Unit : 2

Non-Conventional Machining Processes

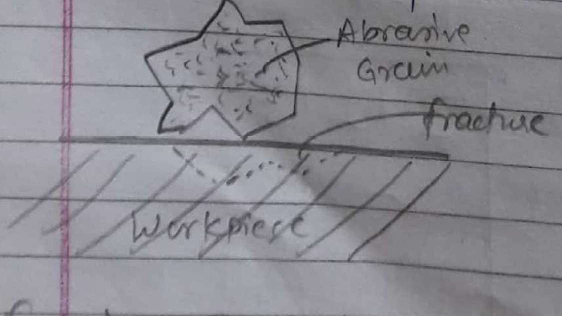
1. Abrasive jet maching.
2. Water jet machining.
3. Electric discharge machining.
4. Laser beam machining.
5. Electron beam machining.
6. Ion-beam machining.
7. Electrochemical machining.
8. chemical machining.
9. Plasma arc machining.

(1) Abrasive Jet Machining (AJM)

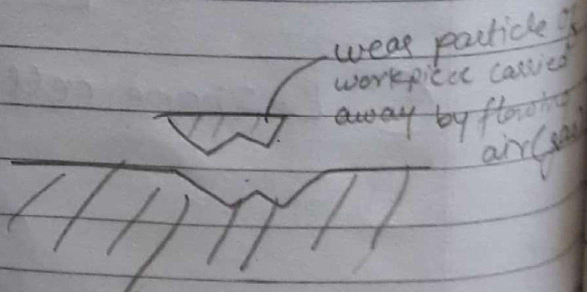
In AJM, machining takes place by the impingement of fine abrasive grain on work surface.

These particles moves with high speed air stream (Gas stream). Generally, air + CO_2

When an abrasive particle impinges on workpiece surface at high speed, the impact cause a tiny little fracture and the flowing air carries away the dis-lodge small workpiece particles



Fracture of work Surface



formation of Cavity.

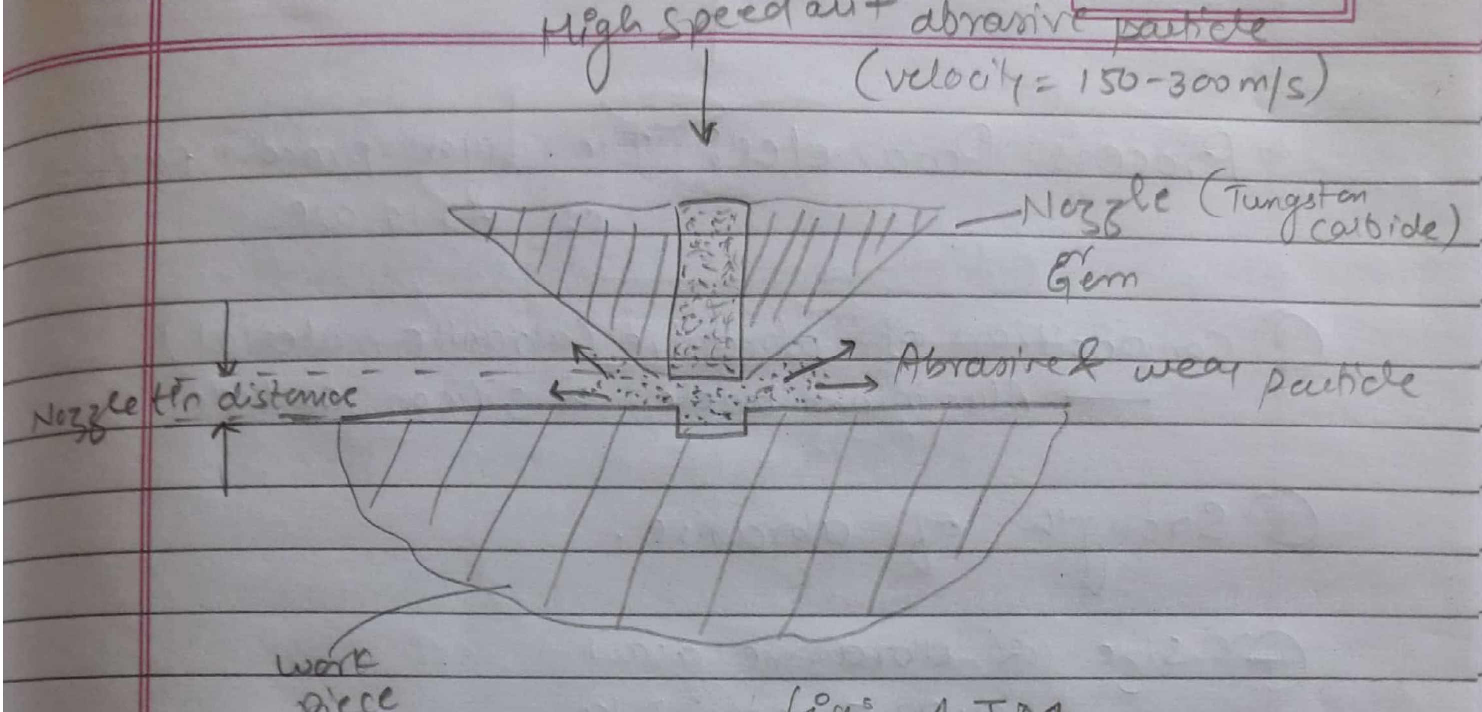


fig: AJM

– The material removal rate (MRR) due to the chipping of work surface by abrasive particle is given by,

$$Q = \chi z d^3 v^{3/2} \left(\frac{\rho}{12 H_w}\right)^{3/4}$$

Where:

z = No. of abrasive particle impacting per unit time.

v = mean velocity of abrasive grain.

d = Mean dia. of Abrasive grain.

ρ = Density of abrasive material.

H_w = Hardness of work material.

χ (chi) = Const.

Process Parameter: The major process parameter of AJM are,

(i) Composition of abrasive (abrasive material)
— Aluminium oxide (Al_2O_3) or silicon carbide (SiC).

(ii) Strength of abrasive.

(iii) Size of abrasive grain
— 0.025 mm = Dia.

(iv) Mass flow rate of abrasive particle
— 2 to 20 g/min

(v) Composition of gas (air)
— Air + CO_2

(vi) Gas pressure
— 2 to 10 atm

(vii) Velocity of gas (air)
— 150 - 300 m/s

(viii) Nozzle geometry.

(ix) Nozzle material
— Tungsten (toit) (WC) Carbide or sapphire

(x) Nozzle dia.

(xi) Nozzle tip distance from work piece.

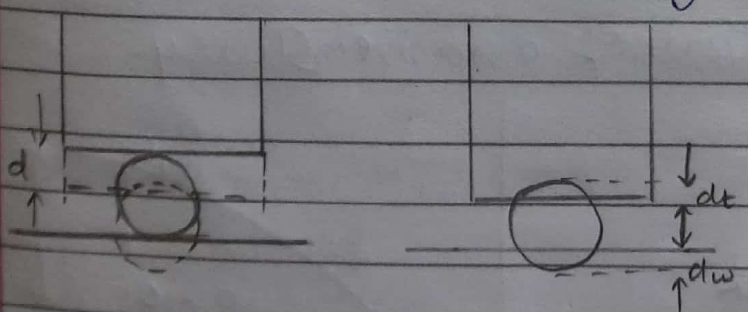
— The process parameter are optimise for getting desired performance characteristics,
- (a) Material removal rate.
- (b) Geometry of cut.
- (c) Roughness of the surface produced.
- (d) Rate of nozzle wear.

(11) Ultrasonic machining: Generally, use for finishing process.

Ultrasonic machining process involved the tool vibrating with a very high frequency & continuous flow of an abrasive slurry in the small gap b/w tool & workpiece.

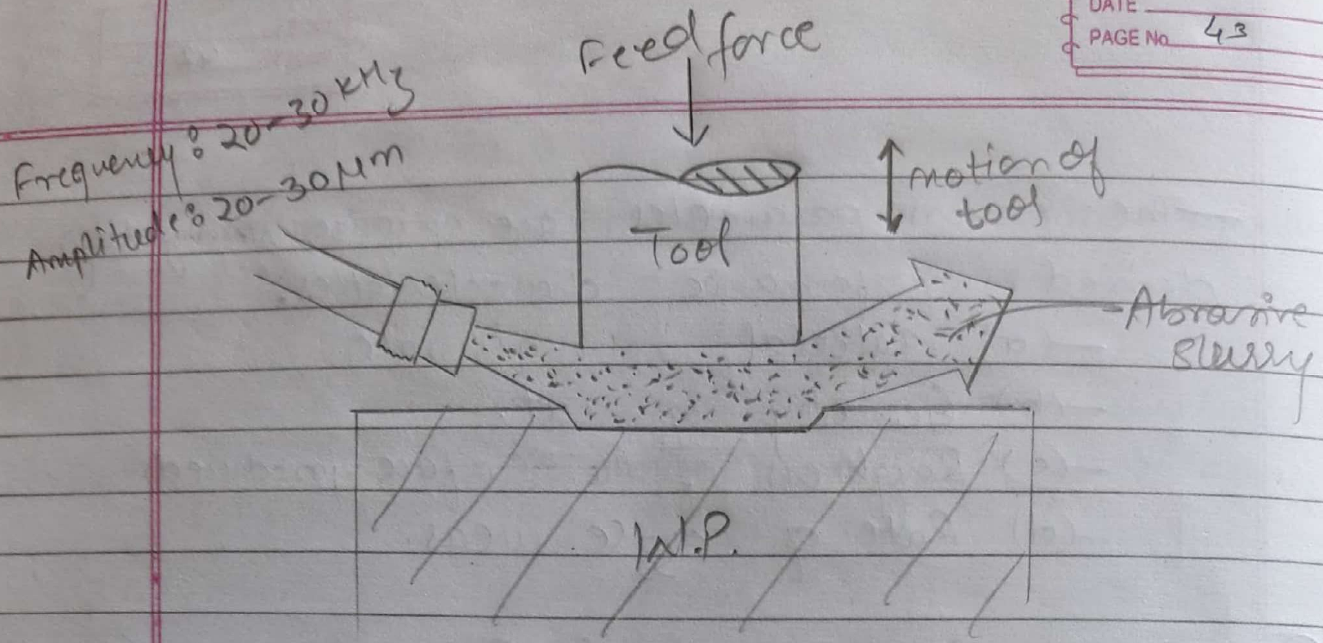
The tool is gradually fed with uniform force. The impact of hard abrasive grain causes fracture on the hard & brittle workpiece.

This results in the removal of work material in the form of small wear particle which are carried away by the abrasive slurry.



$d = d_t + d_w$

The tool material being tough & ductile, wear out at a very slower rate.

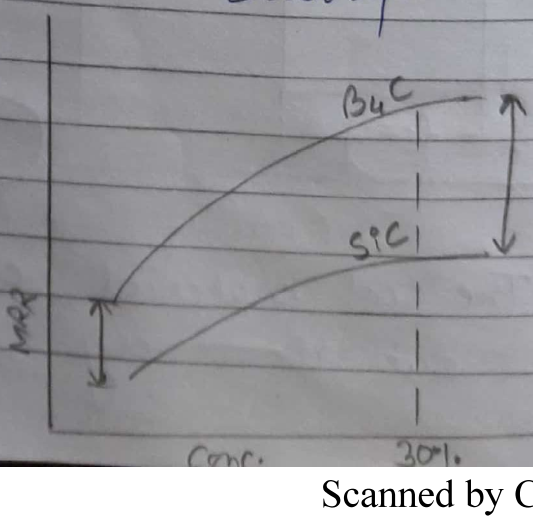


- Feed force must be limited thus increasing in force cause crushing of abrasive particle & wear of tool as well.

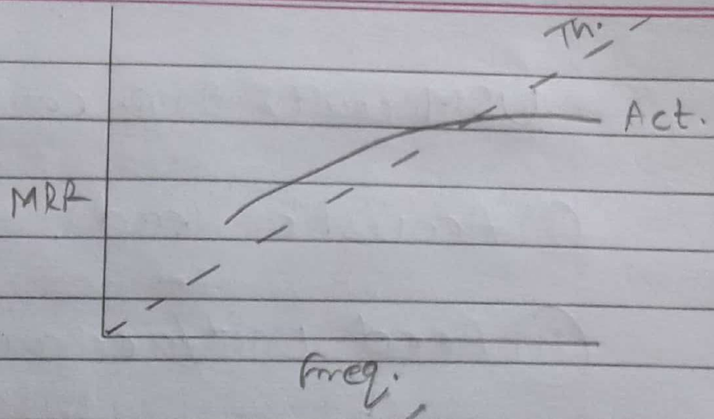
Process Parameter: Some imp process parameters which affect the process are;

(i) Frequency.
(ii) Amplitude.
(iii) Feed Force (static loading)
(iv) Grain Size
(v) Concentration of abrasive in Slurry.

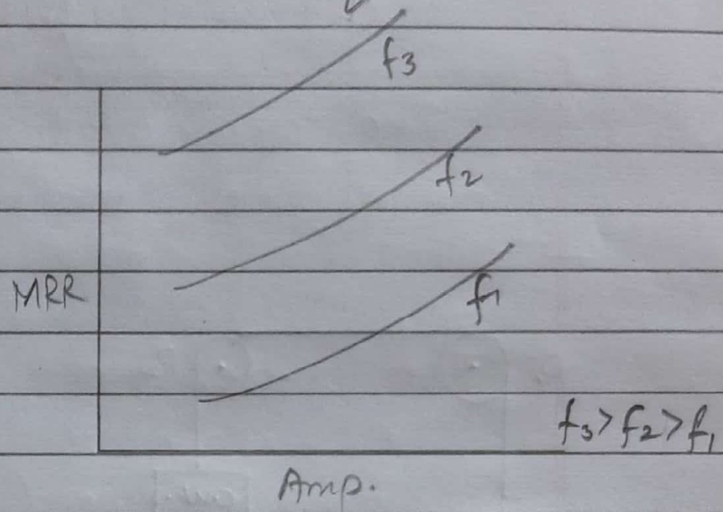
Conc. of abrasive in Slurry Vs MRR



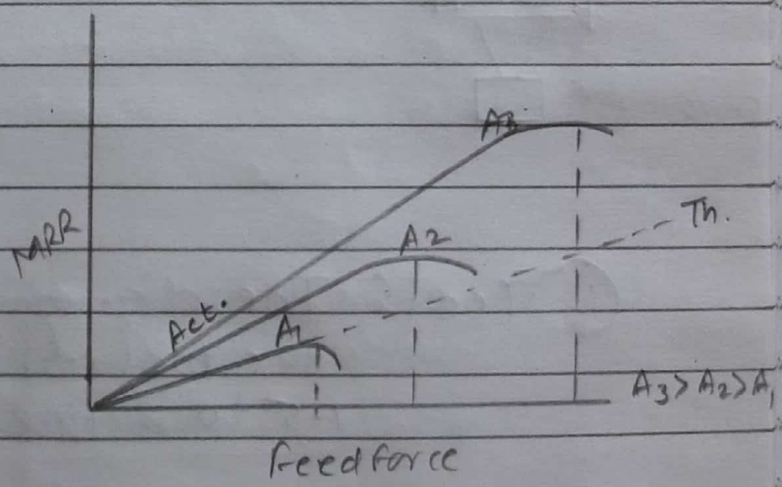
Frequency Vs MRR



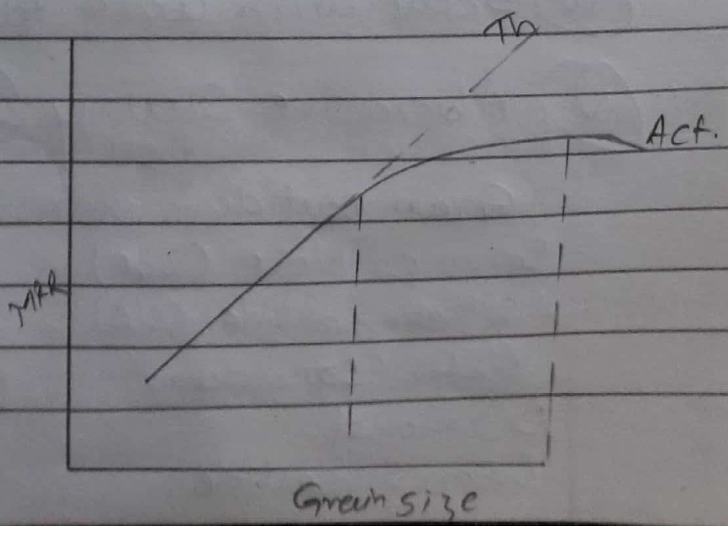
Amplitude Vs MRR



Feed force Vs MRR



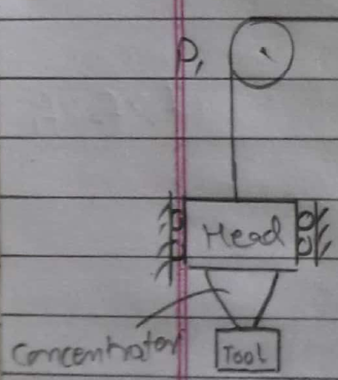
Grain size Vs MRR

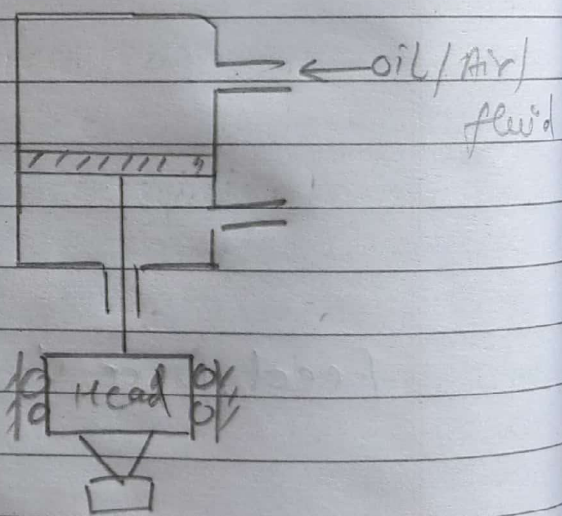


USM unit: Imp. components of machine are,

(i) Acoustic Head.

(ii) Feed Unit/mechanism. (a) Counterweight type
(b) Spring type.
(c) Pneumatic & Hydraulic type
(d) Motor type.





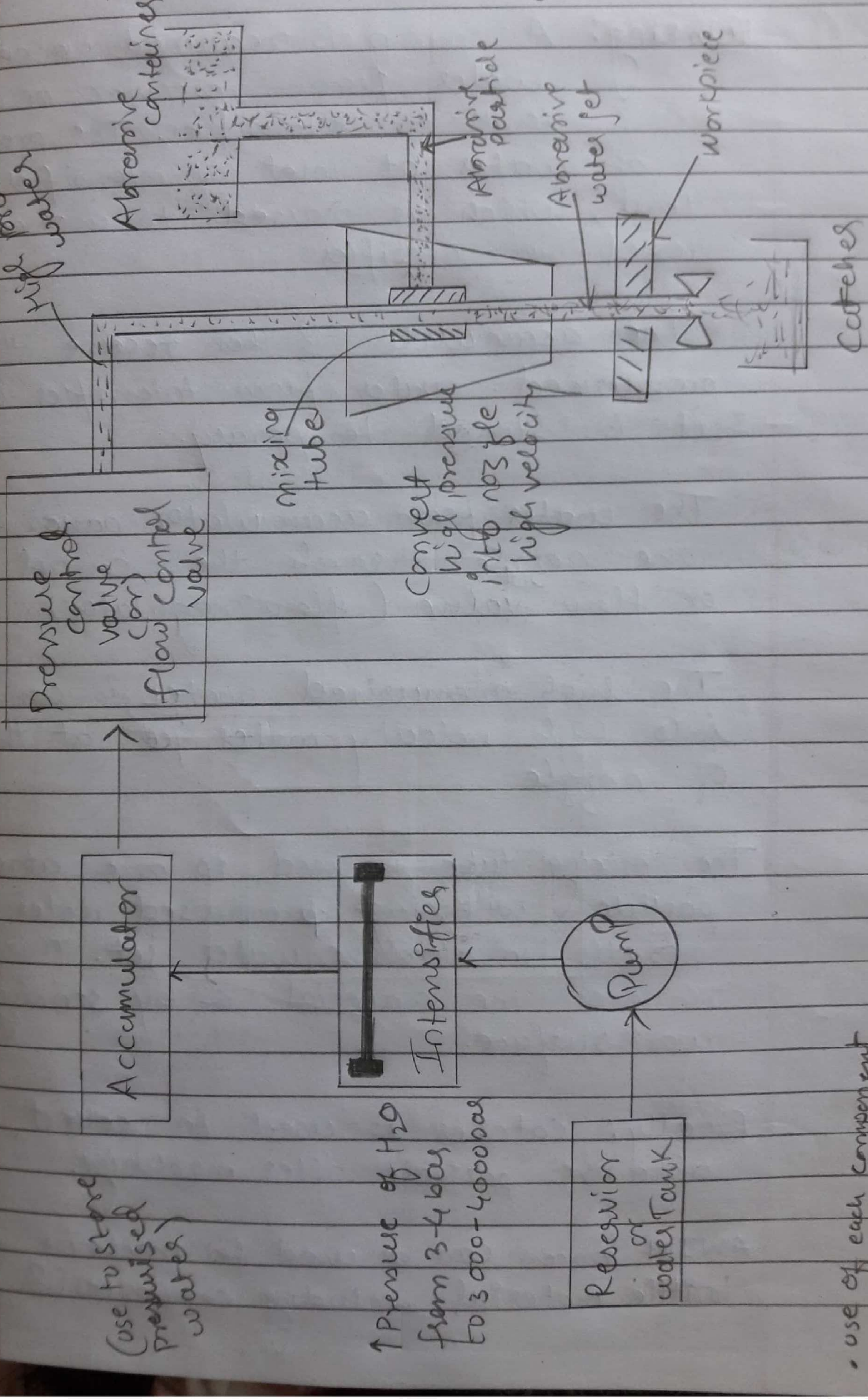
(iii) Tool: The dia. of circle circumscribed about the tool should not be more than 1.5 to 2 times, the dia of end of concentrator

(iv) Body with work table.

(v) ~~Abrasive Slurry & pump unit~~

Grain particles	Liq.
Boron carbide (B_4C)	water
Silicon carbide (SiC)	Benzene
Al_2O_3 (Corundum)	Glycerol
Diamond	Oil
Boron Silicarbide	

(iii) Abrasive Water Jet Machining (AWJM)



• use of each component

Working: A pump is required to carry water from reservior or water tank to intensifier. The pressure of water at inlet of intensifier is low, which is raised to a required level in intensifier

The accumulator is then receive the high pressurised water from intensifier where it is stored temporary.

The water from accumulator passes on to the nozzle through the, control valve or flow valve (flow regulator).

The high pressurised water is converted into high velocity water jet at the exit of nozzle

The mixing tube is used to mix abrasive particle with high pressurised water, which results in abrasive water jet. This AWJ removes the material ~~on~~ by striking on worksurface.

Finally, catcher is used to collect, the abrasive particle after machining.

AWJM process can be used for machining hard & brittle material including composites & ceramics

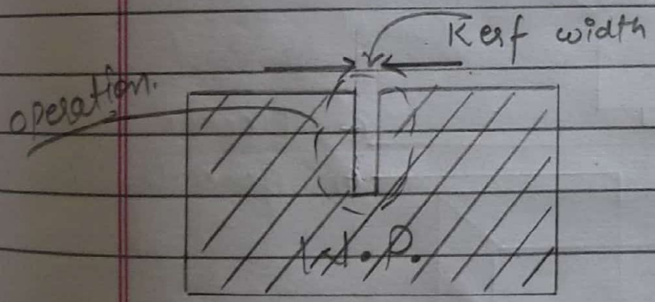
Advantages: i) It is a cold process, due to which it does not lead to thermal damage of the material.

ii) It does not produce any hazardous gases. Hence it is an eco-friendly process.

iii) It is capable of producing any shape.

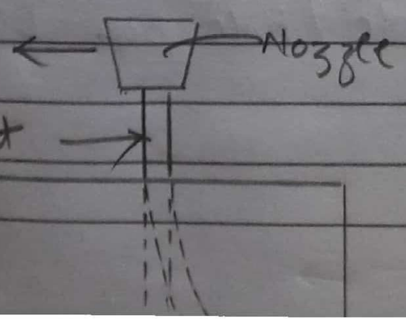
iv) Relatively cheaper process and easy to operate.

v) less material wasteage due to small kerf width. (If kerf width is small it will save the material.)



Disadvantages: i) This process can not cut thick-material effectively, as the nozzle will deflect, it cuts diagonally.

ii) It can machine limited material, economically.



(iv) Electric Discharge Machining (EDM):

- The progress in EDM was made during 1960's and wire EDM was developed in 1970's.
- EDM can precisely machine a large no. of semi-conducting & conducting materials.
- It has capability to drill circular and non-circular holes and produce macro and micro size complex shape.
- Shape that produce on W.P. depends upon the cross-section shape of tool.

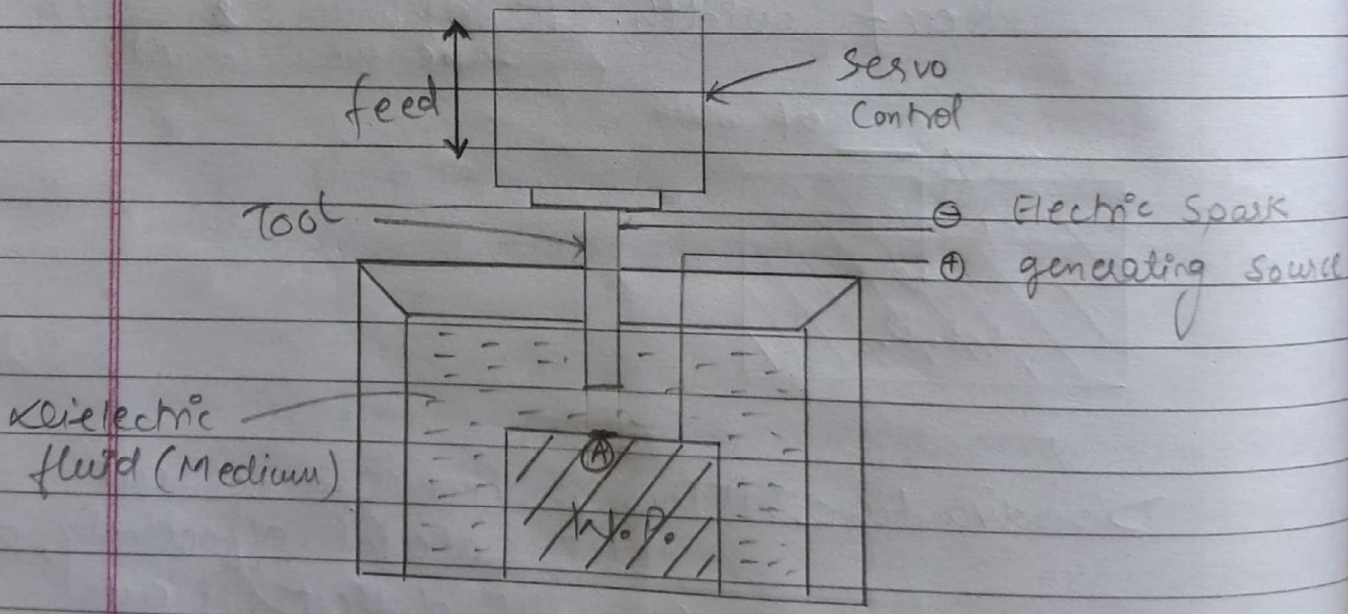


fig: Die-sinking EDM setup.

- Some eg. of EDM are; wire EDM, die-sinking EDM and small hole / Hole pop EDM.

Working: • The material removal takes place by a series of Sparks b/w tool & W.P. The tool and W.P. remain immerged in electrolytic medium during material removal process.

- Spark generated b/w the tool and W.P. results in the generation of high temp which causes melting and evaporation of tool and W.P.

- The acceleration of electron emitted by cathode and that of electrons in di-electric medium toward the anodic surface results in electrical breakdown.

- On reaching the anodic surface (W.P.) the K.E. of electrons is converted into heat Energy.

- Heavy discharge takes place b/w tool & W.P due to ⊕ & ⊖ terminal of electric source and generating a Local Temp. ranging b/w 8000°C to 12000°C & achieve this value in Short duration of about 0.1 μsec to 2000 μsec.

- With increase in temp, pressure also increases ($P \alpha T$). Due to this high Surrounding pressure, evaporation stops. Thus we have to stop sparking to overcome this issue.

- Temp. generated is sufficient for the W.P. (anodic surface) to reach its normal boiling point.

- This causes evaporation of super heated metal & thereby removal of metal takes place. The die-electric fluid (Medium) flushes the debris produces during the EDM process. This also serves as Quenching Medium.

- The most imp. facter is Gap, b/w Tool & W.P. i.e. whole material removal process depends upon this gap.

- Now new feed is given to tool toward W.P. by Adaptive control, which maintain optimum gap.

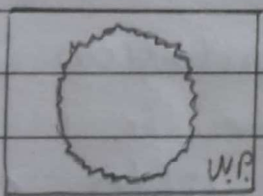
- Sufficient time must be provided to avoid collection of debris which may otherwise make the spark unstable

On the basis of gap, current flow as

(i) Open circuit :- Gap is large
(open Gap voltage)
- No spark.
- No material remove & no tool wear.

(ii) Short circuit :- Gap is small (sudden contact)
- No spark
- No material remove.

(iii) Arc :- Gap is limited
- Material remove but can damage material and shape of required product.



- Required shape: circular
- Final shape: irregular

(iv) Spark :- Most preferably use.
- Possess optimum gap.

Electrode (Tool) : Material should posses good electrical conductivity and high melting point.

The most common electrode material used in EDM process are graphite, copper, brass, copper tungsten Alloys and Silver-Tungsten alloys.

Dielectric Fluid (Medium) : The serves the following function in EDM process,

(a) To flush away the debris from electrode gap.
(b) To provide insulation b/w Tool & W.P.
(c) Quench the W.P. after complition of machining process.

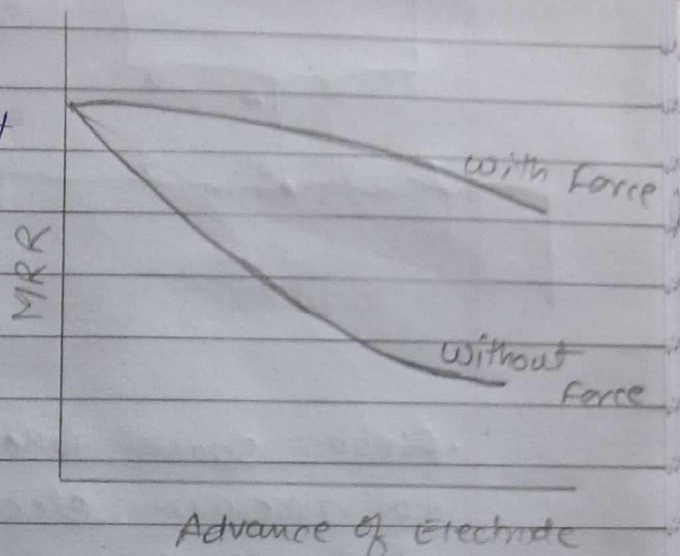
It must posses properties such as low viscosity, oxidation stability, absences of toxic vapours, low cost etc.

eg: Hydrocarbon (petroleum) oil, Kerosene oil, liq paraffin etc. And De-ionised water is used for wire EDM.

- Due to absence of oxygen inside the chamber (for combustion), fluid does not catch fire.

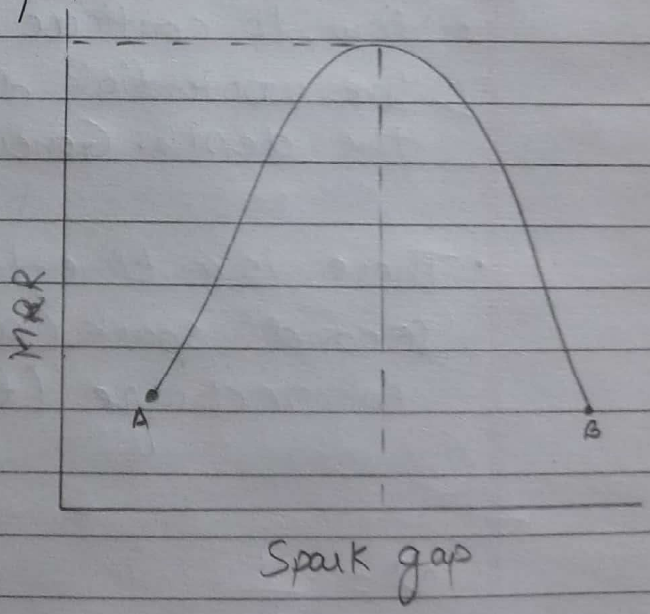
Effect of Forced dielectric circulation:

MRR strongly depends on the circulation of dielectric fluid. Without a forced circulation, the wear particles repeatedly melt & rewrite with the electrode.

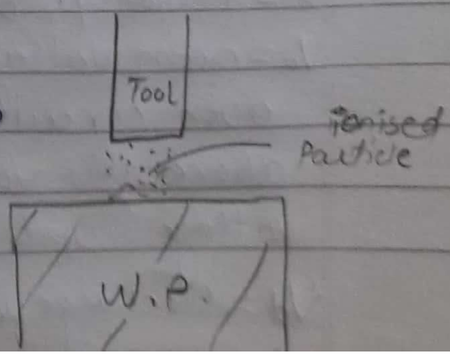


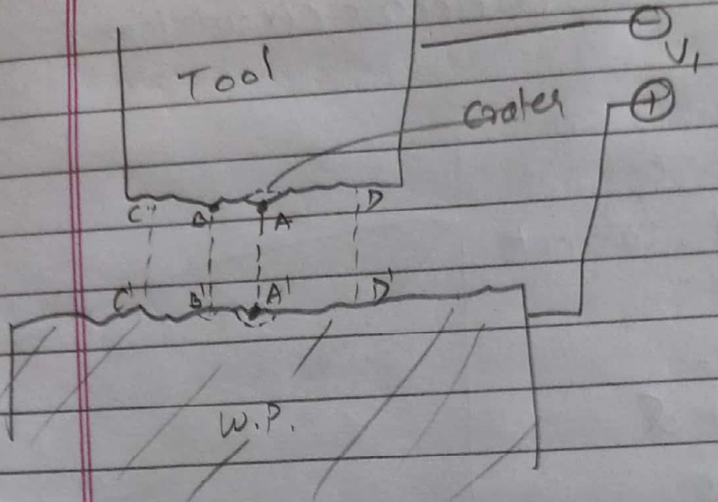
Effect of spark gap:

- Before point (A), short circuit, need low dischage voltage
- Beyond point (B), open circuit, need high dischage voltage.



- These ionised particle make electric contact b/w Tool & W.P., it leads to heavy dischage which forms a crater in both (Tool & W.P).

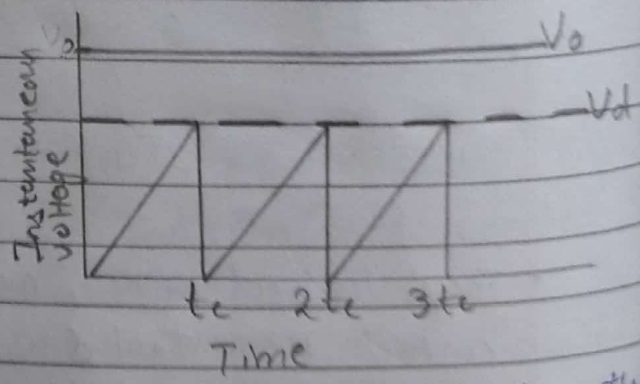




- First spark take place at nearest point (AA') due to maximum electrostatic force and forms crater at A. Hence gap increaced.
- Second Spark take place at new nearest point (BB')
- And the process continue till the gap increase above the spark gap.
- Now, to continue process we have to either increase the potential difference (voltage V_2) or decrease the depth. Generally, we give feed to tool.

- There is a time-lapse, b/w first spark (at AA') and second spark (at BB') — This time is required to recharge. (tc)

$$\nu = \frac{1}{t_c}$$



ν = freqency. of spark
V_0 = main voltag or
open circuit voltage
above this voltage no spark take place and below this voltage spark generate.
V_d = Discharge voltage:

$$E = \frac{1}{2} C V_d^2 \text{ — Joule}$$

$$W_{avg} = \frac{E}{t_c + t_s} \text{ — Watt}$$

$$Q \approx 27.4 W^{1.56} \text{ — mm}^3/\text{min}$$

Here:
E = Discharge energy
C = Capacitance
W_{avg} = Avg. power deliver
t_c = Time to recharge
t_s = Spark time
Q = MRR.

- When the gap is too small the discharge voltage is small, though the frequency is high, mrr is small.

- When the gap is too large, though the discharge voltage is high, the frequency falls down drastically, resulting in a drop in MRR.

Application: ① Complex shapes made up of hard to machine material such as carbide, super alloys etc.

② It is use for micro machining of slots, holes and dies.

Advantages: ① Extremely hard materials can be machine with a very close tolerance

(ii) No distorsion or damage to W.P

(iii) Holes with micro dimensions can be drill with high accuracy.

Disadvantages: ① Time consuming process.

(ii) MRR is low.

(iii) Tool wear is excessive.

(iv) Additional cost is involved for fabrication of electrodes.

(v) Non conducting materials can be machine only with a special set of machining arrangement

Metrology :- derive from Greek word Metrologia - "Science of Measurements."

- There is no manufacturing process which can produce two identical product/component.

- In any production process regardless of well it is designed or how carefully it is maintained a certain amount of natural variability will always exist.

- These natural variables are random in nature and are the cumulative effect of many small uncontrollable causes.

- When these natural variation in a process are relatively small, this can be considered to be an acceptable level of process performance.

- Some variation known as tolerances needs to be allow to produce a part or component.

- No component can be manufactured precisely to a given dimension, it can only be made to lie b/w two limit (Upper or lower limit) or (Max. or Min.)

- The design has to suggest these tolarance limit which are acceptable for each of the dimension, used to define shape and form.

- The difference b/w upper and lower limit which terms as Permissible Tolerance

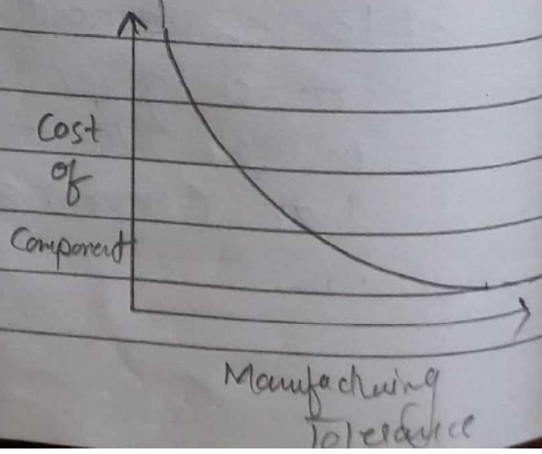
eg (30) ± 0.02 mm ← Basic size

Upper limit = 30.02 mm
Lower limit = 29.98 mm
Permissive Tolerance = 0.04 mm

* Basic or Nominal Size: It is define as the size based on which the dimensional variation are given.

* Tolerances :- It can be define as the magnitude of permissible variation of a dimension from the specified value.

- Tolerance is the algebric difference b/w the upper and lower acceptable dimension and its is an absolute value.

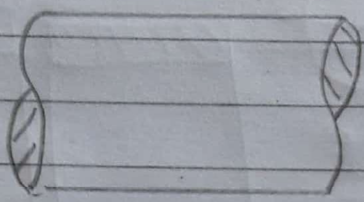


✱ Agencies, which define standard size:

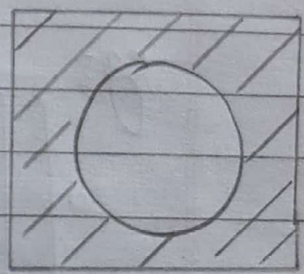
- American Nation Standard Institute (ANSI)
- American Society of Mechanical Engineer (ASME)

✱ Maximum & Least Material limit:

eg: 30 ± 0.02



Shaft



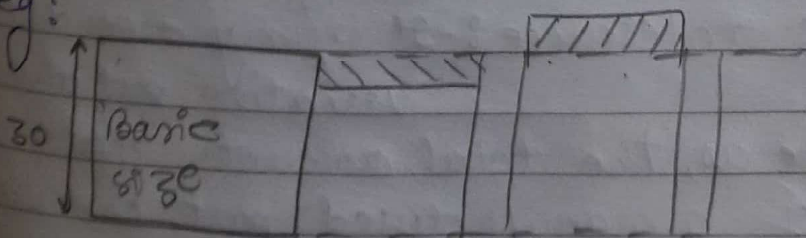
W.P.

	30.02	29.98
Shaft	MML	LML
Hole (W.P)	LML	MML

✱ Classification of Tolerance:

① **Unilateral Tolerance:** – Allow variation on one side.
– When Tolerance distribution is only on one side of basic size, it is known as unilateral Tolerance.

eg:



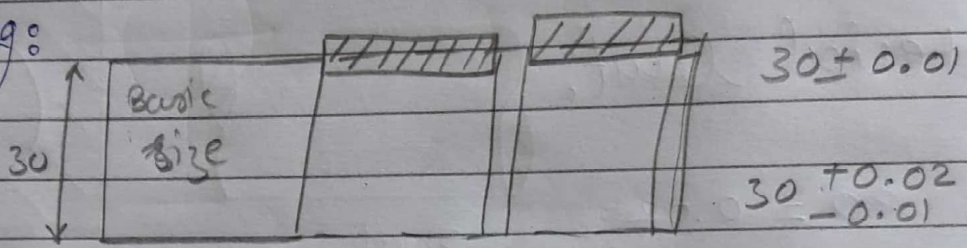
$30^{+0.00}_{-0.02}$

$30^{+0.02}_{-0.00}$

Scanned by CamScanner

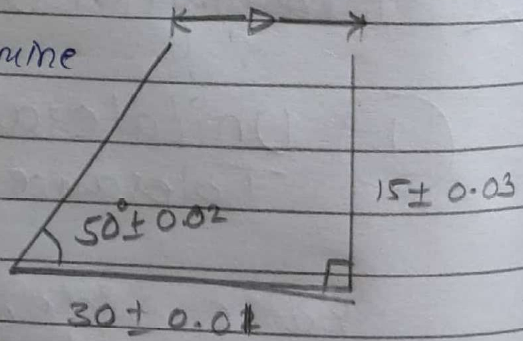
(ii) Bilateral Tolerance :- Allow variation on both side
— When tolerance distribution lies either side of basic size, it is known as bilateral Tolerance.
— Variation is not necessary to be symmetric.

eg:

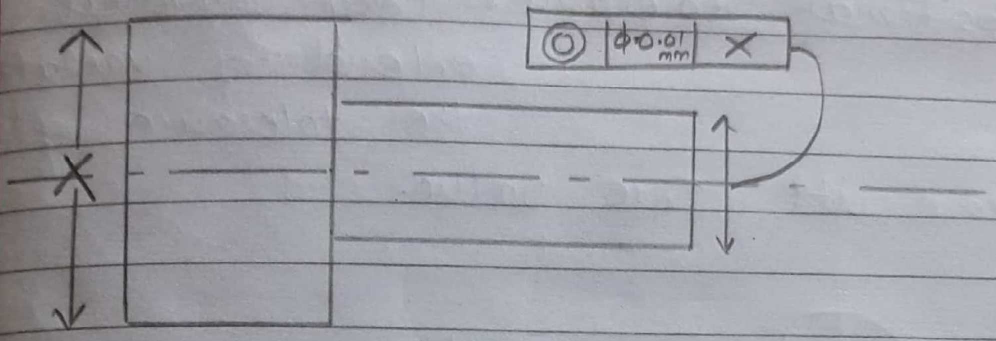


(iii) Compound Tolerance :- Depends upon individual different tolerances.
— When tolerances is determine by stabilised tolerances on more than one tolerance, it is known as compound tolerances.

eg. Tolerance of D is determine by combined effect of tolerance on 30mm, 50° and 15mm dimension.



(iv) Geometric tolerance :- It is not only depends upon size variation but also in shape.
— It is define as, the total amount that the dimension of a manufactured part can vary.
— It underlines the importance of shape of feature against its size.



a) Form Tolerance: They limit the amount of error in the shape of a feature and they are independent.

eg: — Straightness.

○ Circularity.

▱ Flatness.

⌭ Cylindricity.

b) Orientation tolerance: They are used to limit the direction or orientation of a feature in relation to other feature.

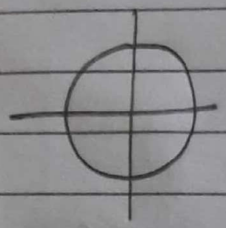
eg: ⊥ Perpendicularity.

// Parallism

∠ Angularity.

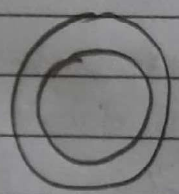
c) Positional tolerance: They controlled the extend of variation of the tolerance of feature from its true value.

eg:



Position

Symmetry



Concentricity

☆ **Fits:** The relationship b/w the two mating parts that are to be assembled w.r.t. the difference in their dimension before assembly is called fit.

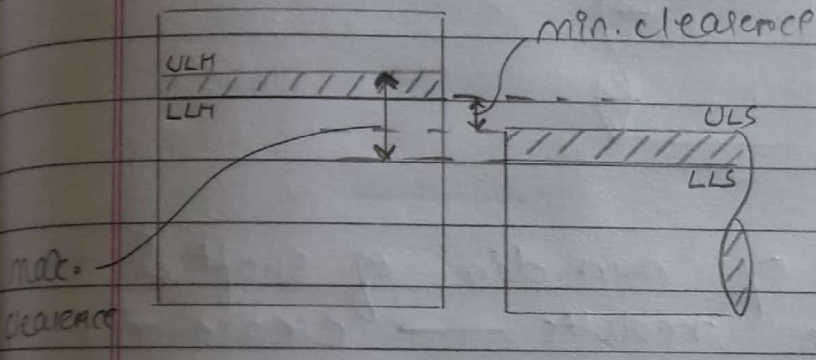
Classification of fit:

Based on types of Tolerances we classified fits as.

(i) Clearence fit:- The largest permissible dia. of shafts is smaller than that of smallest hole.

- Difference b/w sizes (hole - shaft) is always (+)ve.

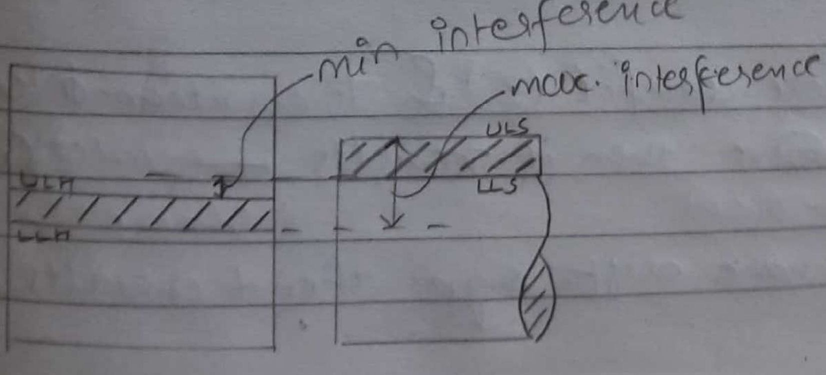
- C = LLH − ULS



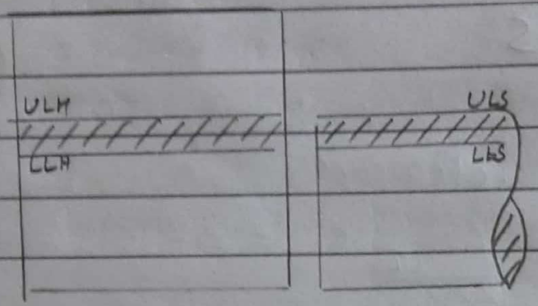
(ii) Interference fit: The min. permissible dia. of shaft exceeds the max allowable dia. of hole. This type of fit provides interference.

- Difference b/w sizes (hole − shaft) is always (−)ve.

- I = ULH − LLS



(iii) Transition fit: The dia. of largest permissible hole is greater than that of smallest shaft and the dia of smallest hole is smallest than that of largest shaft.



- The combination of min dia. of shaft & max. dia of hole results —— clearence fit.

$$C_T = ULH - LLS$$

- The combination of max. dia of shaft & min dia. of hole results —— interference fit.

$$I_T = LLH - ULS$$

* If clearence fit (C) & Transition-clearence (C_T) fit both are ⊕ve then it results —— clearence fit.

* If interference fit (I) & Transition-interferen (I_T) fit both are ⊖ve then it results —— interference fit.

* If both have diff. sign then it results — Transition fit

* Allowence: A allowence is the intensional difference b/w the MML (i.e. LLH or ULS) of the two mating parts.

- Allowence may be (+) (clearence fit) or (-) (interference fit)

* Holes & Shaft basis System: To obtain desired fit, either the size of hole or size of shaft must vary.

(A) Hole basis system: The size of hole is kept constant and the size of shaft is varied to give various types of fits. (i.e. Tolerence is provided to shaft).
- The lower limit of hole is same as basic size (or nominal size).
- Most industries use this System.

(B) Shaft basis System: The dimension of shaft is kept const. and the size of hole is varied to obtain different types of fits. Upper limit of shaft is same as basic size (or nominal size)

Qu: In limit system the following limits are specified for a hole & shaft assembly

Hole $30^{+0.02}_{+0.00}$ mm   Shaft $30^{-0.02}_{-0.05}$ mm

Determine tolerances & Allowance for hole & shaft?

Solⁿ: $T_H = HLH - LLH$
$= 30.02 - 30.00$
$T_H = 0.02$ mm

$T_S = HLS - LLS$
$= 29.98 - 29.95$
$T_S = 0.03$ mm

$A = MML)_H - MML)_S$
$= (30.00) - (29.98)$
$= 0.02$ mm

Qu: Tolerances for hole & shaft assembly having a nominal size of 50mm are as follows:

Hole $50^{+0.02}_{+0.00}$ mm   Shaft $50^{-0.05}_{-0.08}$ mm

Determine the following:

Solⁿ (a) Max clearance & Min clearance

Max clearance
ULH − LLS
$(50+0.02) - (50-0.08)$
$= 0.1$ mm

Min clearance
LLH − ULS
$(50+0.00) - (50-0.05)$
$= 0.05$ mm

(b) Tolerances on hole

ULH − LLH
$(50.02) - (50.00)$
$= 0.02$ mm

Tolerances on Shaft
ULS − LLS
$(50-0.05) - (50-0.08)$
$= 0.03$ mm

(c) Allowances $MML)_H - MML)_S$

$= (50.00) - (50 - 0.05)$

$= 0.05 mm$

(d) Max Metal Limit on Hole

$MML)_{Hole}$

50.00 mm

Max Metal Limit on shaft

$MML)_{Shaft}$

$50 - 0.05$

$= 49.95 mm$

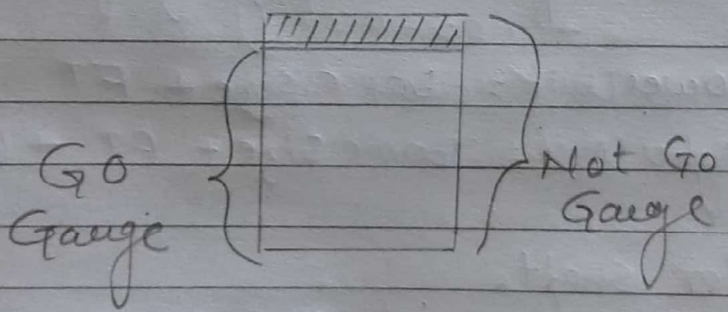
(e) Type of fit

$C_T = ULH - LLS$

$= (50 + 0.02) - (50 - 0.08)$

$= 0.1 mm$ —— Clearence fit

☆



- We have to ~~define~~ design these gauges.
- Fundamental Tolerances (FT) & Fundamental deviation (FD) have unit 'µm'.
- D = Geometric mean (i.e $D = \sqrt{D_{min} \times D_{max}}$)
- For Hole,

LLH = Basic Size + FD

HLH = Basic Size + (FD - FT)

- For shaft,

LLS = Basic size + (FD − FT)
HLS = Basic size + FD

(A) For designing gauges,

A) For Hole,

→ Limits of GO plug gauge.

Lower limit = Basic size + wear Allowance
Higher limit = Basic size + (Wear Allowance + Gauge Tolerance

→ Limits of Not GO plug gauge.

Lower Limit = Basic size + FT
Higher Limit = Basic size + FT + Gauge Tolerance

B) For shaft,

→ Limits of ~~Not~~ GO ~~sn~~ snap gauge.

Higher Limit = Basic size − (FD + wear allowance)
Lower limit = Basic size − (FD + wear Allowance + Gauge Tolerance)

→ Limits of Not GO snap gauge

Higher Limit = Basic size − (FD + FT)
Lower Limit = Basic size − (FD + FT + Gauge Tolerance)

— Gauge Tolerance = 10% of work Tolerance

i.e $GT)_H = 10\%$ of T_H $\quad GT)_S = 10\%$ of T_S

— Wear Allowance = 10% of gauge Tolerance

Que: Design the general type of GO & Not GO gauges as per the British System for a 40mm shaft and hole pair, designated as 40 H8/d9

Given that;

(a) $i = 0.453\sqrt[3]{D} + 0.001D$

(b) 40mm lies in dia. wedge of 30 to 50mm

(c) IT8 = 25i

(d) IT9 = 40i

(e) upper deviation of shaft $= -16D^{0.44}$

(f) Wear Allowance assume to be 10% of gauge Tole.

Solⁿ D — geometric mean

$D = \sqrt{30 \times 50}$

$D = 38.729$ mm

$i = 0.453(38.729)^{1/3} + 0.001(38.729)$

$i = 1.571\ \mu m$

FT for hole = 25i
= 0.039275 mm

FT for shaft = 40i
= 0.06284 mm

FD in hole = 0 (i.e. as it is not given in question)

FD in shaft = $-16D^{0.44}$
= $-79.957\ \mu m$
= -0.07995 mm

For hole

LLH = BS + FD
= 40 − 0 = 40 mm

HLH = BS + (FD + FT)
40 + (0 + 0.039275)
= ~~39.96 mm~~ 40.039

For shaft

LLS = BS + (FD − FT)
40 + (−0.079 − 0.062
= 39.85 mm

HLS = BS + FD
= 40 − 0.07995
= 39.92 mm

T_H = HLH − LLH
= 0.0392

T_S = HLS − LLS
= 0.07

$GT)_H$ = 0.0039 mm

$GT)_S$ = 0.007 mm

☆ Steps for Gauge design:

1) $D = \sqrt{D_{max} \times D_{min}}$ (in mm)

2) i = given (in μm)

3) $FT)_{Hole}$ = (given) × i (in μm)
$FD)_{Hole}$ = 0

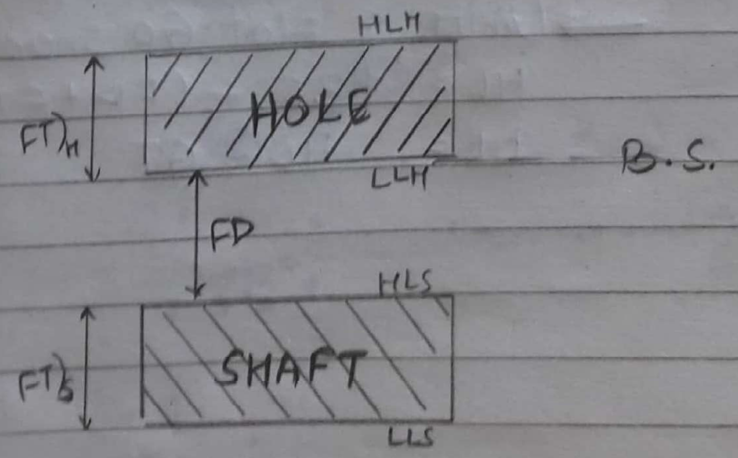
4) $FT)_{shaft}$ = (given) × i (in μm)
$FD)_{shaft}$ = Upper deviation = given (in μm)

5) Hole limit,

LLH = BS + FD
HLH = LLH + FT

6) shaft limit,

HLS = BS + FD
LLS = HLS + FT



Hence, HLH > LLH > HLS > LLS — Magnitude wise

7) Assume, gauge Tolerance = 10 % of work Tolerance

$GT)_{Hole} = 10\%$ of $FT)_{Hole}$ & $GT)_{Shaft} = 10\%$ of $FT)_{Shaft}$

8) Wear Allowance of hole = 10% of gauge Tolerance (Given)

Wear Allowance of shaft = 10% of gauge Tolerance (Given)

9) For Hole,

→ Limits of GO plug gauge.

LL = BS + WA

HL = LL + GT

→ Limits of Not GO plug gauge.

LL = BS + FT)

HL = LL + GT

10) For Shaft,

→ Limits of GO Snap gauge.

HL = BS − (FD + WA)

LL = HL − GT

→ Limits of Not GO snap gauge.

HL = BS − (FD + FT)

LL = HL − GT