$

$$= \frac{4 m_a}{e_g} \left(\frac{D \times V}{D}\right)^{3/2} \left(\frac{e_g}{6\sigma}\right)^{3/4}$$

$$= \frac{4 M_a V^{3/2}}{6^{3/4} e_g^{1/4} \sigma^{3/4}} \simeq \frac{m_a V^{3/2}}{e_g^{\frac{1}{4}} \sigma^{3/4}}$$

$$\boxed{MRR_B \simeq \frac{m_a V^{3/2}}{e_g^{\frac{1}{4}} \sigma^{3/4}}}$$

$$MRR_D = V_D \times N$$

$$= \frac{\pi h^2 D \, 6 m_a}{2\pi D^3 \cdot e_g}$$

$$MRR_D = \frac{6\pi h^2 m_a}{2\pi D^2 \cdot e_g}$$

as $h = DV\sqrt{\frac{e_g}{6\sigma}}$

$$MRR_D = \frac{6 m_a D^2 V^2}{2 D^2 \cdot e_g}\left(\frac{e_g}{6\sigma}\right)$$

$$\boxed{MRR_D = \frac{1}{2}\,\frac{m_a \cdot V^2}{\sigma}}$$

Water Jet Machining (WJM)

This process is good for cutting & slitting of porous non metals like wood, leather, foam etc.

It is also used for cutting composites, wire stripping; and deburring.

quality of machined edge obtained during this process is usually superior to the other conventional cutting processes.

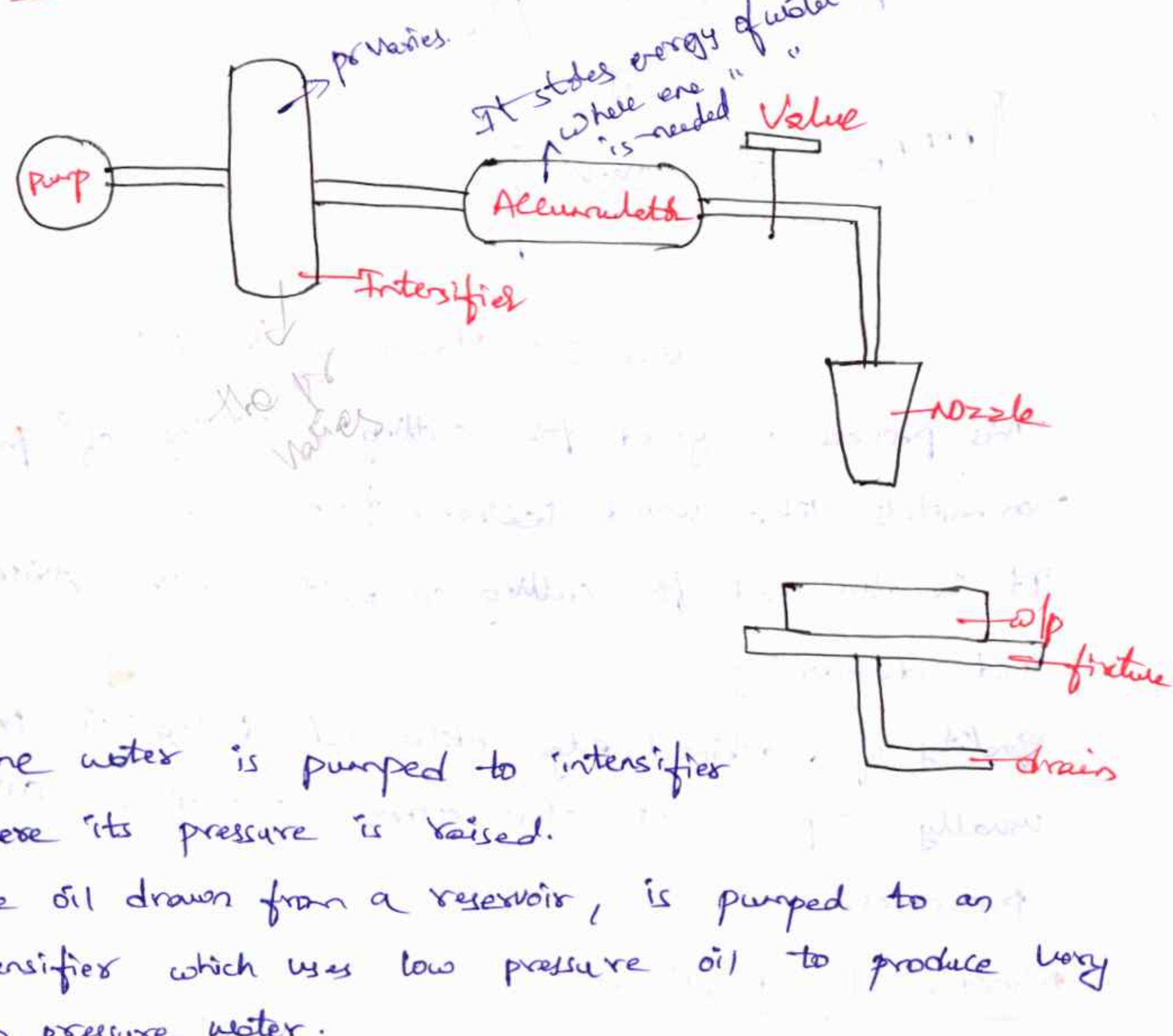
Principle of operation :-

If the Jet of water is directed at a target in such a way that on striking the surface, the high velocity flow is stopped, then most of KE of the water is converted into pressure energy.

Erosion occurs if the local fluid pressures exceed the strength of bond binding together the atoms of the material.

In other words, liquid jet cutting removes material by the mechanical action of a high velocity stream impinging on a small area.

working procedure of WJM :-



The water is pumped to intensifier where its pressure is raised.

The oil drawn from a reservoir, is pumped to an intensifier which uses low pressure oil to produce very high pressure water.

The intensifier produces water pressure as high as 40 times that of the oil.

water pressure can be determined as follows as :-

$$P_w = \frac{P_o \times A_o}{A_w}$$

where P_o = oil pr

A_o = oil piston Area

A_w = water " "

To minimize pulsation in water flow, a (9)
high pressure accumulator (to gives smooth outflow) is used.

→ The high pressure water coming from the accumulator is controlled by a control panel where it goes to the nozzle after passing through the stop start valve.

→ The jet coming out of the nozzle cuts the material from w/p & is then collected in a drain system.

Advantages :-

(1) water is cheap, Non toxic, readily available and can be easily disposed.

(2) water jet approaches the single point cutting tool.

(3) Any contour can be cut. Further operation is possible in horizontal & vertical planes.

4) The process gives a clean & sharp cut.

5) unlike conventional machining methods, this method does not generate heat. There is no danger of degrading the material thermally.

6) Best suited for explosive environments.

7) Dustless atmosphere - this is particularly advantages for cutting asbestos & glass fibers insulation materials which produce dust.

8) Noise is minimized as the power units & pump can be kept away from the cutting point.

9) No moving parts are present & ∴ less maintenance is required.

10) Jet takes away all the cutting residue & hence there are No pollution problems.

11) Fluid can be reused by filtering out the solids.

12) only a small amount of fluid is required (usual requirement is of the order of 100-150 lt/hr)

13) No tool changing.

Disadvantages of WJM :-

(1) limited No of materials can be cut economically.

(2) Thick parts cannot be cut by this process economically and accurately.

(3) Taper is also a problem with water jet machining in very thick materials.

Taper is when the jet exists the part at different angle than it enters the part & cause dimensional inaccuracy.

(4) The jet cannot drill blind holes or mill flat surfaces on the w/p.

Applications :-

1) cutting soft materials

2) Mining of coal

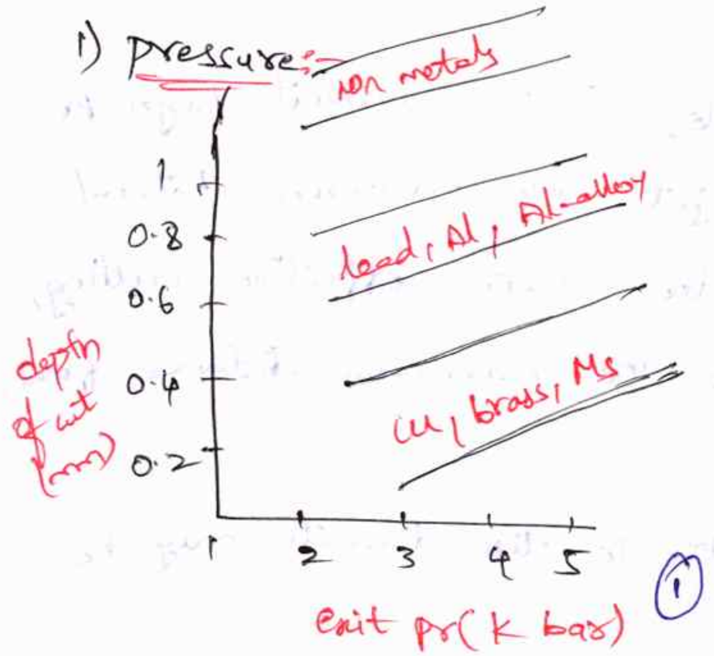
3) drilling

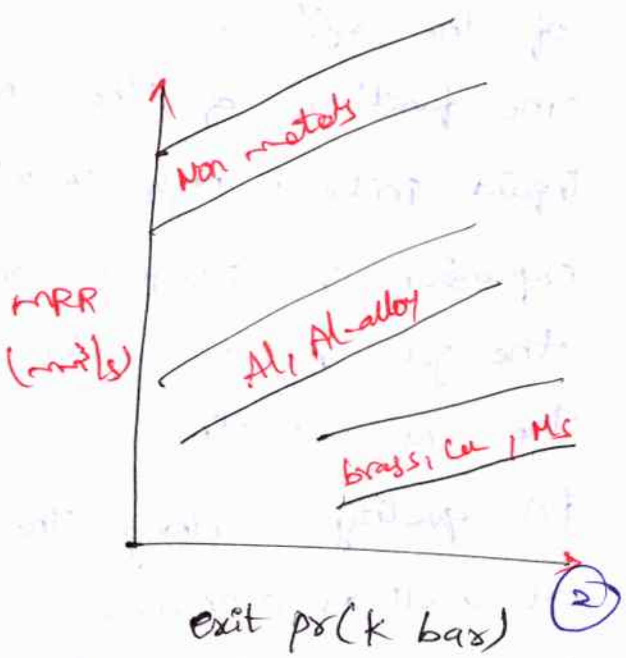
4) demolishing reinforced concrete

5) Cleaning & descaling
6) oil Refineries
7) chemical plants
8) power stations
9) cutting frozen food.

process characteristics :-

1) pressure :-





The feed rate, depth of cut (hence MRR) & quality of finish go up with increase in pressure with respect to the strength of the material.

Figs (1) & (2) shows the Variation range of groove depth & MRR with pr for various classes of materials.

(2) stand off Distance (SOD) :-

MRR increases with the increase of SOD upto a certain limit, after which it remains unchanged for a certain tip distance & then falls gradually.

Small MRR at low SOD is due to a reduction in Nozzle pressure with decreasing decroses where as a drop in MRR at large SOD is due to a reduction in the jet velocity with increasing distance.

(3) Nozzle diameter :-

The Nozzle is the most important & critical part of the system.

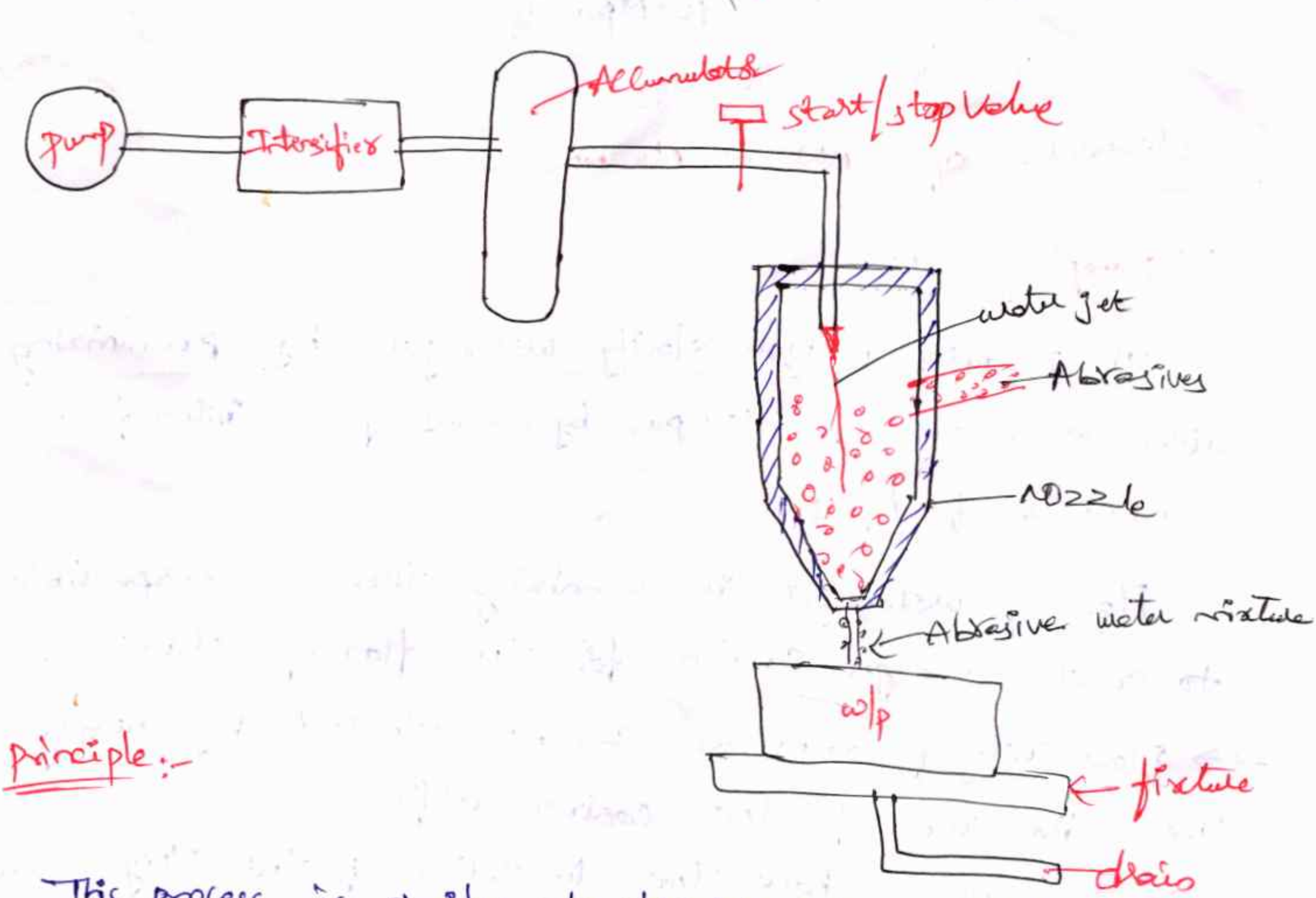
The function of the Nozzle is to convert high pr liquid into a high velocity jet with minimum lateral expansion & spray; and the ensure effective cutting, the jet must remain over the maximum distance from the Nozzle tip.

For quality cutting the Nozzle tip diameter may be as small as 0.05mm.

long exponentially tapered Nozzels have been developed to give better results.

However, these are much more complicated, difficult to manufacture & expensive.

Abrasive water Jet Machining (AWJM)



Principle:-

This process is similar to abrasive jet machining that in this case water is used as a carrier fluid in place of gas.

→ A water jet & a stream of abrasives coming from two different directions, mix up & pass through the abrasive jet nozzle.

— Here a part of the momentum of water jet is transferred to the abrasives.

— As a result, velocity of abrasives rises rapidly.

→ Thus a high velocity stream of mixture of abrasives & water impinges on w/p & removes m/l.

Depending upon the type of w/p material being cut, m/l removal may occur due to erosion, shear or failure under rapidly changing localised stress fields.

Pressure → 400 Mpa

Velocity → 900 m/s

Elements of AWJM Machine :-

(1) pumping system :-

It produces a high velocity water jet by pressurizing water to as high as 415 Mpa, by means of an intensifier.

(2) Abrasive feed system :-

Flow of water jet in a mixing tube is responsible to create enough suction for the flow of abrasives.

→ Flow rate of abrasives can be controlled by changing the diameter of the control orifice.

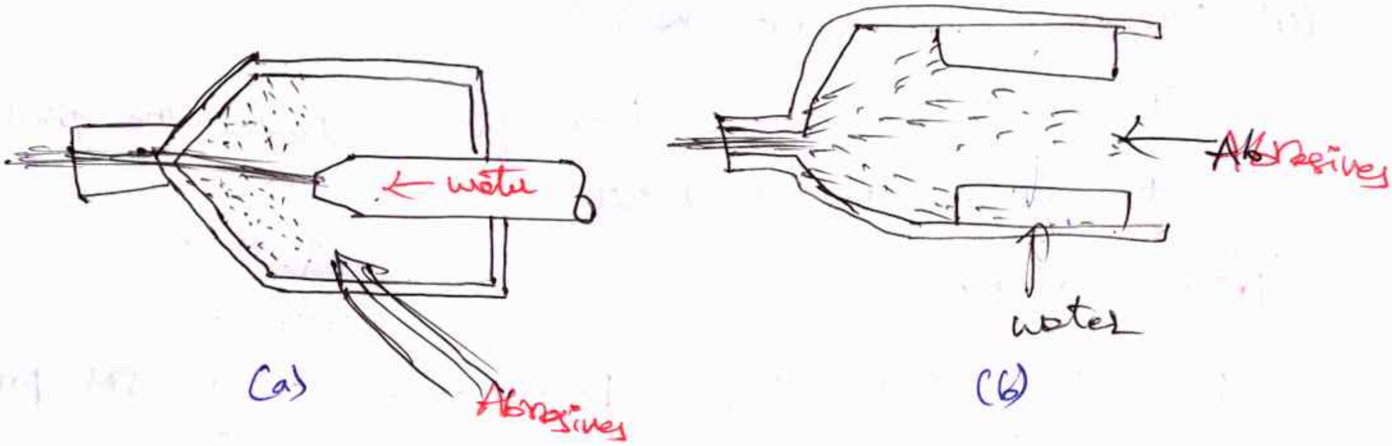
→ such systems have the limitations of that they cannot supply the abrasives over a long distance.

→ To overcome this drawback, researchers are developed a system in which it is possible to directly use slurry instead of mixing team in a Nozzle.

→ This system would make it possible to feed slurry over a long distance.

→ However it would require more than power than the power required by dry abrasive feed system.

(3) Nozzle :-



(a) (b)

It performs two functions. (a) Mixing of abrasive jet & water (b) to form a high velocity water abrasive jet.

→ It should give a coherent focused abrasive stream at exit from the nozzle which is made of sapphire, tungsten carbide (WC) or boron carbide.

→ There are two kinds of nozzels.

(a) single jet side feed nozzle

(b) multiple jet central "

In a single jet side feed nozzle, abrasives fed from the side mix with water jet in the mixing chamber.

→ This nozzle is less expensive, simple to make but does not provide an optimal mixing efficiency & experiences a rapid wear at exit part of the nozzle.

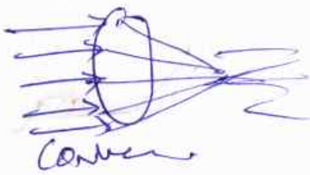
→ The multiple jets central feed nozzle consists of a centrally located abrasive feed system surrounded by multiple water jets.

→ It gives higher nozzle life & better mixing of abrasives in to the water jet.

However it is difficult & costly to fabricate such nozzles because of angle of convergence.

(4) Catcher :- (Turn to hit the)

It is a long narrow tube placed under the point of cut to capture the used jet.



process Variables :-

parameters which affect performance of AWJM process are water (flow rate & pressure), abrasives (type, size & flow rate), water nozzle & abrasive jet nozzle (design)., cutting parameters [stand off distance, tranverse speed & no of passes.]

a) water :-

(i) pressure :-

Relationships b/w pressure & depth of cut for different abrasive flow rates & nozzle diameters are shown in fig.

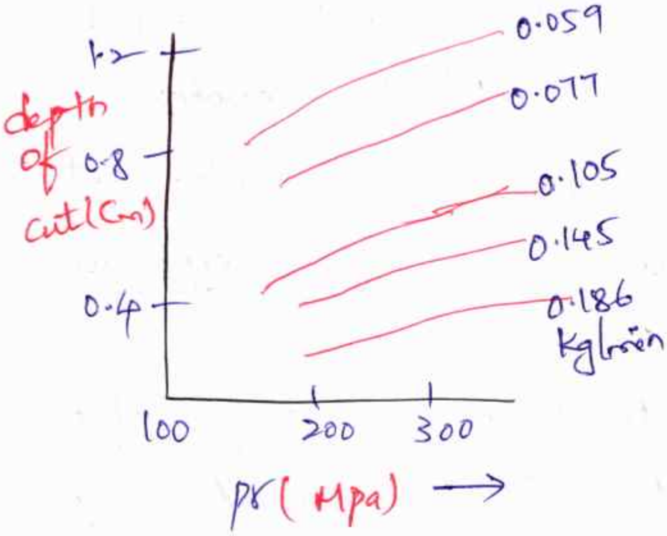


fig ①

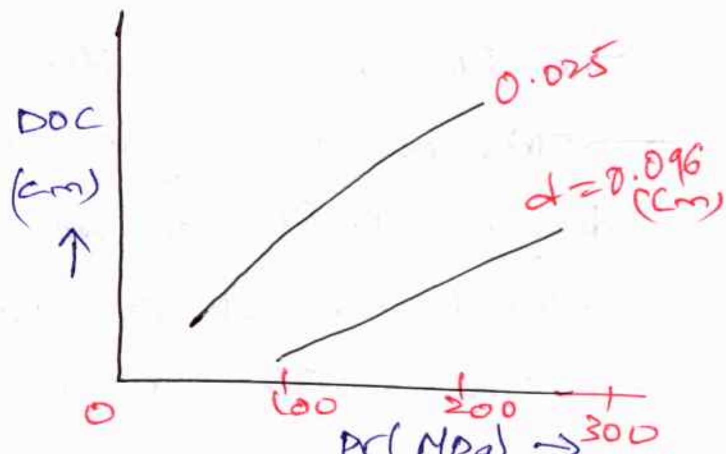


fig ②

Fig(1) shows the effect of water jet pressure on the depth of cut for various abrasive flows.
fig(2) shows the relationship b/w depth of cut & water jet pressure for two nozzle diameters.

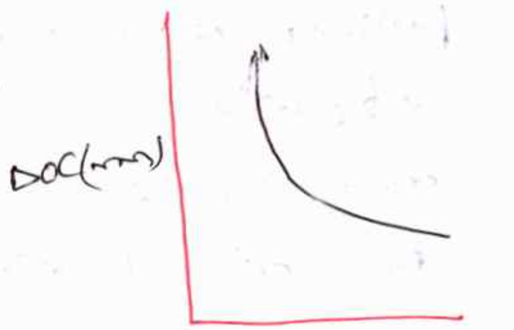
→ There is a minimum pressure (i.e critical pr & threshold pr) below which no machining would take place of critical pressure is different for different workpiece material.

→ The DOC increases with increase in abrasives flow rate.

→ An increase in pressure also increases the rate of nozzle wear & cost of pump maintenance lowers volumetric efficiency.

(2) Flow rate :-

→ In AWJM, high water flow rates (0.1–5 kg/min) are required to accelerate abrasives to high velocities over (300 m/s).

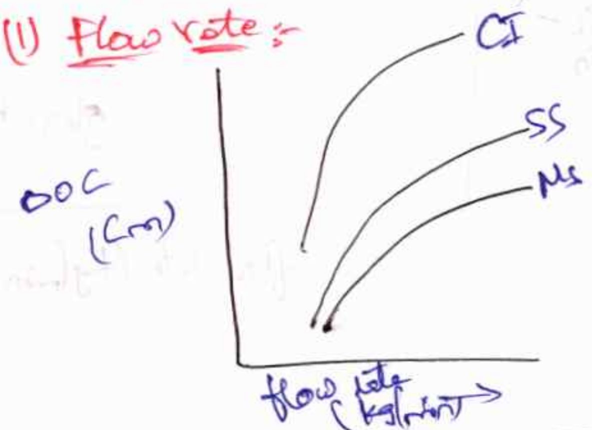


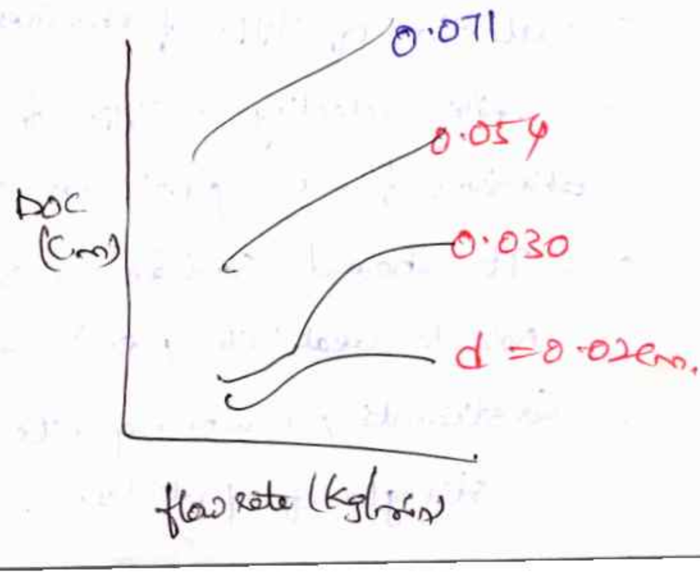
→ water flow rate is proportional to square root of pressure ($Q \propto \sqrt{P}$) & square of diameter of the nozzle ($Q \propto d^2$)

→ It is concluded from the experimental study that a percentage increase in depth of cut is always low.

(b) Abrasives :-

(1) Flow rate :-





DOC is proportional to the abrasive flow rate ($\dot{m}_a$) & sq of particle velocity (v_p).

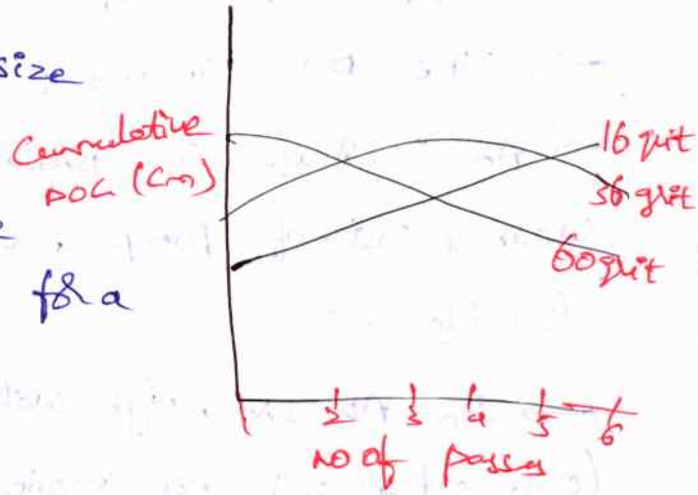
However an increase in abrasive flow rate beyond critical value would reduce machined depth.

→ Increase in abrasive flow rate enhances wear rate of mixing nozzels & reduces mixing efficiency inside the nozzle.

(2) particle size :-

Commonly used abrasive particle size ranges from 100-150 grits.

There is an optimum particle size for a particular w/p m/l and also for a particular nozzle mixing chamber configuration.



mesh size 60 is more effective for relatively low DOC obtained with two passes during machining of SS.

→ Approximate diameter of abrasive grit can be obtained from following eq $d_n = \frac{0.6 \times 25.4}{S}$ S = mesh size.

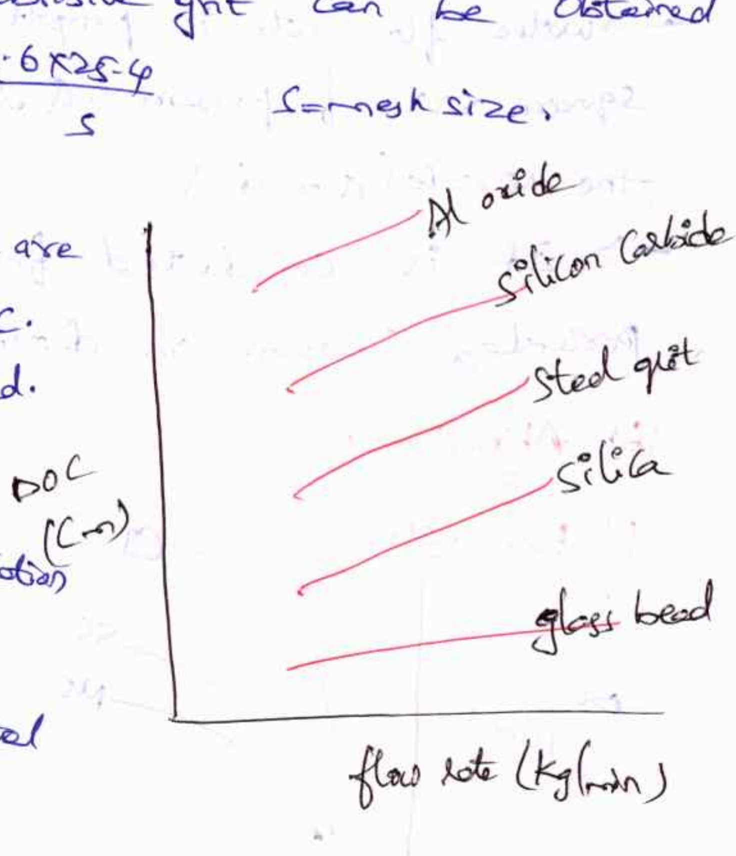
(3) Abrasive m/l :-

Garnet, silica & silicon carbide are commonly used abrasives in AWJC.

→ Selection of type of abrasives used.

→ while selecting a type of abrasives for a particular application

→ It should consider cost, nozzle wear rate, environmental constraints, machining rate & strength of particles.



(c) cutting parameters :-

1) transverse speed :-

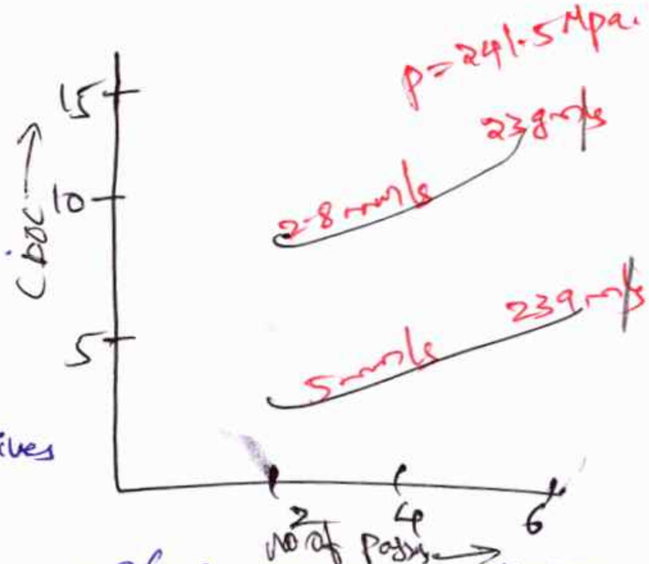
A decrease in transverse rate increases the DOC.

2) No of passes :-

multiple passes can be employed in following two different ways.

→ single jet with multiple passes.

multiple " single "



→ In case of a single water jet, whole power & quantity of abrasives are used by a single jet.

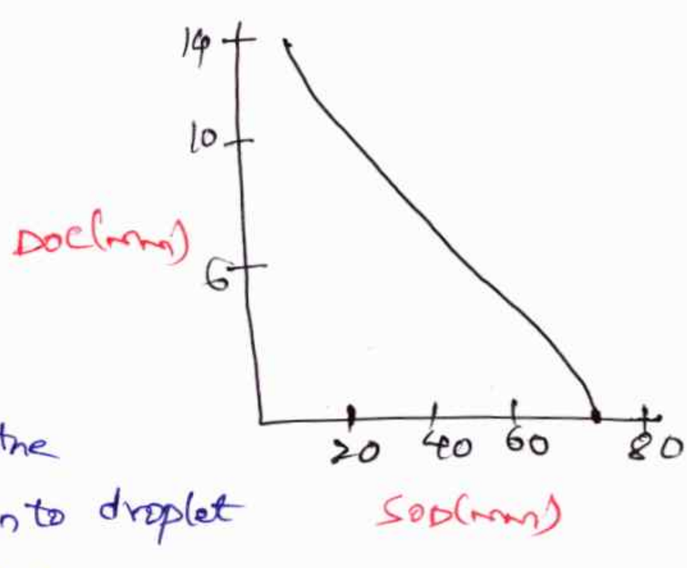
→ while in second case; both available power & abrasives are divided among the multiple jets.

→ fig shows a relationship b/w no of passes & Cumulatile DOC.

(3) SOD :-

p = 241.5 mpa ; v = 2.5 m/s

m = 15 g/s



An increase in SOD, rapidly decreases with machined depth as shown in fig.

This has been explains that the liquid phase of jet breaks up into droplet resulting in free abrasive particles.

→ These free abrasives particles rebound upon the impact that leads to a shallow penetration.

→ There is an upper value of SOD beyond which the process will no longer do the cutting.

than a percentage increase in water flow rate.

→ Increase in water flow rate beyond a certain value may result in insignificant gain in particle velocity, high pr losses.

(16) (15)

Advantages :-

1) No heat affected zone.

2) low cutting forces on w/p.

3) No Burr → burrs are unwant m/l remaining on w/p after being machined.

4) Can cut any material & thickness.

5) Can achieve high accuracy upto ± 0.001

6) In most of the cases, no secondary finishing is required.

7) smaller kerf size reduces material wastages.

8) eliminates thermal distortion.

9) precise, multi plane cutting of contours, shapes & bevels of any angle.

Limitations :-

1) High capital cost & high noise levels during operation.

2) surface finish degrades at higher cut speeds which are frequently used for rough cutting.

3) Cannot cut materials that degrades quickly with moisture.

Applications :-

1) stone & tile machining

2) metal & non metal cutting

3) Aerospace machining (no heat affected edge)

4) Automotive parts manufacturing

5) Gasket manufacturing (rubber products)

6) Glass/ceramics (cutting) machining.

UNIT-3 → Electro Chemical Processes

Electro Chemical Machining :- (ECM) :-

The word Machining means removal of any substance & the word electrochemical resembles the mode of energy used.

ECM :- It is a process of removing metal with the help of the electrolysis process.

The process is also known as reverse of the electroplating process, in electroplating, the metal is deposited on the surface of w/p, while in electrochemical machining the metal is removed from the w/p.

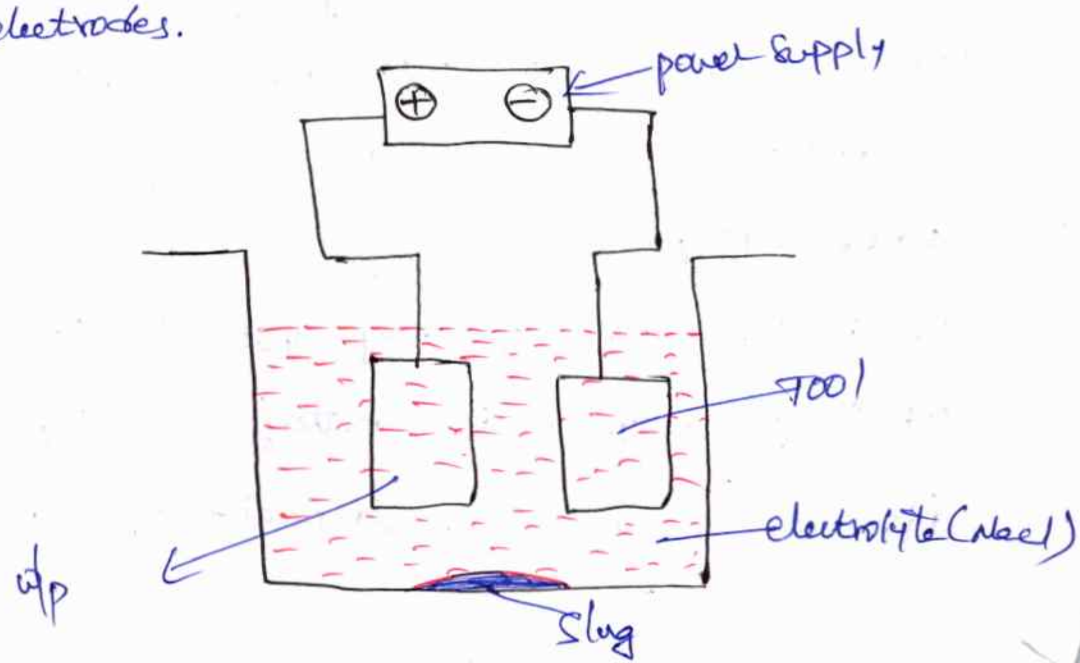
This process is used for large-scale production of machined parts.

principle of ECM :-

The ECM process is based on Faraday's law of electrolysis.

Faraday's law of electrolysis :-

It states that when two electrodes anode (+ve) & Cathode (-ve) are placed in an electrolyte the mass of the metal deposited on the Cathode coming from the anode is directly proportional to the potential difference applied across the electrodes.



Conceptual EC Model :-

NaCl is used as an electrolyte, the w/p is placed as the anode, tool is used as cathode & a potential difference is applied.

There is a very small gap b/w w/p & tool for removal of m/l.

As soon as a potential difference is applied b/w anode & cathode, the ions start moving from anode to cathode.

The negative ions are attracted towards the w/p which is placed at the +ve potential & positive ions are attracted towards the tool which is placed at -ve potential.

→ The chemical reaction taking place in basic process of ECM are as follows :-

$$2H^+ + 2e^- = H_2$$

Hydrogen ions gain electrons & get converted into hydrogen gas.

$$Fe = Fe^{++} + 2e^-$$

The iron atom releases its 2 electrons & gets converted into iron ions.

$$Na^+ + OH^- = NaOH$$

$$Fe^{+2} + 2Cl^- = FeCl_2$$

Sodium ions react with hydroxyl ions to form NaOH.

Iron ions reacts with chlorine ions to form iron chloride (slag)

Construction :-

(1) power supply :-

It is the source of energy that is provided to the setup.

It is generally a DC battery consisting of a potential difference from 3 to 30V depending upon the requirement.

(2) Electrolyte :-

An electrolyte is a salt solution in which w/p & tool are kept during the process of machining.

It acts as a current-carrying medium b/w w/p & tool.

→ It also helps in the removal of waste products from internal gaps & also acts as a coolant by preventing overheating of tool & w/p.

→ different electrolytes used in ECM are NaCl, $NaNO_3$, HCl etc.

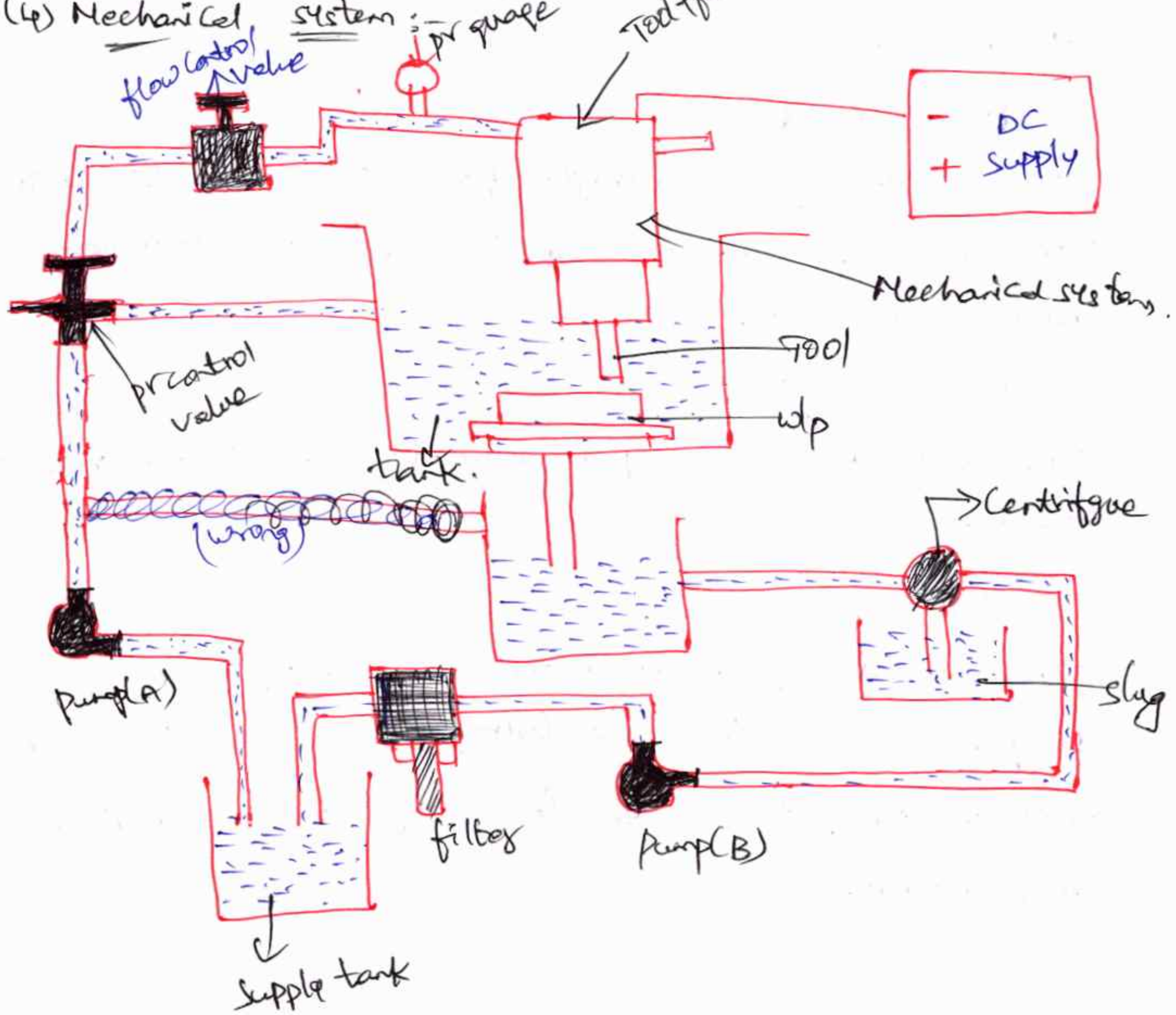
(3) Tool :-

Tool & cathode used in ECM is one of the electrodes.

→ It is also the desired shape in which w/p is to be cut.

→ The tool used in ECM should always have accurate dimensions.

(4) Mechanical system :-



one of the most important elements in ECM is the mechanical system.
It is used for the advancement of a tool that is to the w/p & is at a constant velocity.

(5) Tank :-
It contains the electrolyte, tool & w/p. All the reactions take place here.

(6) pressure gauge :-
It is used to measure the pr of electrolytes which is supplied to the tool.

(7) Flow control valve :-
It is used to control the flow of electrolyte which is supplied to the tool.

(8) pressure Relief valve :-
In case the pr of electrolyte flow exceeds a certain limit, the pr relief valve opens &. it sends the electrolyte back to the tank.

(9) Reservoir tank :-
The tank that stores pure electrolytes is called reservoir tank.

(10) pump :-
There are two pumps used namely A & B.
pump A is used to draw electrolytes from the reservoir tank & pump B is used to supply the electrolyte to reservoir tank.

(11) filter & centrifuge

A filter is used to filter the electrolyte reaching the reservoir tank.

It prevents the accumulation of excess electrolytes.

The function of a centrifuge is to separate the slug from the electrolyte.

(12) slug container :-

A slug container is used to store the slug which is separated from the electrolyte.

The slug can be used for various experimential purposes.

Working :-

The machining starts with the advancement of tool towards the w/p.

The tool & w/p are kept in a suitable electrolyte with a very small gap b/w them.

As soon as the potential difference is applied (DC), the w/p starts behaving as an anode & tool starts behaving as a cathode.

When the condition of electrolysis is fulfilled, the removal of metal from w/p starts.

The removal takes place according to the shape of the tool. m/l is removed from w/p & gets settled down in the form of a slug, which is due to flow of electrolytes.

The electrolyte then goes through a filtration process. In the filtration process, the electrolyte is passed through a centrifuge where slug is removed.

Then it passes through a filter where other remaining impurities are removed.

If there is an increase in pr of electrolyte, the pr value deviates flow of electrolyte directly to the tank.

Applications :-

→ It is used for heavy machining of hard materials which cannot be machined using caventional methods.

→ due to its high accuracy & high surface finish, ECM is used for micromachining. As there is no contact b/w tool & w/p, the final products obtained is accurate at the atomic level.

→ It is used for production of very small gear systems which cannot be machined using typical machining process.

→ It is used for machining turbine blades as it is difficult to m/c due to its complex concave structures.

→ used for drilling & milling operations.

Advantages :-

(1) Suitable for hard materials

(2) Negligible stresses

(3) No heat produced.

(4) No Tool wear

(5) Surface finish is excellent.

(6) Accurate dimensions.

(7) mass production.

Disadvantages

(1) Higher Cost

(2) Corrosion

(3) Large area

(4) Limited materials

(5) Harmful to the environment.

4) profiling & any odd shape contouring.
5) multiple hole drilling
6) Trepanning
7) Broaching
8) deburring
9) grinding
10) honing.

Electroplating, Electrofinishing, electro forming.

Material Removal Rate (MRR) :-

MRR is an important characteristics to evaluate efficiency of a non traditional machining process.

→ In ECM; m/l removal takes place due to atomic dissolution of work m/l.

ECM dissolution is governed by Faraday's laws.

→ The first law states that the amount of EC dissolution or deposition is proportional to amount of charge passed through the electrochemical cell which may be expressed as :-

$$m \propto Q \rightarrow (1)$$

where m = mass of m/l dissolved or deposited.

Q = amount of charge passed (current)

→ The second law states that the amount of m/l deposited or dissolved further depends on EC equivalence (ECE) of the m/l that is again the ratio of atomic weight & valency.

Thus $m \propto ECE \propto \frac{A}{V} \rightarrow (2)$

Combining (1) & (2)

$$m \propto \frac{QA}{V}$$

$$m = \frac{QA}{FV}$$

$$m = \frac{ItA}{FV}$$ where F = Faraday's constant = 96500 amp

where A = atomic weight

I = Current

t = time

V = valency

$$\therefore MRR = \frac{V}{t} = \frac{m}{e\,t} = \frac{ItA}{eFVt}$$

$$\boxed{MRR = \frac{IA}{FeV}}$$ where e = density of m/c

The engineering m/cs quite often alloys rather than element consisting of different elements in a given proportion.

→ let us assume there are 'n' elements in an alloy.

$A_1\ A_2\ A_3 \ldots A_n$ → Atomic weights

$\alpha_1\ \alpha_2\ \alpha_3 \ldots \alpha_n$ → weight percentage of different elements

Now for passing a current of I for a time t, the mass of m/c dissolved for any element 'i' is given by

$$m_i = V_a\, e\, \alpha_i$$

where V_a = total volume of alloy dissolved.

each element present in the alloy takes a certain amount of charge to dissolve.

$$m_i = \frac{Q_i A_i}{F v_i}$$

$$Q_i = \frac{F m_i v_i}{A_i}$$

$$= \frac{F V_a e \alpha_i v_i}{A_i}$$

Total charge passed, $Q_T = \Sigma Q_i = It$

$$Q_T = F V_a e \Sigma \frac{\alpha_i v_i}{A_i} = It$$

Now $MRR = \frac{V_a}{t} = \frac{It}{\frac{Fe \Sigma \frac{\alpha_i v_i}{A_i}}{t}}$

$$MRR = \frac{I}{Fe \Sigma \frac{\alpha_i v_i}{A_i}}$$

problems:-

1) In ECM of pure iron a MRR of 600 mm³/min is required. Estimate current requirement.

$$MRR = \frac{IA}{Fve}$$

$MRR = 600\ mm^3/min = 10 \times 10^{-3}\ cc/s$

As $A_{Fe} = 56$ $v_{Fe} = 2$

$F = 96500$ amp $e = 7.8$ gm/cc

$$\therefore I = \frac{MRR \times Fve}{A} = \frac{96500 \times \cancel{600} \times 2 \times 7.8 \times 10 \times 10^{-3}}{56}$$

$$I = 268.8 \text{ amp}$$

→ Composition of Ni alloy is as follows :–
Ni = 70%. Cr = 20% Fe = 5% & rest titanium. Calculate the rate of dissolution if area of tool is 1500 mm² & a Current of 2000A is being passed through the cell. Assume dissolution to take place at lowest Valency of elements.

$A_{Ni} = 58.71$ $\rho_{Ni} = 8.9$ $V_{Ni} = 2$

$A_{Cr} = 51.99$ $\rho_{Cr} = 7.19$ $V_{Cr} = 2$

$A_{Fe} = 55.85$ $\rho_{Fe} = 7.86$ $V_{Fe} = 2$

$A_{Ti} = 47.9$ $\rho_{Ti} = 4.51$ $V_{Ti} = 3$

$$\rho_{alloy} = \frac{1}{\sum \frac{\alpha_i}{\rho_i}}$$

$$= \frac{1}{\frac{\alpha_{Ni}}{\rho_{Ni}} + \frac{\alpha_{Cr}}{\rho_{Cr}} + \frac{\alpha_{Fe}}{\rho_{Fe}} + \frac{\alpha_{Ti}}{\rho_{Ti}}}$$

$$= \frac{1}{\frac{0.7}{8.9} + \frac{0.2}{7.19} + \frac{0.05}{7.86} + \frac{0.05}{4.51}}$$

$\rho_{alloy} = 8.07$ gm/cc

$$MRR = \frac{I}{F\rho \sum \frac{\alpha_i v_i}{A_i}}$$

$$= \frac{1000}{96500 \times 8.07 \times \left(\frac{0.70 \times 2}{58.71} + \frac{0.2 \times 2}{51.99} + \frac{0.05 \times 2}{55.85} + \frac{0.05 \times 3}{47.9}\right)}$$

Electrochemical Honing (ECH):-

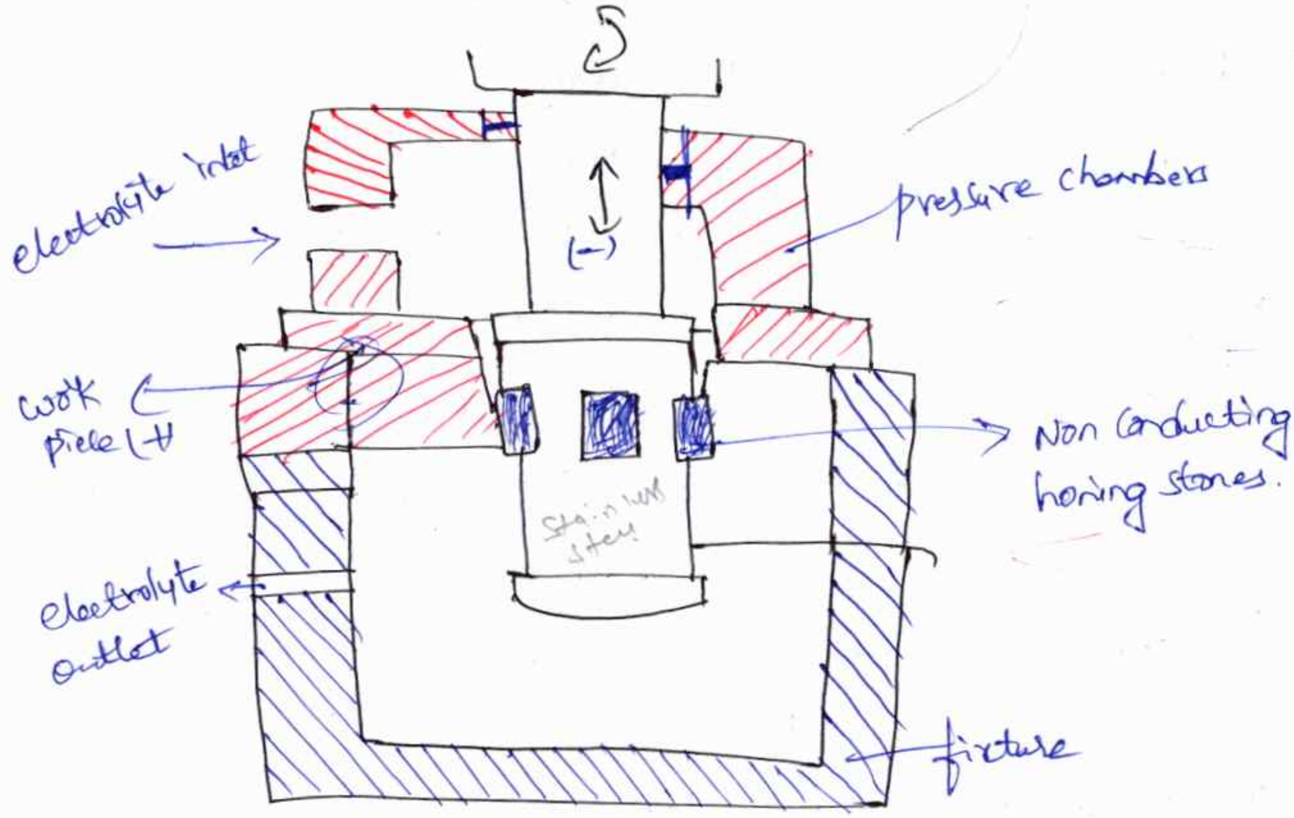
Introduction:-

It is a process in which the metal removal capabilities of ECM are combined with accuracy capabilities of honing.

→ The process consists of a rotating & reciprocating tool inside a cylindrical component.

→ material is removed through anodic dissolution & mechanical abrasion 8% of mole, of material removal occurs through electrolytic action.

→ workpiece is the anode & a stainless steel tool is the cathode.



Tool Construction:-

It consists of a hollow stainless steel body that has expandable, Non conducting honing stones protruding from atleast three locations around the circumference.

→ The honing stones are identical with those used in conventional honing operations, except that they must resist the corrosiveness of the electrolyte.

→ The honing stones are mounted on tool body with a spring loaded mechanism so that each of the stones exerts equal pressure against the workpiece.

→ The length of the stones is selected to be approximately one-half of the length of bore being processed.

Working :-

At the begining of ECH cycle, the stones protrude only 0.075 – 0.127 mm from the stainless steel body establishing gap through which the electrolyte flows.

→ The electrolyte enters the tool body via a sliding inlet sleeve from which it exits into the tool – w/p gap through small holes in the tool body.

→ After passing through the gap, the electrolyte flows from the workpiece through the gap at top & bottom of the bore.

→ The mechanical action of tool is the same as with conventional honing, the tool is rotated and reciprocated so that the stones abrade the entire length of the bore.

→ electrolytes used in ECH are essentially the Same as those used in ECM, although the control of pH, Composition & sludge is less critical because the abrasive action of the stones tends to correct any resulting surface irregularities.

→ As in ECM, the electrolytes are recirculated & reused after passing through appropriate filtration & the most commonly used electrolytes are sodium chloride & sodium nitrate.

process parameters :-

(1) Machines are available that deliver up to 6000amp.

(2) Current density at the workpiece can range from 12 to 47 amp/cm².

(3) working voltages are 6–30 VDC.

(4) The electrolyte is delivered to the work area at pressures of 0.5–1 Mpa.

(5) It can remove materials at rates up to 100% faster than convetional honing, the gain being more pronounced as the material hardness increases.

(6) Machine capacities are currently able to accommodate bore lengths up to 600mm & bore diameters from 9.5 to 150mm.

Advantages :-

(1) Increased MRR on hard materials.

(2) Since most of the m/l is removed electrochemically, honing stone life is greatly extended.

(3) Burr-free operation.

(4) No micro scratches are left on the w/p.

(5) less pressure required b/w stones & work.

(6) Reduced noise & distortion when honing thin-walled tubes.

(7) Cooler action leading to increased accuracy with less material damage.

(8) No residual stresses in the w/p.

(9) Capable of achieving surface finishes of 0.05 µ & dimensional accuracies of ± 0.012mm.

(10) By turning off the power to the tool before the end of the honing cycle, the stones can be used in a conventional manner to achieve tolerances of ± 0.002mm & to impart a compressive residual stresses on the work surface.

Limitations :-

(1) High Capital Cost

(2) Corrosive environment

(3) High preventive maintenance cost.

(4) Non Conductive materials cannot be machined.

(5) Requires disposal & filtering of electrolytes.

Electro Chemical Deburring :-

The word deburring means removal of burr from the source of any workpiece to provide a smooth finished surface.

-> The term electrochemical means the mode of energy used for deburring.

-> Together electrochemical, chemical deburring refers to a machining process in which burrs are removed using electrochemical energy.

-> A speical type of tool is used for this operation which is called a deburring tool.

-> Like any other electrochemical process, in electrochemical deburring also there is no contact b/w deburring tool & the workpiece.

-> It acts as a reverse electroplating process,.. In this process, the tool acts as the cathode & the workpiece acts as the anode.

-> Both tool and the workpiece are kept in a flowing electrolyte medium.

-> ECD is also known as electrolytic deburring due to the use of electrolytes.

-> It is a fast and easy process.

Need of ECD :-

-> Removal of burrs is considered a serious problem in many industries which deal with high accuracy.

→ A burr can sometimes have sharp edges which may harm the operator or a worker, hence it is important to remove it.

→ It can cause cracks on the surface of the mating parts.

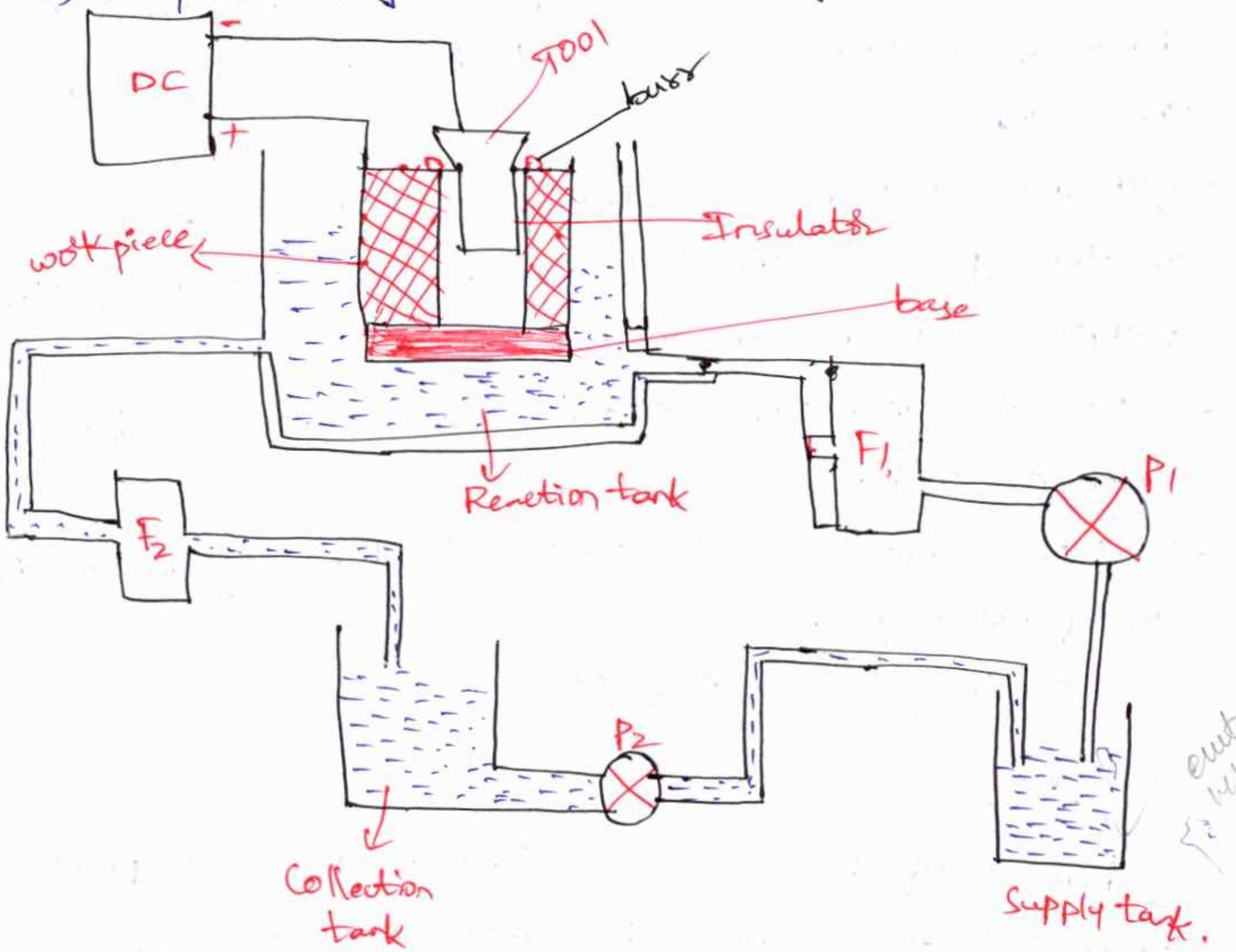
→ As the pressure increases when the area of contact decreases.

→ It also lessens the beauty of the work piece.

→ ECD is also important for deburring hard metals.

Components of ECD :-

1) supply tank 2) pumps 3) collection tank 4) Reaction tank 5) DC power supply 6) Base 7) Electrolyte & Tool.



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Supply tank :-

The tank carrying electrolyte for its supply is called a supply tank.

Pumps :- There are two pumps P_1 & P_2.

P_1 is used to supply electrolytes to the reaction tank & P_2 is used to supply the electrolyte from the collection tank to the supply tank.

Collection tank :-

The tank which collects the filtered electrolyte is called a collection tank.

Reaction tank :- The area or the containers carrying the tool-workpiece and the electrolyte are called a reaction tank.

→ The EC reaction b/w workpiece and the tool takes place in the reaction tank.

→ The tank is designed in such a way that there is a constant flow of electrolytes in the tank to carry the slag.

DC power supply :-

The voltage values of DC power supply used in ECD are low.

But the current value is high, this promotes faster removal of metal from the surface of the workpiece.

Base :-

The base is made of a conducting material that is used to keep the workpiece stable.

The base also connects the two workpieces electrically.

→ DC supply is given to the base which connects the two workpieces.

Electrolyte :-

It is a solution of simple salt with water.

It is generally a conductive solution of sodium chloride & sodium nitrate in water.

→ For general applications sodium, nitrate & water are mixed in the ratio of 2:1.

The temperature of the electrolyte is maintained at 20°c for best results.

The mixture of several salts is used in case of metals like titanium.

Tool :-

The tool is the most important component of an electro chemical deburring setup.

For various purposes, various different tools are used.

→ It consists of a conductometric which is insulated from the outside.

→ The tool acts as the cathode which is connected to the negative terminal of DC power supply.

→ A gap of 0.5-1mm should be maintained b/w workpiece & tool.

→ The basic procedure to design an ECD Tool is as follows :-

→ If the height of the workpiece is 15mm & height of burr is 2mm.

→ Then the tool has to be designed in such a way that its height should be more than 15+2 = 17mm.

→ It should be insulated till 15mm so that the m/c removal takes place above 15mm which removes the burr.

Working of ECD :-

Working principle :-

The ECD works on the principle of reverse electroplating. According to Faraday's law of electrolysis, the amount of metal displaced is directly proportional to the electric current.

When a high current is applied to the ECD setup, the material removal takes from the w/p to the tool.

→ The removal takes place from the gap b/w the tool and the workpiece.

→ The material does not get deposited on the tool, it flows away due to the flow of electrolyte.

In this way, a highly finished surface is obtained.

Working :-

The workpiece is kept on the base & tool is positioned b/w the workpieces.

The w/p is connected to the positive terminal of DC power supply.

And the tool is connected to the negative terminal of DC power supply.

The pump is activated & the flow of electrolytes is started.

→ The electrolyte reaches the reaction tank by passing through a filter.

Then DC power supply is switched on & the reaction starts.

Electron transfer takes place b/w the workpieces & the electrolyte.

The electron transfer results in the removal of burrs from the surface of the workpiece.

The remaining electrolyte is made to flow through the filter (F_2) in to the collection tank.

From the collection tank, the electrolyte is again supplied to the supply tank. And the process is repeated.

once the burr is removed the power supply is switched off & the w/p is removed.

Advantages :-

1) It is a highly accurate process which gives excellent surface finish.

2) Heat generation is negligible.

(3) There are no thermal stresses developed in w/p.

(4) No wear of tool takes place.

(5) The efficiency is/ more.

(6) Faster process increases productivity of the plant.

(7) quality products are manufactured.

Disadvantages :-

(1) High inital cost of the equipment.

(2) Different tool must be designed for different w/ps.

(3) Complex process.

(4) highly skilled operator is required.

(5) only the workpieces that conducts electricity can be machined.

Applications :-

(1) It is used for deburring of gears.

(2) " " " removing sharp edges from highly precise equipment.

(3) used for surface finishing of hard m/ls.

Electro chemical Grinding (ECG):-

The term grinding refers to a machining process in which the m/l is removed from the surface of a w/p.

The Term electrochemical resembles the mode of energy used for the machining process.

It is a combination of ECM & G processes.

The major difference b/w ECM & ECG is that in ECG, grinding wheel is used instead of a cutting tool.

ECG is done when there is a need to remove the m/l from the surface of w/p.

It is generally used when the mechanical & traditional grinding of a w/p takes a lot of effort due to hardness of w/p.

ECM is used for grinding materials with greater hardness

ECG is also reverse of Electroplating.

In this metal surface is converted into its respective oxide which is then removed by rotating grinding wheel. only 5-10% of m/l is removed by the abrasive grinding wheel, the rest is removed by flow of electrolyte.

parts (or) Construction of ECG :-

The w/p is kept on the worktable which acts as a rigid base.

There are fixtures located on the table to clamp the w/p.

Below the worktable, a collecting tank is ~~secit~~ situated for the collection of waste electrolytes.

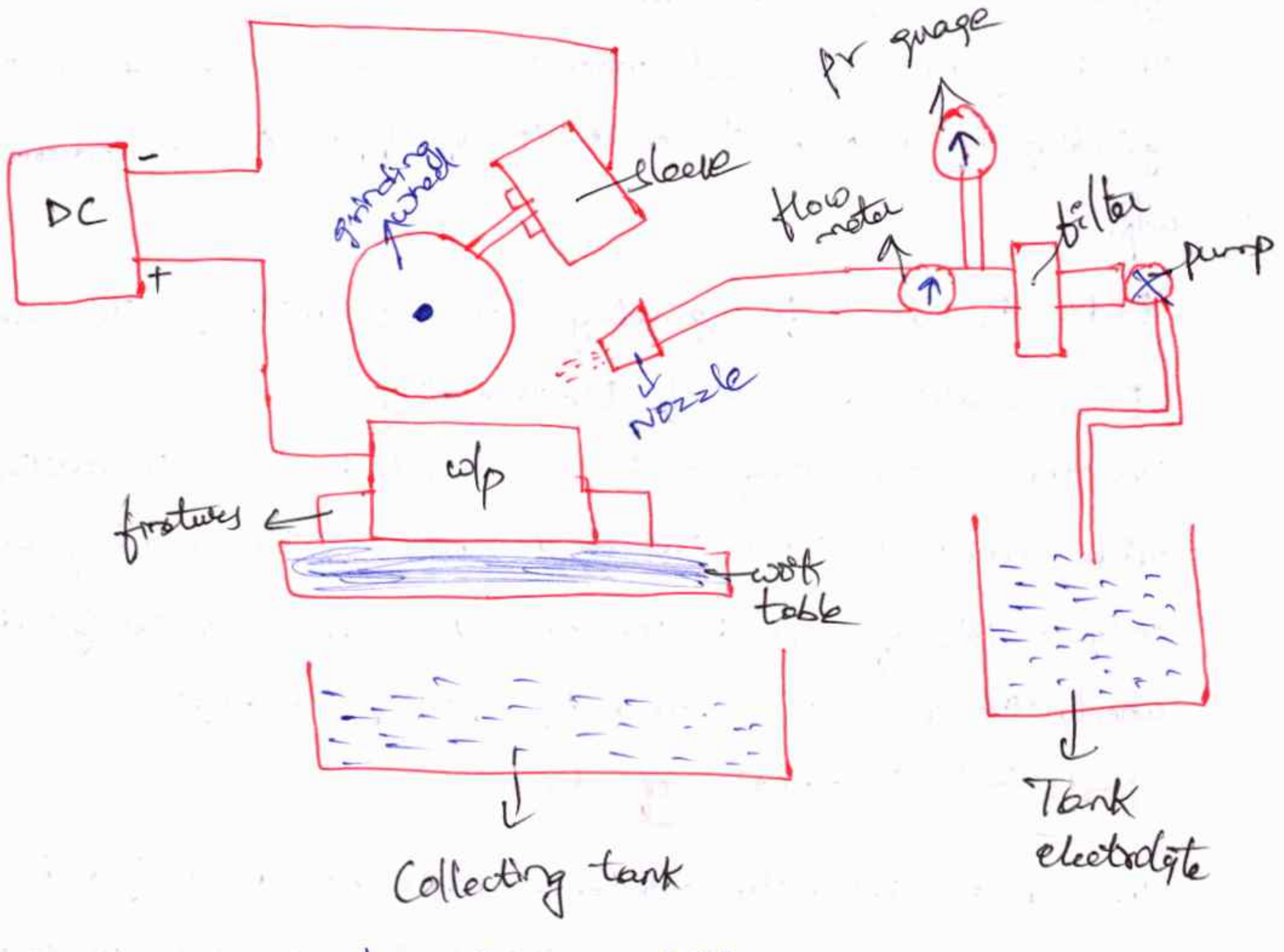
→ The w/p is connected to the positive terminal of power supply and acts as an anode while grinding wheel acts as the cathode.

→ The power supply to the grinding wheel is given through the sleeve.

The supply line consists of an electrolyte tank.

The pump is used to draw the electrolyte from the tank which is followed by the filters, pressure gauge & flowmeter.

→ The end of supply line is connected with a Nozzle for increasing the pressure.



Various parts involved in an ECG setup are as follows :-

DC power supply; worktable & fixtures, pump, Tank, filter, pr guage & flow meter, nozzle, sleeve, grinding wheel.

(1) DC power supply :-

A DC power supply with low voltage & high current is used for providing electrical energy to setup.

The voltage is kept low to avoid the generation of heat & for safety purposes as well.

High current on the other hand provides a faster process.

(2) Work table & fixtures :-

For any machining process, it is important to provide a rigid base and restrict all the degrees of freedom of the w/p.

→ The worktable provides rigid support to the w/p & fixtures are used to clamp the w/p.

(3) Electrolyte tank :-

It is a reservoir in which the electrolyte is stored.

An electrolyte is a conducting solution that plays a imp role in ECG.

The first function of electrolyte is to complete the circuit by providing a conducting medium.

The second function is to oxidize the metal surface & carry out the oxidized particles.

Electrolytes are generally sodium compounds formed by electrovalent bonds.

There are various types of electrolytes are used in ECG are NaCl, (used) ~~$NaNO_3$~~, Carbonate, hydroxide & NaCl.

(4) Pump :-

It is used to carry the electrolyte from the electrolyte tank to the nozzle. The pump used is generally electrically driven.

(5) Filter :- The electrolyte passes through a filter where all the micro impurities get filtered and pure electrolyte is obtained.

(6) pressure gauge and flow meter :-

pressure gauge and flow meter are safety equipment that shows pressure and flow of electrolyte respectively.
If any of these values belone more than the safety limit the operator simply turns off the equipment.

(7) Nozzle :-

It is a device with decreasing cross section area, which is used to direct the electrolyte to the correct position.

→ The decreasing area helps in increasing the velocity of the electrolyte which in turn removes the mill from the w/p.

→ The Nozzle is placed in such a way that the electrolyte flowing out of it must come in contact with the w/p as well as grinding wheel.

(8) sleeve :-
sleeve is used to transfer electrical energy to the grinding wheel.

(9) Grinding wheel :-
The grinding wheel is the most important & unique part of the electrochemical grinding machine.
It is connected to the negative terminal of the power supply and acts as the Cathode.
The grinding wheel is made of insulating materials such as diamond & aluminium oxide.
The wheels rotate & increase the flow of the electrolyte.

The grinding wheel is responsible for only 5-10% of the material the rest is removed by the electrolyte.
There is hardly any contact of the grinding wheel with the w/p hence no or very little wear takes place.

(10) collecting tank :-

It is used to collect all the used electrolyte which is then disposed & reused as per the requirement.

ECG working :-

diagram :-

principle :-

When a metal surface is acted upon with an electrolyte under a high current, the metal surface gets oxidized to form an oxide layer (corrosive layer)
This layer is removed with the action of a flowing electrolyte & rotating grinding wheel.
metal is removed in the form of oxide layer so to obtain a surface finish.

working :-

The workpiece to be machined is first kept on work table & then clamped using fixtures.
The grinding wheel is placed at the required position. A gap is maintained b/w w/p & grinding wheel.
The gap is generally 0.02 mm.
Now the power supply is switched on. The pump is then driven to supply the electrolyte to the required position.

→ At first, the electrolyte passes through a filter where all the impurities are filtered. Then the electrolyte is passed through a pressure gauge where the operator checks for the correct pressure.

→ Then the electrolyte is passed through a flow meter where flow is checked by the operator.

→ After passing through all the stages the electrolyte reaches the Nozzle. Nozzle increases the velocity of the electrolyte & sprays its over the w/p.

→ As soon as the electrolyte comes in contact with the w/p & grinding wheel, the circuit is completed which results in oxidation of the metal surface.

→ This forms a layer of oxide which is removed by the flow of electrolyte & abrasive particles in the grinding wheel.

→ After grinding is done, the flow is stopped & power supply is switched off.

→ The w/p is then unclamped & the remaining electrolyte is wiped out from the surface.

Applications :-

1) It is used for grinding turbine blades.
2) Used in aerospace industries for grinding honeycomb.
3) used for finishing hard surfaces.
4) used for creating sharp objectives.
5) used for grinding fragile articles.

Advantages :-

1) The accuracy of ECG grinding is very high, As there is no contact of tool with the w/p.

(2) A high tolerance can be obtained.

3) The process does not leave any scratches on surface of w/p.

4) The heat generated during the operation is very less.

5) The electrolyte also acts as a coolant.

6) There are no internal stresses developed in the w/p.

7) Hard materials can be grinded easily.

8) clean edges can be obtained.

9) No or very little wear of grinding wheel takes place.

Disadvantages :-

(1) MRR is low about 15mm/s.

(2) power consumption is very high as there is a need to drive the grinding wheel & pump as well.

(3) The initial cost of equipment is also high.

(4) The production rate is low.

(5) Disposing of waste electrolytes becomes a problem, which makes the process non-eco friendly.

(6) A large area is required for setup.

Chemical Machining :-

The chemical machining process is also known as etching process.

→ This process sounds like magic due to its easy outputs.

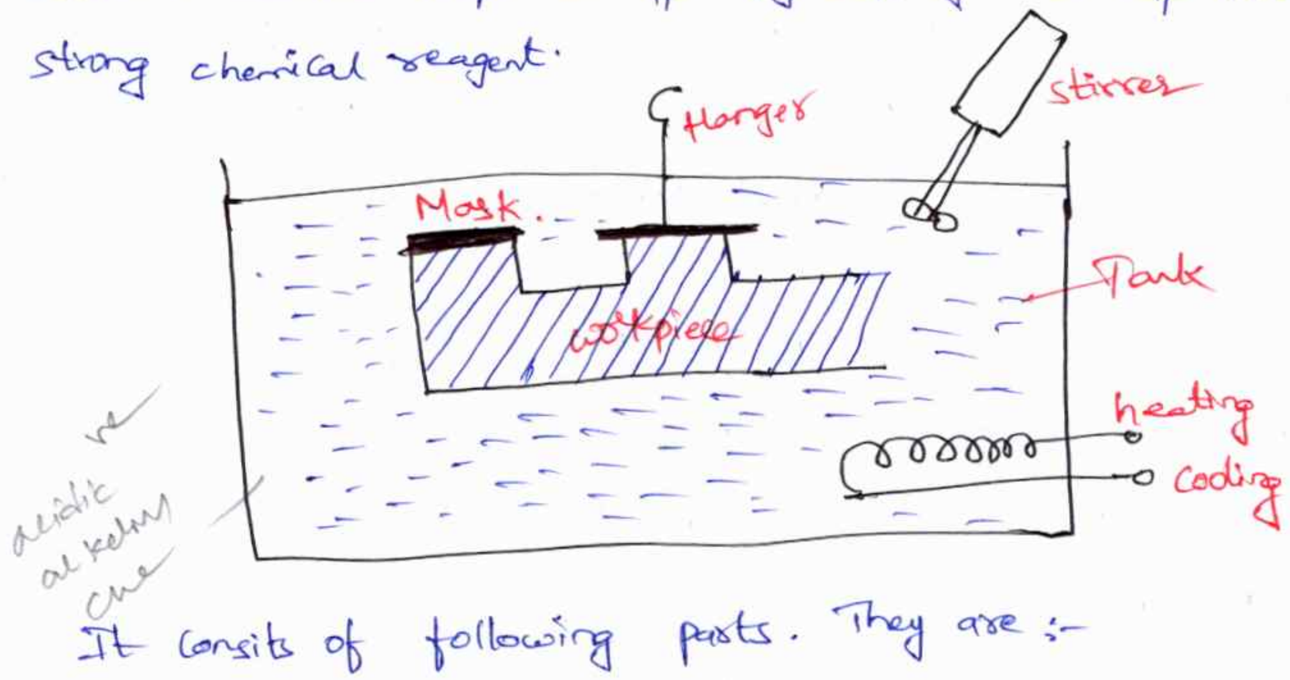
→ In this process we are just dipping the workpiece into a tank of chemical solution & in just a few seconds, we will be obtaining the desired structure on the workpiece.

→ This machining process is not magic, but scientifically practical.

→ This process uses a strongly acidic or alkaline chemical reagent to remove material from the w/p.

→ This is an age-old process prior to 400BCE when organic chemicals such as citric acids & lactic acids were used to etch metals to manufacture the desired shapes of armors.

→ chemical machining is a process of material removal to obtain a desired shape on w/p by dipping the w/p into a strong chemical reagent.



It consists of following parts. They are :-

(1) Tank

(2) Heating coil

(3) stirrer

(4) workpiece

(1) Tank :-

This process has a tank with its face open.
The tank is built of strong Metal coated with materials that are non-reactive to etchant depending on the applications & concentration of chemical reagent.

(2) Heating coil :-

It is mounted at the lowest section of tank to maintain the temperature of the tank at a constant level.
It is practical that in any metal removal process the heat generation is natural. Also, the coil does cooling in necessary conditions.

(3) stirrer :-

A stirrer is placed in the etchant whose main purpose is to mix the etchant consistently to maintain a uniform concentration & heat along the volume of etchant.

-> It is well known to us that the hot particles always accumulate at the top, leaving the cold below.

-> so to spread the heat uniformly along the etchant, the stirrer is used.

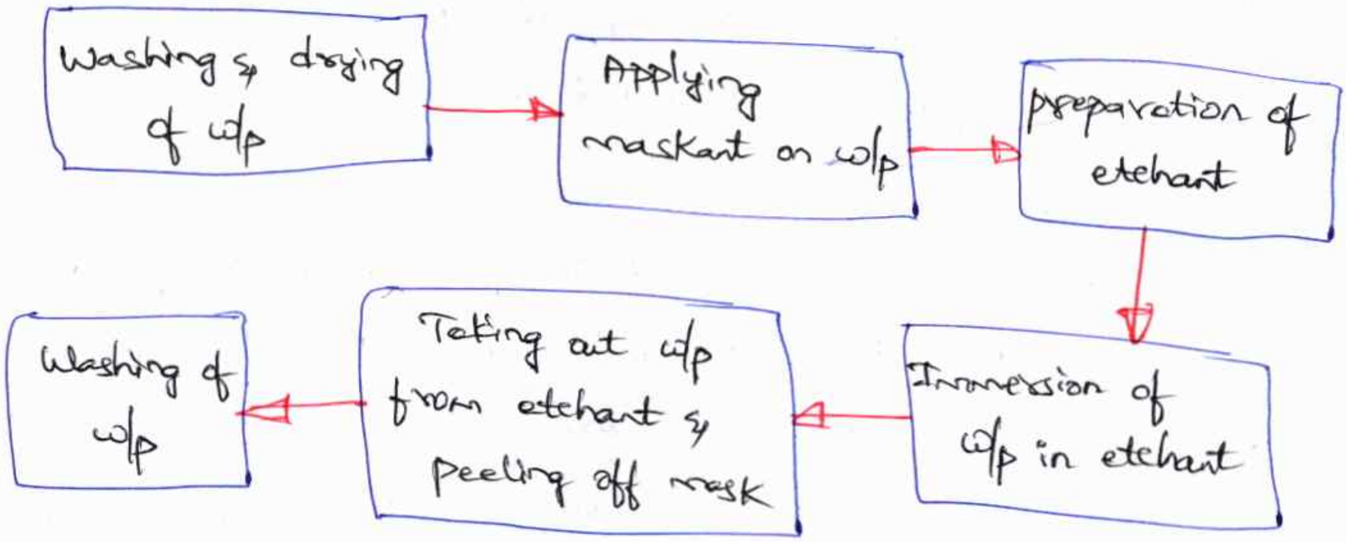
The stirrer also helps in the flushing of dissolved metal from the workpiece simultaneously breaking the bubbles formed during machining due to oxidation.

(4) workpiece :-

The workpiece is held in the etchant by the use of a hanger in the case of small applications.
The length of the hanger is fastened over a masked area so that the fixing of w/p does not disturb machining zone.

In the case of a larger workpiece, fixtures coated with rubbers & polymers are used to hold the workpiece.

working principle :-



CM is based on chemical etchant.

An etchant is a mixture of strong chemical acids which are reactive to metal.

when the w/p is dipped in the etchant, the etchant reacts with the w/p causing a uniform rate of dissolution of metal from the w/p.

→ To obtain a desired shape or structure, an elemental coating that is non-reactive to a chemical reagent called "Maskant" is applied on w/p before machining.

Localised machining is achieved by applying a suitable mask on all areas where we do not want the etchant to react.

Thus exposing the machining zone for necessary removal of metal.

CM involves 4 major processes performed in a series :-

(1) Clearing :- It is a preparatory process to ensure that the surface of w/p is free from contaminants, rust & foreign particles.

It is usually performed by high pressure water jets, alcoholic solutions & diluted HCl.

Needs of clearing :-

→ Improper cleaning results in poor adhesion of maskant, inaccurate final dimensions & improper dissolution of metal.

→ contaminants like oil, grease can lead to oxidation.

→ Improper cleaning can result in peeling of maskant letting etchant flow beneath the mask does spoiling the geometry.

→ Foreign particles could lead to the formation of scales.

After washing of the workpiece, the workpiece is dried under hot air blowers.

The cleaning process is always carried out in advanced CNC Machinery.

(2) Masking :-

It is a process of applying maskant over the surface of the workpiece.

A layer of polymer or rubber is coated on the workpiece.

→ It is done to prevent the area which does not require machining from the etching process.

It is done all over the workpiece except the areas to be machined.

(3) Etching:-

This is the process in which the required metal removal takes place.

After perfect masking, the workpiece is dipped in to the tank of the chemical reagent with the heater & the stirrer turned on.

As soon as the workpiece is dipped, the etchant starts to react with the non-masked areas of the workpiece.

→ The highly concentrated acid begins to react with the workpiece altering its chemical features.

This reaction causes the predefined portions to melt & separate from the workpiece layer by layer.

In this process, the depth of cut is directly parallel to the time for which is the workpiece is dipped.

The more time the workpiece is in the etchant, the more metal is removed.

The less time, the less is the DOC.

This is calculated by formula

$$E = \frac{S}{T}$$

where E = Etch rate ; S = Depth of cut required

T = Time in seconds.

The values of etch rate are precalculated by experimentations.

→ Etch rate is consigned with the concentration of chemical reagent & type of workpiece to be machined.

→ The depth of cut is obtained in the design. Hence, the time can easily be calculated before immersion of the w/p in the etchant.

(4) Demasking:-

It is a process of peeling off the maskant that was applied before the etching process.
Once the maskant is removed from the workpiece, the w/p is again sent to cleaning operation where any leftover etchant is washed away by pressurized cold water.
The w/p is then dried up & ready for final dispatch.

CM operation types:-

CM (1) Chemical milling (CHM):- This operation is performed to obtain pockets, contours on the w/p (or) to remove bulk material from the w/p.

CE (2) Chemical engraving (CHE):- This operation is performed to reproduce a speical design on a w/p with a lot of precision.
Ex:- Titles, brand names, serial numbers.

CP (3) Chemical polishing (CHP):- This operation is performed to make up a fine finishing & deburring of the w/p.
This is possible by using of usage of lighter diluted chemical reagent.

PCM (4) photo chemical machining (PCM):- It is a process of manufacturing stress-free & crack-free components.
→ It is used where micro details are to be machined on a w/p.

CHM CHE CHP PCM

Applications:-

(1) Weight reduction of complex contours, impossible by conventional methods.
(2) Machining of thin & delicate components.
(3) used to machine the contours present inside a hole.

(5) used in automobile & aviation industries.

(6) Making of fine screens & meshes.

(7) Removal of metal where holding of a w/p is difficult.

Advantages:-

(1) This machining process removes metal uniformly.
(2) Good surface finish with close tolerances.
(3) Complex contours can be easily machined.
(4) material removal along all the axes at the same time.
(5) less skilled operator is required.
(6) No mechanical stress is produced on w/p.
(7) low initial cost.
(8) low machining cost.

Disadvantages:-

(1) Chances of corrosion after days of machining.
(2) machining of alloys can lead to poor surface finish.
(3) process is not eco-friendly.
(4) Disposal of byproducts can cause harm to the surroundings.
(5) MRR is less in comparision with other machining processes.
(6) Chances of bubble formation, which may result in improper machining.

Important parameters:-

Maskant:- It is defined as a m/l used to coat the w/p for preventing the portion of w/p from etching.

Factors to consider to select type of maskant

(1) It should be inert to the chemical reagent used.

(2) Tough to withstand handling.

(3) It should not change its characteristics during machining process.

(4) Also withstand heat.

(5) It should allow itself for cutting & scribing.

(6) It should adhere well to the w/p.

(7) Availability & low cost

w/p m/e	maskant m/e
Al & its alloys	Butyl rubber, polymers & Neoprene
Copper & its alloys	polymer
Iron based alloys	Butyl rubber & polymer.
Nickel	Neoprene
mg	polymer
Titanium	polymer

UNIT-IV

Electrical Discharge Machining :-

EDM is also called as Spark Machining, spark eroding, burning, die sinking, wire burning & wire erosion.

→ This is a manufacturing operation in which we used to make desired shapes by using an electrical spark.

→ This spark near to 8000—12000°C.

Definition :-

It is the process of metal removal from the work surface due to an erosion of metal caused by electrical spark discharge b/w two electrodes tool (cathode) & work (anode).

Parts :-

DC pulse generator; Voltmeter; Ammeter; Tool; die electric fluid, pump, filter; servo controlled feed; fixtures, table.

(1) DC pulse generator :-

This is a power source for the machining operation. DC power is supplied.

(2) Voltmeter :-

Voltmeter measures the voltage. Here in this device the same for use.

(3) Ammeter :- It measures & checks the flow of current. If Ammeter is not connected we might not see or check current is flowing or not.

(4) Tool :-

Tool is connected to the negative sources of power whereas the workpiece is connected to the positive sources.

From the filter, the fluid comes to the tool for operation.

→ when power supply will increase b/w tools w/p the spark generates & then machining starts.

(5) Die electric fluid :-

It acts as a insulation m/l.

It will be ionized in the form of ion which will help b/w tool & w/p again when power supply stops the fluid comes to its initial position.

(6) pump :-

The pump is connected there for sending the fluid to the filter. This works like flowing the fluid from one source to another one.

(7) Filter :-

It is used to filtrate the different particles.

In this device, If there is dust particles presence the filter will remove that particle & then it will send to the tool for the operation.

(8) servo controlled feed :-

The constant feed will be supplied by servo for operation.

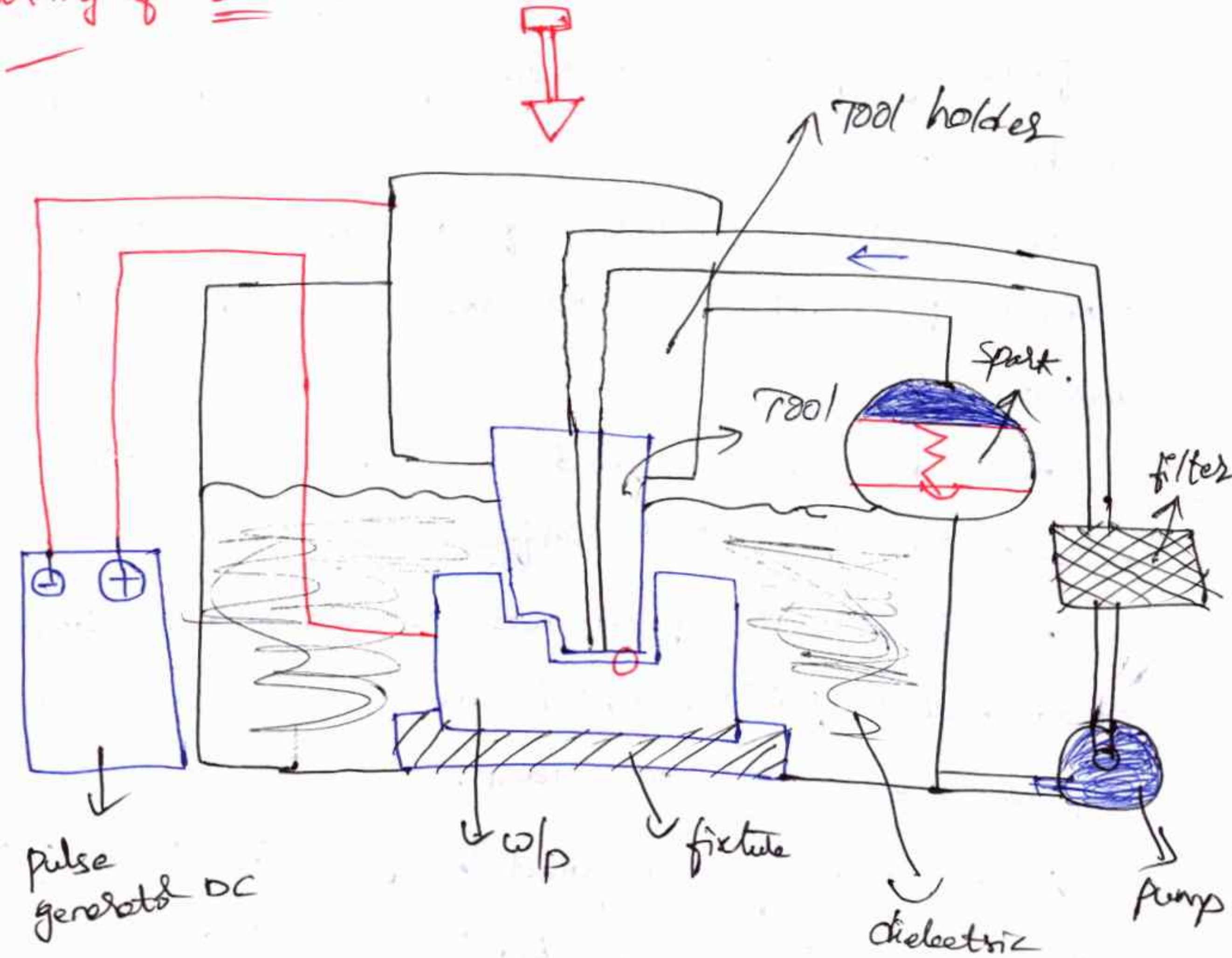
(9) Fixture :-

To hold the table.

(10) Table :-

To hold the w/p.

working of EDM :-



It consists of an electric power supply, the dielectric medium, the tool, w/p, & servo control.

The w/p is connected to the +ve terminal & tool is connected to a -ve terminal of DC power supply.

→ An air gap of 0.005 to 0.05 mm is maintained b/w tool & w/p.

→ The die electric fluid which is non conductor of electricity is forced under pr through the gap.

→ when a DC power is supplied, the fluid in the gap gets ionized & produces a spark b/w tool & w/p, causing a local rise in temp at about 1000°c, when melts the metal in small area of w/p & vapolizes.

→ The DC supply generates a pulse b/w 40-3000V & frequency of spark at rate of 10,000 sparks per sec can be achieved.

→ The electric & magnetic fields on heated metal cause a compressive force which removes the metal from the work surface.

→ The die electric fluid acts as a coolant carry the cooled metal from work surface.

→ The die electric fluid acts as a coolant carries the eroded metal particles which are filtered regularly & supplied back to the tank.

→ A servomechanism is used to feed the tool continues to maintain a constant gap b/w two electrodes.

→ The accuracy of about 0.005 mm can be achieved in this process.

Applications :-

1) This is used in thread cutting
2) wire cutting
3) Rotary form cutting
4) Helical profile milling
5) Curved hole drilling
6) engraving operation on harder materials.
7) cutting off operation.
8) The shaping of alloy steel & tungsten carbide dies.

Advantages :-

1) It can be used for any hard m/l & even in the heat treated condition.
2) Any complicated shapes made on tool can be reproduced.
3) High accuracy of about 0.005mm can be achieved.
4) Good surface finish can be achieved economically upto 0.2 μm.
5) machining time is less than the conventional machining process.
6) No mechanical stresses are developed in this process.
7) Higher tool life due to proper lubrication & cooling.
8) Hard & erosion resistant surface on dies can be developed easily.
9) It can be applied to any electrically conductive m/ls.

Disadvantages :-

1) Excessive tool wear.
2) High power consumption.
3) sharp corner cannot be reproduced.
4) High heat developing causing the change in metallurgical properties of m/l's.
5) w/p must be an electrical conductor.
6) surface cracking may take place in some m/ls.
7) Redressing of tool is required for deep holes.
8) over cut is formed.
9) difficult finding expert machinists.

Applications :-

1) Drilling for micro holes in Nozzle.

2) used in thread cutting

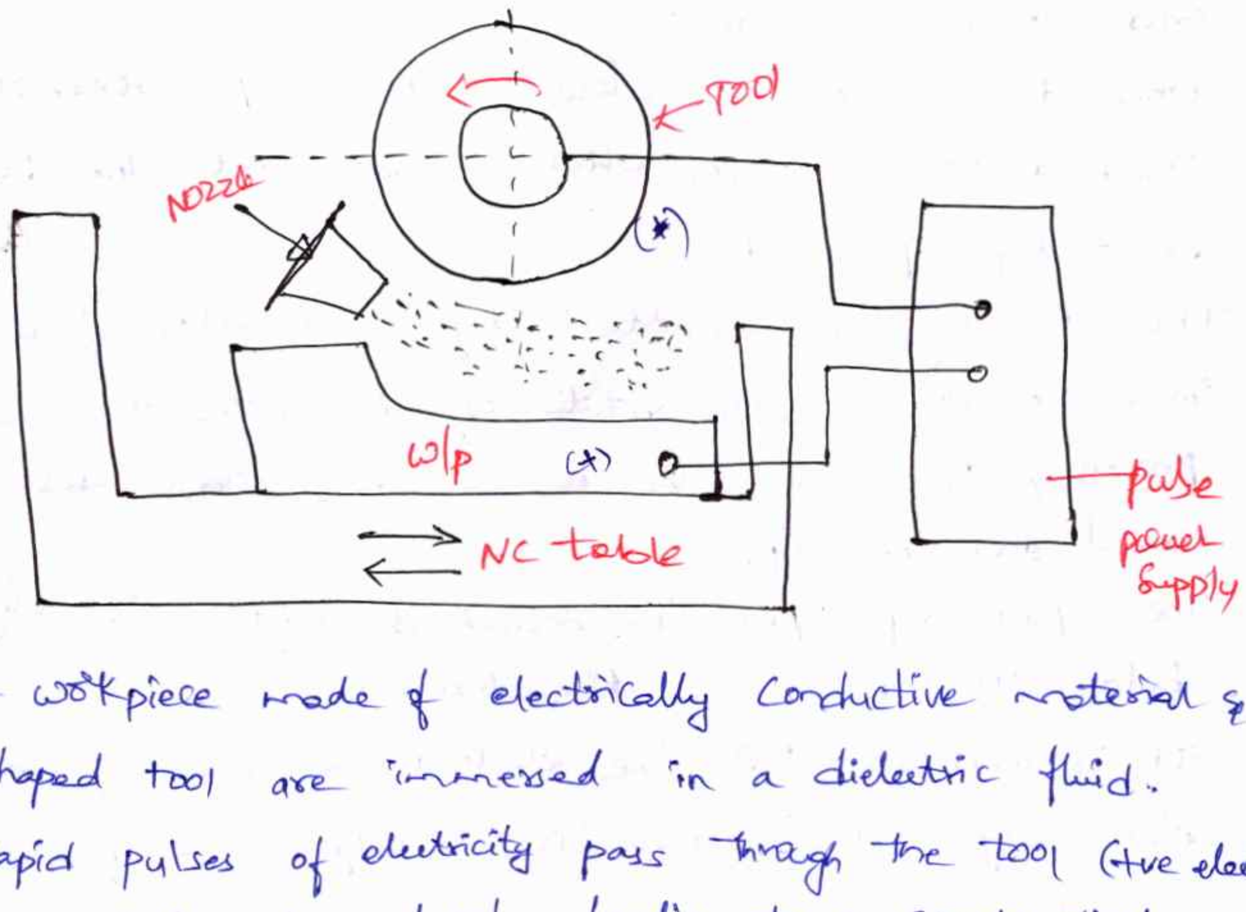
3) wire Cutting

4) Rotary form Cutting

5) helical profile milling

Electric Discharge grinding (EDG) :-

It enables manufacturers to produce cutting tools with stable cutting edges & complex features out of very hard materials like polycrystalline diamond (PCD).
The process uses a copper electrode to produce micro sparks that erode away the binder material.



A workpiece made of electrically conductive material & a shaped tool are immersed in a dielectric fluid.
Rapid pulses of electricity pass through the tool (+ve electrode) & negatively charged w/p, leading to a spark discharge.

Advantages:-

-> frequently used for one-off tool & die production, but can be used in mass production & transfer lines.
-> production rate is low; aerospace industries.
-> many production parameters; most imp are current, spark gap & frequency, dielectric type & flow rate tool (electrode) m/l & polarity.

→ Abrasive machining method where controlled spark discharges from an electrically charged, rotating wheel grinds the w/p surface.

Process:-

The Tool consists of a disc which rotates around its horizontal axis.

Connection via power supply makes the disc act as cathode and w/p as the anode.

When disc is brought close to the w/p, intermittent spark discharges occur, which means that the w/p is melted & vapourised.

The discharge is supported by a dielectric fluid, which in combination with rotation of disc helps to cool the process & carry away the removed m/l while disc is moved over the w/p.

The spark gap makes the machined surface is slightly below the discs over diameter.

It is important that the electrode the rotating wheel is electrically conductive, so its normally made of metal or graphite.

Advantages:-

→ It can grind thin electrically conductive m/l.
" brittle " "

How wire cut EDM works :-

(5)

EDM cutting is always through the entire w/p.
To start wire machining it is first necessary to drill a hole in the w/p or start from the edge.

→ on the machining area, each discharge creates a crater in the w/p & an impact on the tool.

→ The wire can be inclined, thus making it possible to make parts with taper or with different profiles at top & bottom.

→ There is never any mechanical contact b/w the electrode & w/p. The wire is usually made of brass or stratified copper & is b/w 0.1 to 0.3mm diameter.

→ depending on the accuracy & surface finish needed, a part will either be one cut or it will be roughed & skimmed. on a one cut the wire ideally passes through a solid part & drops a slug or scrap piece when it is done.

→ This will give adequate accuracy for some jobs, but most of time, skimming is necessary.

What types of shapes can a wire EDM machine produce?

A wire EDM m/c is a type of CNC m/c that can move along four independent axes to generate taper cuts.

examples:- a stamping die can be machined with 1/4 degree taper or a mold with one degree taper in some areas & two degrees in another with precision.

What is wire electrical discharge machining

Wire EDM is also known as wire cut EDM, wire cutting, EDN cutting, EDM wire cutting, wire burning, wire erosion, wire eroding, wire cut electric discharge machining & cheese-cutter EDM.

Wire electrical discharge machining uses a metallic wire to cut or shape a w/p, often a conductive m/l, with a thin electrode wire that follows a precisely programmed path.

Typically the electrode diameters range from 0.004" – 0.12" (0.10mm – 0.30mm), although smaller & large diameters are available.

during wire cutting process there is no direct contact b/w wire & w/p which allows for machining without causing any distortion in the path of wire or shape of the m/l.

→ To accomplish this, the wire is very rapidly charged to a desired voltage.

→ The wire is also surrounded by deionized water.

→ when the voltage reaches the correct level, a spark jumps the gap & melts a small portion of w/p.

→ The deionized water cools & flushes away the small particles from the gap.

→ The hardness of w/p m/l has no detrimental effect on the cutting speed.

→ extrusion dies & blanking punches are very often machined by wire cutting.

→ extrusion dies or nozzles & horns can be cut with constantly changing tapers.

→ A detailed shape on top of w/p can transition to a simple circle on the bottom.

Uses for EDM cutting:-

1) Thick parts requiring good finishes
2) Complex shapes or narrow slots
3) larger parts that need to hold accurate tolerances.
4) delicate, hard, exotic/expensive or weak materials.

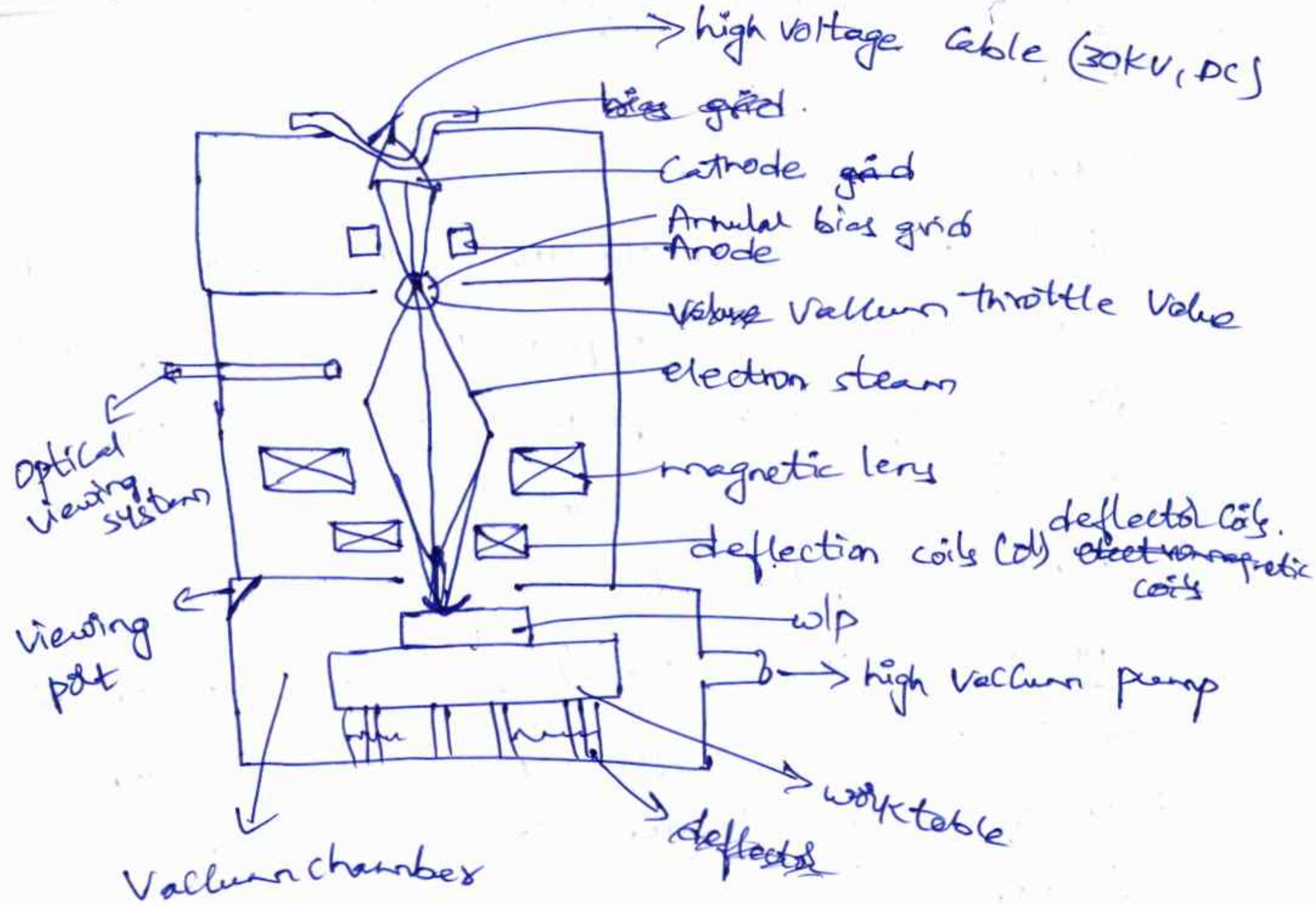
Electro discharge machining (EDM)	Electro discharge grinding (EDG)
(1) A form electrode made of electrically conductive metal is used as cathode. So spark is generated b/w the form electrode & conductive w/p.	(1) A wheel made of electrically conductive m/l acts as cathode. No separate electrode is used. Thus spark is genereated b/w wheel & w/p.
(2) The electrode usually remains static (it only moves slowly as machining progress).	(2) The EDG wheel always rotates at a fixed rpm about a fixed axis (the wheel also moves slowly as machining progresses)
(3) EDM electrode can be given complex shapes. They several simple & complex profiles (or) curvatures can be fabricated by EDM.	(3) owing to simple geometry of wheel (disk type), EDG has limited ability in terms of complexity of profile or feature that can be produced.

(4) EDM electrode is commonly made of conductive metals like copper, brass, tungsten etc.	(4) The EDG wheel is commonly made of conductive but non metallic solid like graphite.
(5) A suitable flushing Technique is highly desired for continuous delivery of fresh dielectric fluid in inter-electrode gap.	(5) No additional flushing Technique is required as rotating grinding wheel continuously sucks fresh dielectric fluid into IEG.
(6) Accumulation of debris in IEG is one major problem in EDM. dielectric flushing helps removing debris from IEG.	(6) Debris is inherently removed from IEG due to wheel rotation

Electron Beam Machining :-

It is a Non Conventional Machining process.

use for Machining of very hard & brittle materials which otherwise cannot be machining by using conventional machining processes.



working principle :- In a EBM, the electrons strike the w/p with a high velocity.

As the electron strikes the w/p, the kinetic energy of electron changes into heat energy.

The heat energy so produced is used to melt & Vapolize the materials from the w/p.

The whole process takes place in Vacuum.

Vacuum environment is used to prevent the Contamination and avoid collision of electrons with air molecules.

→ If the electrons collide with the air molecules, it will lost its KE.

Main parts :-

1) Cathode :- It is negatively charged & it is used to produce electrons.

2) Annular bias Grid :-

It is present next to the Cathode. Annular bias grid is a circular shaped bias grid & prevents the diversion of electrons produced by the cathode.

It works as a switch & makes the electron gun to operate in pulse mode.

(3) Anode :- It is placed after the annular bias grid. It is positively charged. Annular anode attracts the beam of electron towards it & gradually the velocity of electron increases.

As the electron beam leave the anode section, its velocity becomes half of the velocity of light.

(4) Magnetic Lenses :- It reduce the divergence of electron beam & shape them.

It allows only convergent electrons to pass & captures the low energy divergent electrons from fringes.

It improves the quality of the beam.

(5) Electromagnetic Lens :-

It helps the electron beam to focus on the desired spot.

(6) Deflector coils :- It carefully guides the high velocity electron beam to a desired location on the w/p & improves the shape of the holes.

Working :-

In EBM; first the electron is generated by the cathode & an annular biased grid does not allow the electron to diverge.

From the annular bias grid, the electron produced by the cathode is attracted towards the anode & gradually its velocity increases.

As the electron beam leaves the anode section, its velocity reaches to half of the velocity of the light.

→ After that it passes to the series of magnetic lenses. The magnetic lenses allows only convergent beam to pass through it & captures the divergent beam from the fringes.

→ And then a high quality electron beam is made to pass through the electromagnetic lens & deflector coils.

→ The electromagnetic lens focuses the electron beam to the desired spot on the w/p.

→ The deflector Carefully guides the beam to the desired locations & improves the shape hole.

Characteristics :-

1) EBM is operated in pulse mode & this is achieved by the biasing annular biased grid.

2) The beam Current Can be as low as 200 μ amp to 1amp.

3) The pulse duration achieved in EBM M/c is 50 μs to 15ms.

4) The energy posessed by pulse is 100 J/pulse.

5) It utilizes voltage in range of 150kV to 200kV.

6) And this voltage is used to accelerate electrons to about 200,000 km/s.

Advantages :-

→ It Can produce bolts of small sizes.

→ high accuracy & better surface finish.

→ almost all types of materials Can be machined.

→ highly reactive metals such as Al & mg Can be machined easily.

→ As it does not apply any mechanical cutting forces on the w/p, so cost of work holding & fixtures is reduced.

Disadvantages

1) high equipment cost
2) low metal removal rate.
3) high skilled operator
4) high power consumption,
5) not applicable to produce perfectly cylindrical deep holes.

Applications

Smaller size holes in various industries like marine, automobile, aerospace etc.

Laser Beam Machining :-

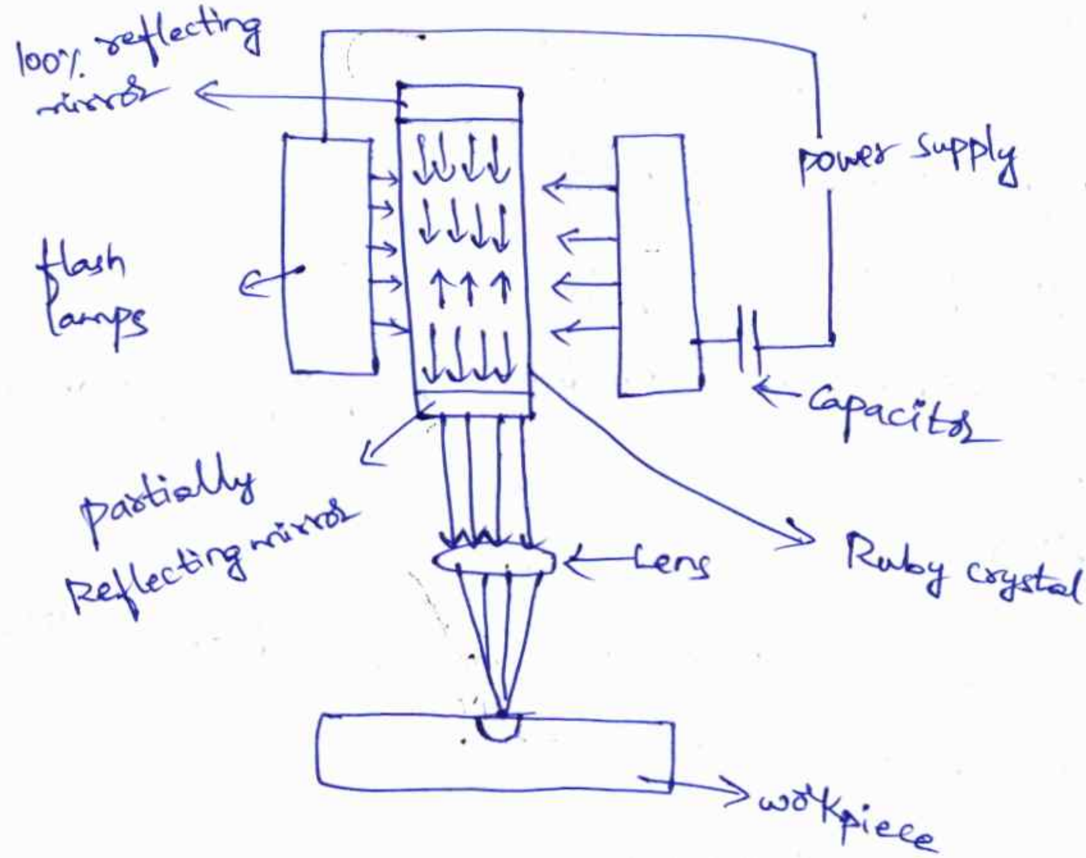
LASER — Light Amplification stimulated emission of Radiation.

→ The different types of laser are solid state, gas & Semiconductor.

At high power lasers required for machining & welding, solid state lasers are used.

Definition :- It is a non-convetional machining process in which the w/p is being holed by the laser machining process. To remove the m/l from the w/p the process used thermal energy.

Machining parts :-



powersupply ; Capacitor ; Flash Lamps ; Reflecting mirror ; Laser Light Beam ; Ruby crystal ; Lens , workpiece.

(1) power supply :-

The electric Current or power is supplied to the system.

-> A high voltage power system is used in laser beam machining.

-> It will give initial power to the system after that the reaction starts in a laser that will machine the material.

-> There is high voltage supply so that pulses can be initiated easily.

(2) Capacitor :- During the major portion of the cycle, a Capacitor bank charges & releases the energy during the flashing process.

The Capacitor is used for pulsed mode for Charging & discharging.

(3) Flash Lamps :-

It is the electric arc lamp that is used to produce extremely intense production of white light which is a coherent high intensity beam.

It is filled with gases that ionize to form great energy that will melt & vaporizes the m/l of the w/p.

(4) Reflecting mirror :-

There are two main types of internal & external.

Internal mirrors also called a resonator that is used to generate maintain & amplify the laser beam. It is used to direct the laser beam towards the workpiece.

(5) Laser Light Beam :-

It is the beam of radiation produced by the laser through the process of optical amplification based on the coherence of light created by the bombarding of active m/l.

(6) Ruby Crystal :-

It produces a series of coherent pulses which is deep red in colour. It achieves by the concept of population inversion. It is a three-level solid state laser.

(7) Lens :- Lenses are used to focus the laser beam on to the workpiece. First laser light will enter into the expanding lens & then into the Collimating lens which makes the

light rays parallel & expanding lens expands the laser beams to the desired size.

workpiece :- It can be metallic or non-metallic. In this machining process, any m/l can be machined.

working principle :-

Laser machining is based on LASER & conversion of process of electric energy into light energy & into the thermal energy.

Negatively charged electrons in the atomic model rotate around the positively charged nucleus in orbital paths.

→ It depends on no of electrons, electron structure, neighbouring atoms & the electromagnetic field.

→ every orbital of electrons is associated with different energy levels. An atom is considered to be at ground level at absolute zero temperature at this, all electrons occupy their lowest potential energy.

→ The electrons at the ground state move to a higher state of energy by absorbing energy like an increase in electronic vibration at elevated temperatures.

→ high voltage is applied at the ends that leads to discharge & gas plasma will be formed. population inversion & lasing action will take place due to energy transformation.

The laser has one 100% reflector & other one is a partial reflector. 100% reflector directs the photons inside the gas tube & partial reflector allows only some part of the laser beam that will be used for processing of the materials.

→ The laser beam produced is focused on the w/p that has to be machined. when the laser strikes the w/p, the thermal energy impinges on w/p.

→ This will heat then melt, vapolize & finally the m/l will be removed from the w/p. so laser machining is a thermal m/l removal process that uses a coherent beam of light to m/c the w/p very precisely.

→ In Laser machining process, MRR depends on the wave length used because it will decide the amount of energy impinged on it.

Applications

1) It is used for making very small holes, welding non conductive & refractory m/l.

2) It is best suited for brittle m/l with low conductivity & Ceramic, cloth & wood.

3) It is also used in surgery, micro drilling operations.

4) Spectroscopic science & photography in medical science.

5) used in mass macro machining production.

6) cutting complex profiles for both thin & hard materials.

7) used to make tiny holes er nipples of baby feeder.

Advantages :-

1) In LBM, any m/l including non metal also can be machined.

2) Extremely small holes with good accuracy can be "

3) Tool wear rate is very low.

4) There is no mechanical force on the work.

5) soft materials like plastic, rubber can be machined easily.

6) → very flexible & easily automated m/c.

7) heat affected zone is very small.

8) It gives a very good surface finish.

9) Heat treated & magnetic materials can be welded without losing their properties.

10) The preise location can be ensured on the w/p.

Disadvantages :-

1) It cannot be used to produce a blind hole & also not able to drill too deep holes.

2) The machined holes are not round & straight

3) The capital & maintenance cost is high.

4) There is a problems with safety hazards.

5) The overall efficiency of laser beam machining is low.

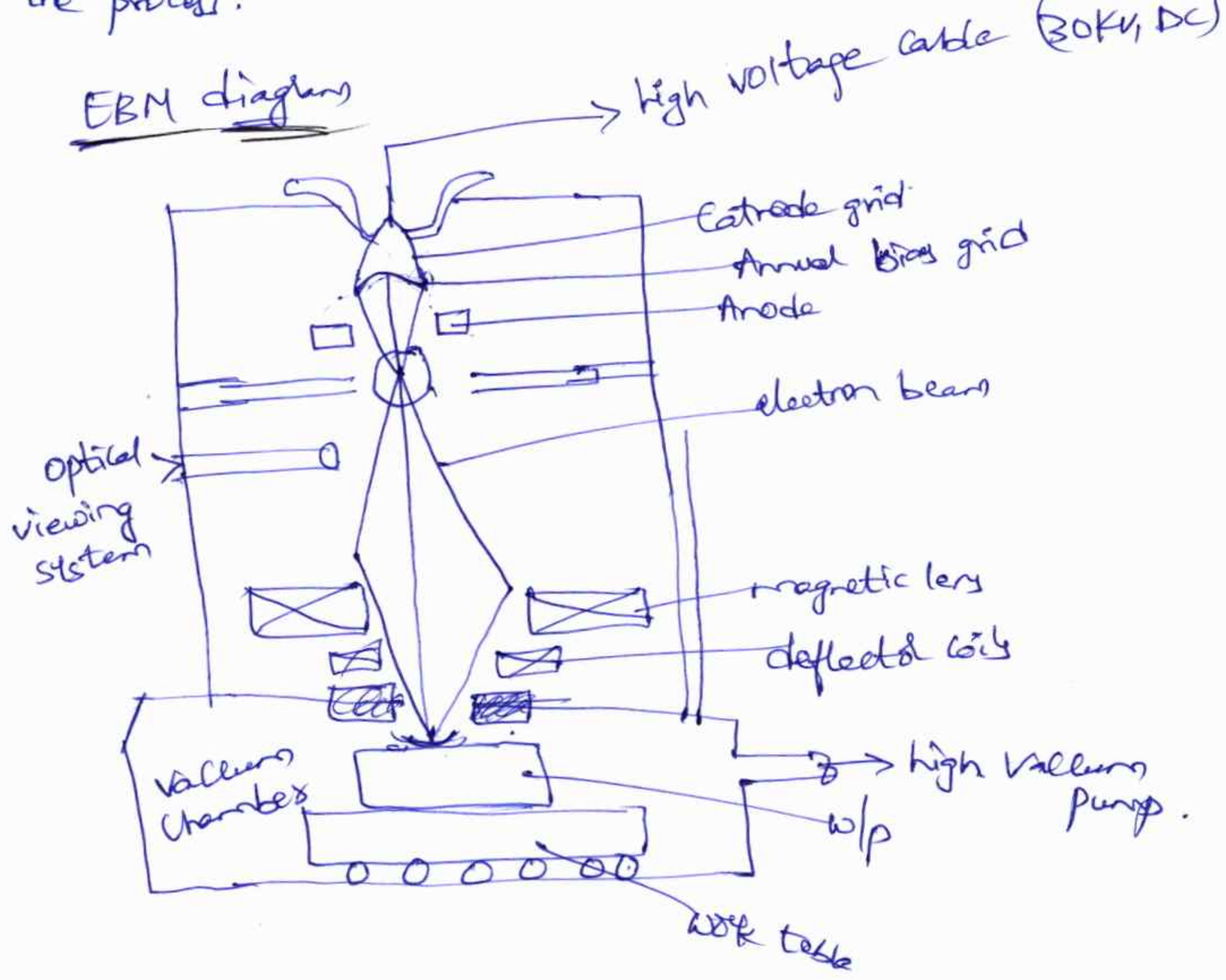
6) It is limited to thin sheets.

7) The metal removing rate is also low.

8) The flash lamp life is short.

9) There is a limited amount of metal removing during the process.

EBM diagram

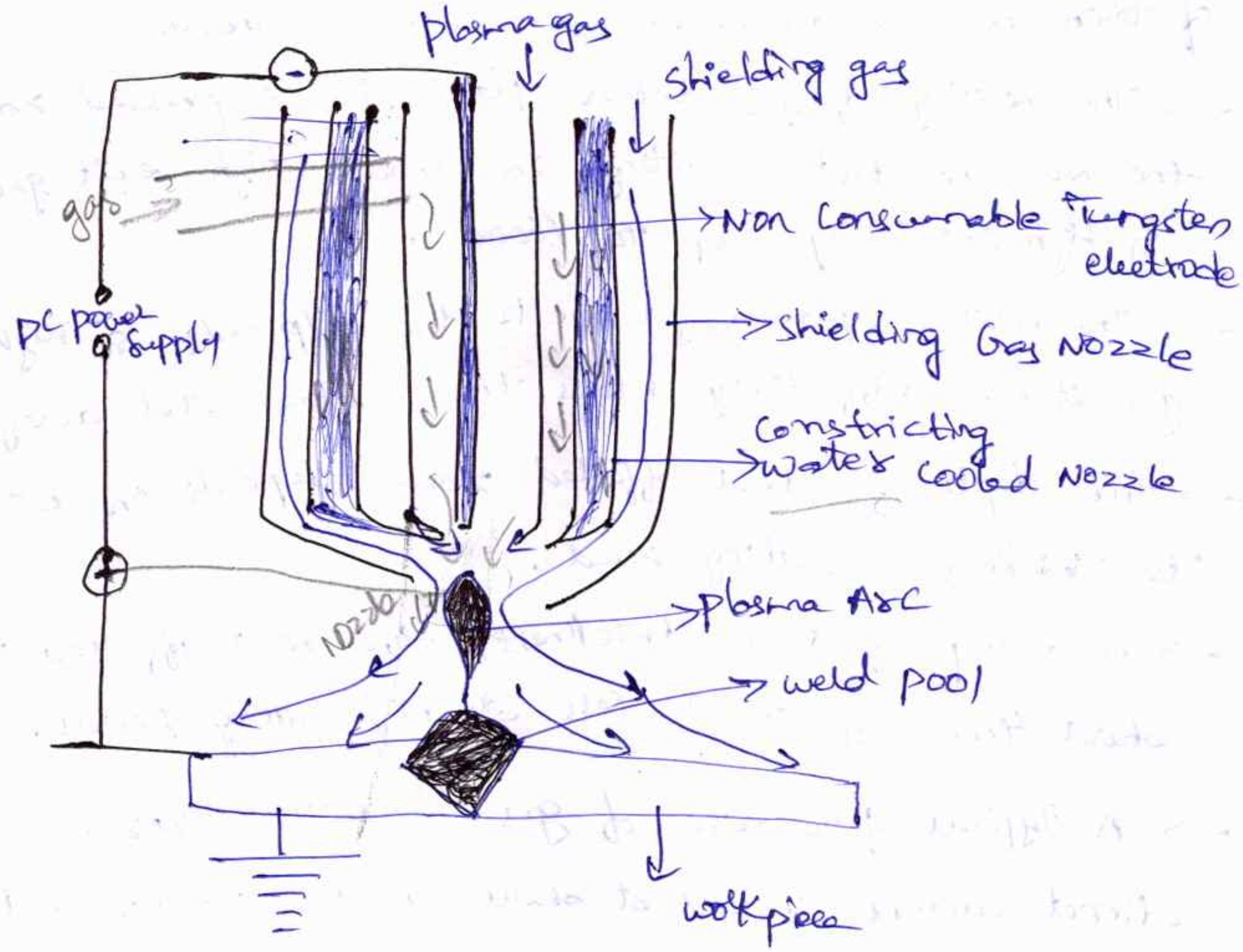


Plasma Arc machining :-

when a flowing gas is heated to a sufficiently high temperature to become partially ionized it is known as plasma.

This is virtually a mixture of free electrons, positively charged ions & netural atoms.

Definition :- It is a metal removal process in which the metal is removed by focusing a high velocity jet of high temp (11000°c to 30,000°c) ionized gas on the workpiece.



working principle :-

In a plasma torch, known as the gun or plasmatron, a volume of gas such as H_2, N_2, O_2 etc is passed through a small chamber in which a high frequency spark (arc) is maintained b/w tungsten electrode (cathode) & the copper Nozzle (anode) both of which are water cooled.

→ In certain torches, an inert gas flow surrounding the main flame is provided to shield the gas from the atmosphere.

→ The high velocity electrons generated by arc collide with the gas molecules & produce dissocation of diatomic molecules of gas resulting in ionization of atoms & causing large amounts of thermal energy to be liberated.

→ The plasma forming gas is forced through a Nozzle duct of torch in such a manner as to stabilise the arc.

→ The heating of gas takes place in compressed zone of the Nozzle duct resulting in almost high exit gas velocity & high core temp up to 16000°C.

→ The relative plasma jet melts the w/p m/l & high velocity gas stream effectively blows the molten metal away.

→ The depth of heat affected zone depends on work m/l, its thickness & cutting speed.

→ on a w/p of 25mm thickness, the heat affected zone is about 4mm & it is less at high cutting speeds.

→ A Typical flow rate of gas is 2 to 11m/hr.

direct current, rated at about 400V & 200kw output is normally required.

→ Arc current ranges b/w 150 & 1000 A for a cutting rate of 250 to 1700mm/min.

Accuracy :- This is a roughing operation to an accuracy of about 1.5mm with a corresponding surface finish. Accuracy on width of slots & dia of holes is ordinarily from ±0.8mm on 6 to 30mm thick plates & ±3mm on 100 to 150mm thick plates.

Applications :-

→ This is chiefly used to cut stainless steel & Al alloys.

→ profile cutting of metals especially of these metals & alloys has been the common prominent commerical application.

→ on the machining side, plasma has been used successfully in conventional turning & milling of very difficult materials.

Merits

→ It is almost equally effective on any metal, regardless of its hardness or refractory nature.

→ No contact b/w tool & w/p, only a simply supported w/p structure is enough.

Demerits :-

→ The process are the metallurgical change of the surface.

→ safety precautions are necessary for the operator & those in nearby areas. This adds an additional cost.

→ Rougher surface finish.

→ larger power

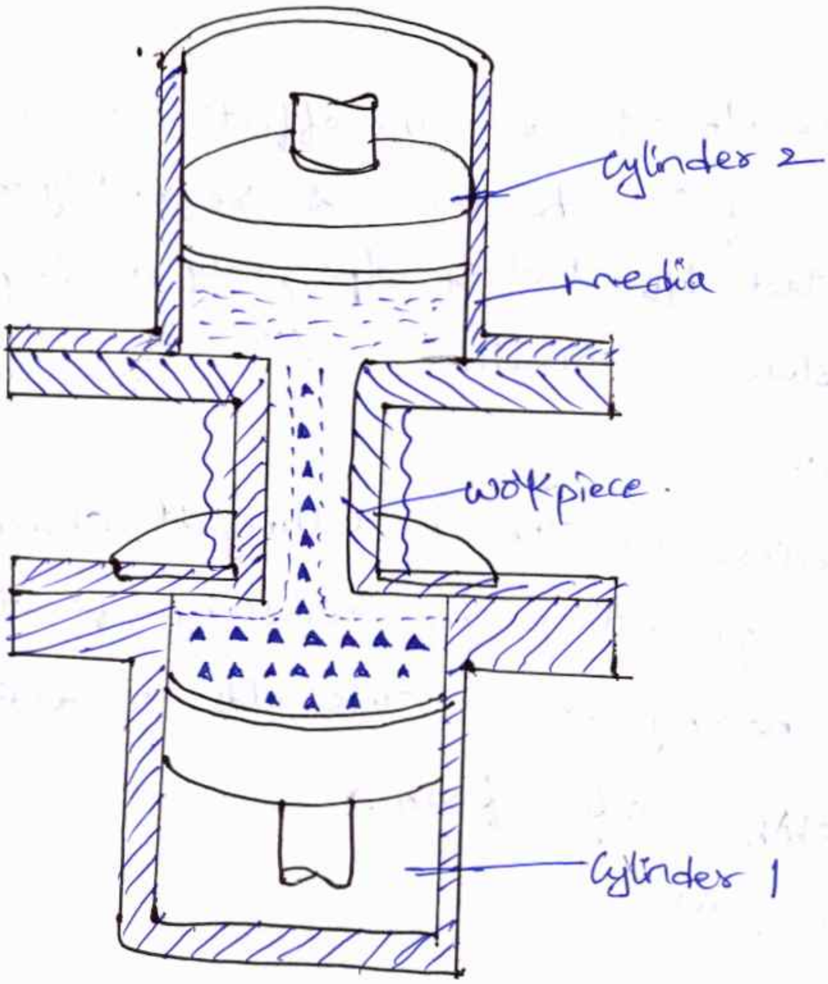
Abrasive Flow Finshing :-

It is a process of finishing the Surfaces by using a Semisolid abrasive which flows over the surfaces in order to remove the small quantity of material.

→ It is used to meet the following requirements such as

(1) The Constant demand for decreasing the lead time from design to production.

(2) The Cost of finishing operation is necessary to be taken nearly as 15% of total machining cost.



Working principle :-

Thus a manual finshing operation is needed instead of automated finishing operation.

The working principle of abrasive flow finishing process is shown in above fig.

It comprises of two cylinders placed vertically in the opposite direction to each other, and partially filled with media.

And workpiece is positioned in the between the cylinders.

The viscosity of media is so high that it can hold b/w the fingers.

The media deforms like a ball made of rubber when certain of amount of pressure applied.

The abrasive media is forced through the passages formed by workpiece or tooling in the forward & backward direction.

If the restriction offered by the passage way is more than the large amount of force is required.

In AFF, the velocity of media is controlled by the cross sectional area of passages.

It is also known as multi point cutting process since abrasive particles are used as cutting tools.

Advantages :-

It is used for machining multiple components simultaneously to increase the productivity.

The same machine can be used for wide range of jobs by Varying tools and machining parameters, media & abrasive due to high flexibility.

It is applicable for both metals & Non metals.

It provides the better accuracy, high efficiency, economy & Consistency.

limitations:-

1) The finishing rate is low when compared to other machining process.

2) The abrasive particles tends to get embedded in the ductile materials.

3) It is limited to closed environment.

4) The tool wear is relatively high.

Applications:-

1) Deburring of aircraft valve bodies

2) Radiusing of cooling turbine blades

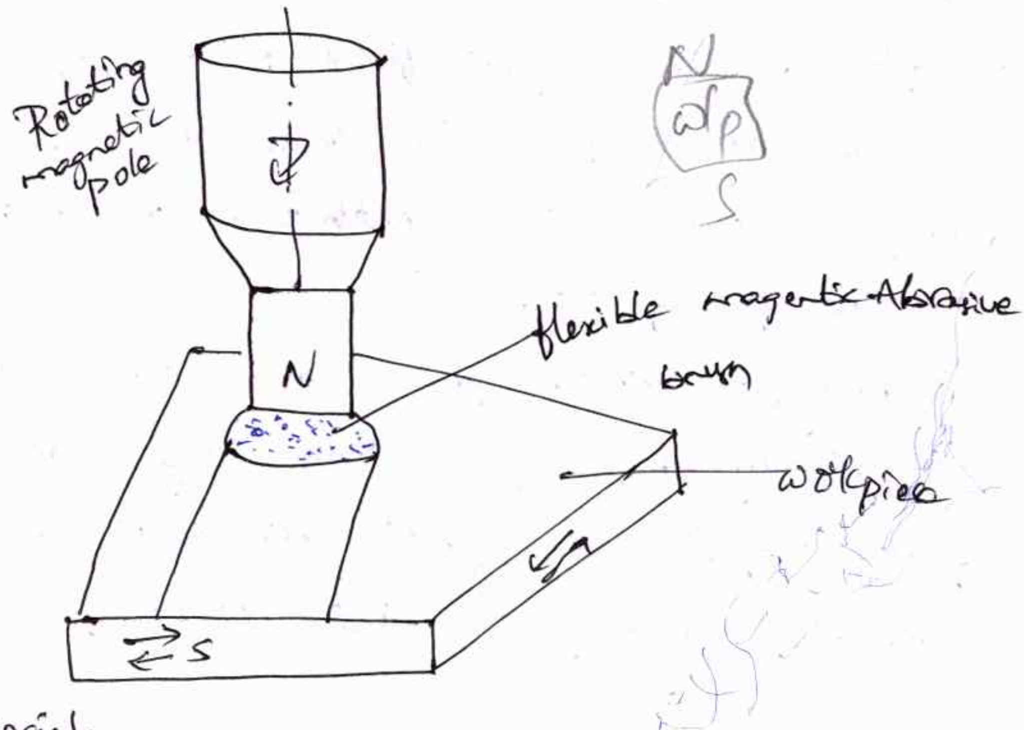
3) Removing recast layer.

4) producing compressive residual stresses.

Magnetic Abrasive Finishing process :-

It is one of the non conventional finishing processes, which produces a high level of surface quality & is primarily controlled by magnetic field.

w/p is kept b/w two poles (N & S) of a magnet.



working principle :-

workpiece is kept b/w two poles (N & S) of a magnet.
The working gap b/w w/p & the magnet is filled with magnetic abrasive particles.

A magnetic abrasive flexible brush (MAFB) is formed acting as a multipoint cutting tool due to the effect of magnetic field in the working gap.

Advantages :-

Very low magnitude of finishing forces is applied on magnetic abrasive particles to obtain nanometre surface finish.

It is useful in finishing brittle w/p without developing micro cracks & other defects.

MAF is one such unconventional finishing process developed recently to produce efficiently & economically good quality finish on the internal & external surfaces of tubes as well as flat surfaces made of magnetic or non magnetic materials.

→ In this process, usually Ferromagnetic particles are sintered with fine abrasive particles (Al_2O_3, SiC, BC or diamonds) & such particles are Ferromagnetic abrasive particles.

→ force due to magnetic field is responsible for normal force causing abrasive penetration inside the w/p while rotation of the magnetic abrasive brush (North pole) results in material removal in the form of chips.

→ magnetic abrasive grains are combined to each other magnetically b/w magnetic pole along a line of magnetic force, forming a flexible magnetic abrasive brush.

→ It uses this magnetic abrasive brush for surface & edge finishing.

→ magnetic field retains the powder in the gap & acts as a binder causing the powder to be pressed against the surface to be finished.

→ 3D minute & intricately curved shape can also be finished along its uneven surface.

→ controlling the exciting current of magnetic coil precisely controls the machining force of the magnetic abrasives on the w/p.

Applications :-

It can be used for surface finishing as well as surface modification of hard to finish surfaces such as brass, stainless steel etc.

Advantages

1) A very high volume of internal deburring is possible.
2) MAFM deburrs precision gears.
3) " polishes internal & external features of various components.
4) " removes recast layer from components.
5) Effective on all metallic materials.
6) less time consumption.
7) Controllability, repeatability & cost effectiveness.

Disadvantages:-

1) It is difficult to implement magnetic abrasive finishing in mass production operation.
2) Time consuming process.
3) The cost of process is high.
4) Not applicable for some ordinary finishing task where conventional finishing technique can be easily implemented.

Applications:-

1) Cutting tools
2) Turbine blades
3) Air foils
4) optics
5) food industry
6) Curved pipes