MACHINING

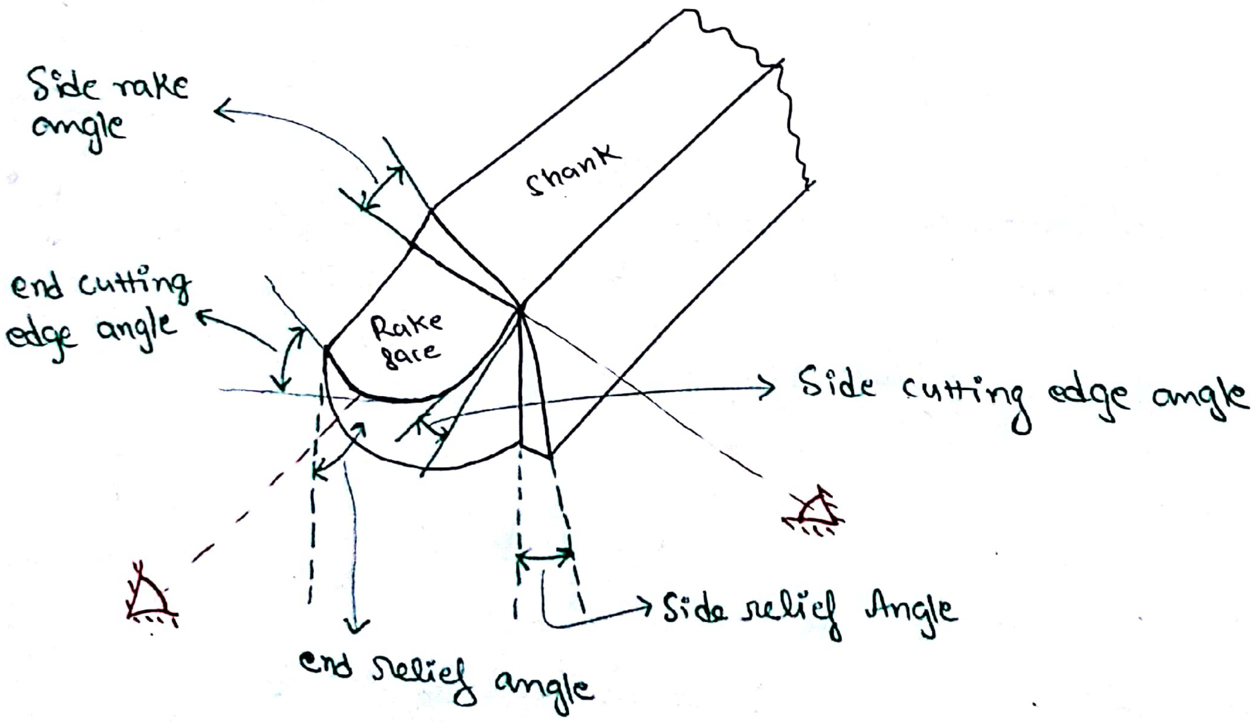
↓

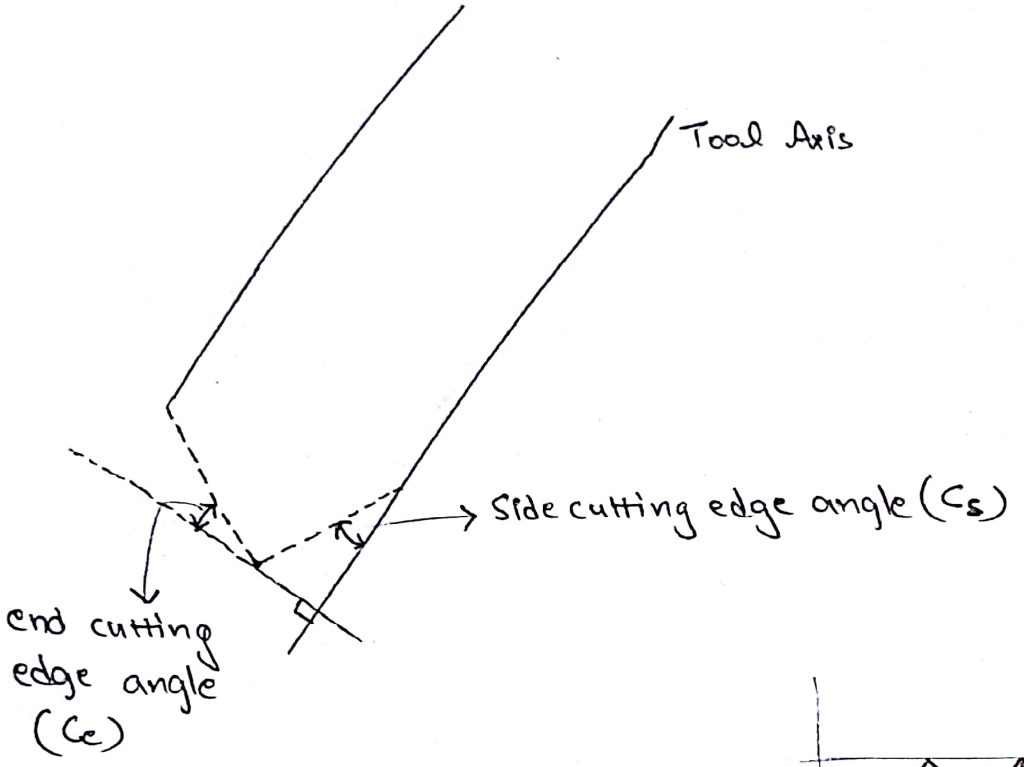
metal removal process

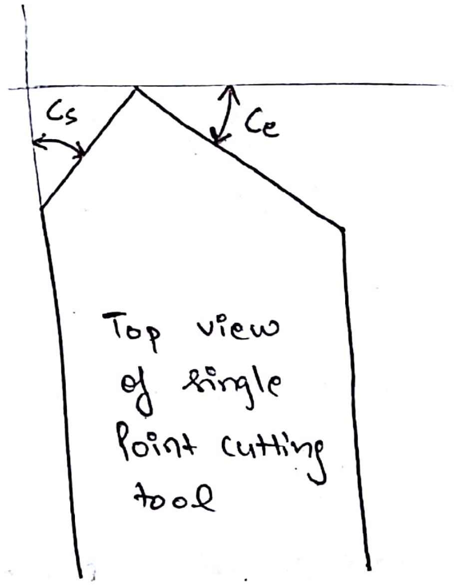
- Single point cutting process
  - Turning
  - facing
  - Grooving
  - shaping
  - Planning
- multi point cutting processes
  - milling
  - Drilling
  - Broaching
  - Grinding
  - Reaming

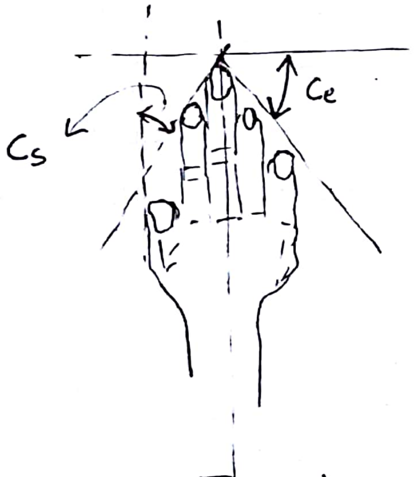
- Multi point cutting tool is a combination of 'n' no. of single point cutting tool.

Geometry of single point cutting tool

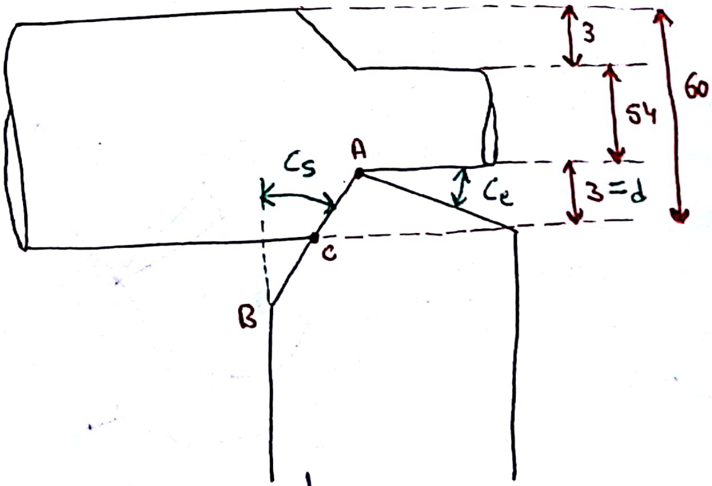








Tool axis
(Right hand)



AC= engaged length of cutting edge
d= depth of cut

width of chip = f (contact length of cutting edge)

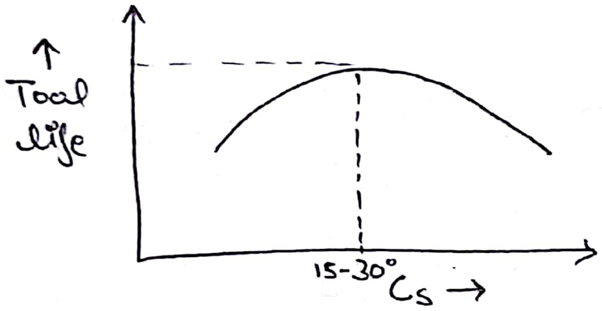
$$\cos(C_s) = \frac{d}{AC} \Rightarrow AC = \text{width of chip} = \frac{d}{\cos(C_s)}$$

So,

$C_s \uparrow \Rightarrow$ width of chip $\uparrow \Rightarrow$ thickness of chip $\downarrow \Rightarrow$ Ar for heat dissipation on chip increases

- On increasing the side cutting edge angle broader and thinner chips are produced, due to which area of Heat dissipation by the chips increases and more amount of Heat is carried away by the chips thereby reducing the Heat interaction of the tool. So tool wear will be less.
- Beyond a certain limit if side cutting edge angle is increased then tendency of chatter increases [High amplitude vibration] due to which tool life decreases.

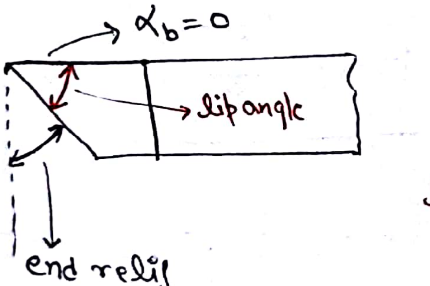
Note: ① $C_s \uparrow$ ⇒ tool life first increases & then decreases



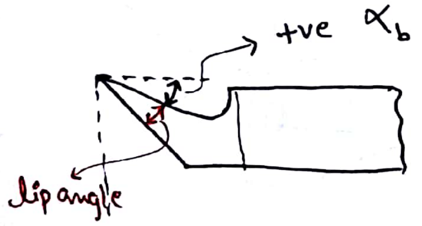
② Heat distribution

Tool	w/p	Chips	
33%	33%	33%	ideal situation
15%	15%	70%	Generally
10%	10%	80%	optimum condition.

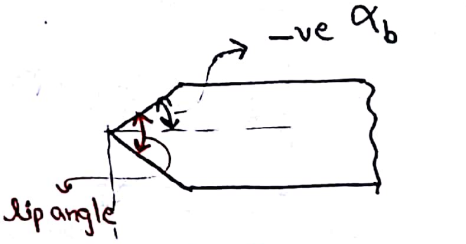
Back rake Angle (α_b) [Side view]



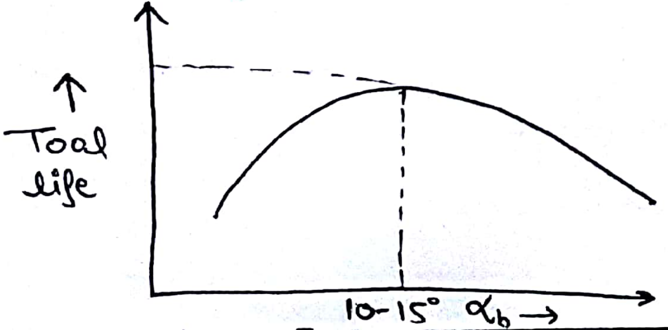
ex:- CI, Brass
used for medium strength w/p



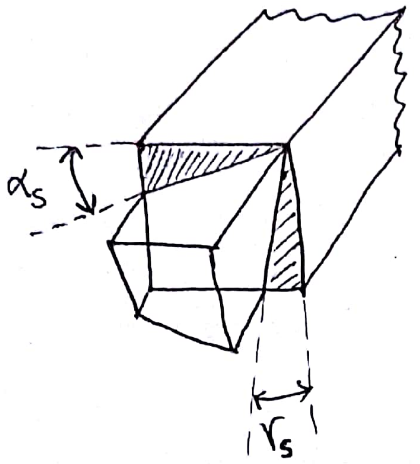
used in case of soft & Ductile work piece
ex:- Ductile metals [M.S.]



used in case of Hard & Brittle w/p
eg:- Carbide



- Tool must be atleast 30% stronger [Traditional machining]



Parameters of machining

1. **Cutting Speed (V)**

$$V = \frac{\pi D N}{60} \quad mm/s \qquad [\because D \text{ in } mm]$$

$$\boxed{V = \frac{\pi D N}{1000}} \quad m/min \qquad [\because D \text{ in } mm]$$

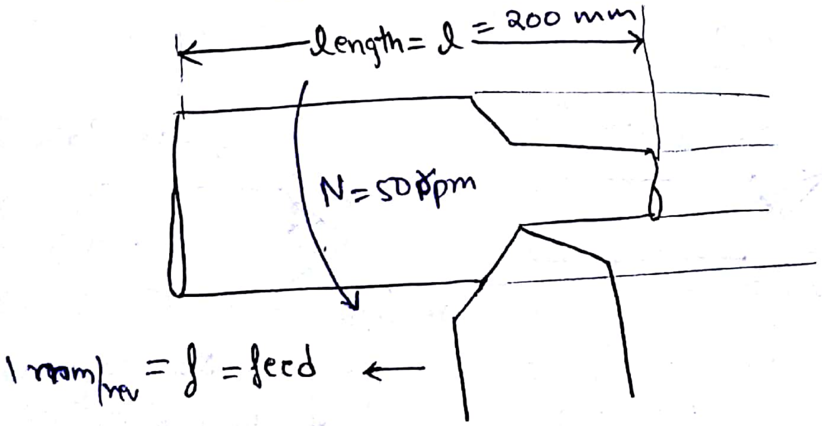
D = Diameter which is intially encountered

i.e. D = internal dia (D_{min}) for boring

D = external dia (D_{max}) for turning

i.e. D is taken as ~~at~~ starting diameter

2. **Feed** : It is the distance traversed by tool per revolution of w/p.



machining time = t_m

$$\boxed{t_m = \frac{l}{f N}}$$

$$t_m = \frac{200}{1 \times 50} = 4 \text{ min}$$

Ques: GATE 2016

A cylindrical specimen of l = 900 mm & Dia 200 mm is turned at a cutting speed V = 300 m/min. if the feed provided to tool is 0.25 mm/rev.

Calculate m/c time in min.

Solu^n

$$V = \frac{\pi D N}{1000}$$

$$5 \times 300 = \frac{\pi \times \cancel{200} \times N}{\cancel{1000}_{5}}$$

$$N = 477.4648 \text{ rpm}$$

$$t_m = \frac{900}{.25 \times N} = 7.539 \text{ min}$$

Ques:
ESE
5 marks

$d = 50$ mm

$D_i = 50$ mm

$D_f = 42$ mm

$N = 450$ rpm

$f = 0.2$ mm/rev

$d = 3$ mm

$AL = 3$ mm

$l = 50 + 3 = 53$

$l' = 106$

$$t_m = \frac{106}{.2 \times 450} = 1.177 \text{ min}$$

Ques:
ESE
10 marks

$l = 200$ mm

$D_i = 52$ mm

$D_f = 44$ mm

$AL = 5$ mm

$V_{rough} = 35$ m/min ; $d = 3$ mm ; $f = 3$ mm/rev

$V_{finish} = 50$ m/min ; $d = 1$ mm ; feed = 1 mm/rev

$$t_m = \frac{205}{.3 \times N_1} = 0.3189 \times 10$$

$$t_m = \frac{205}{.1 \times N_2} = 0.59 \times 10$$

$$t_{tot} = 0.911 \text{ min} \times 10$$

$$= 9.11 \text{ min}$$

$$35 = \frac{\pi \times 52 \times N}{1000}$$

$$N_1 = 214.24$$

$$50 = \frac{\pi \times 46 \times N}{1000}$$

$$N = 345.98$$

Note: 1) if N = given then $t_m = \frac{l}{fN} \times n$ [∵ n = no. of passes]

2) if V = given

then, find 'N' step by step

Ques: length of hollow shaft is 100 mm, inner dia = 30 mm which is to be enlarged to 40 mm. All cuts are 2 mm deep if V = 30 m/min & feed is 0.01 cm/rev. then m/cing time = ?

Soln

$\boxed{V=30}$

$l = 100$ mm

$d_1 = 30 \rightarrow 34$

$d_2 = 34 \rightarrow 38$

$d_3 = 38 \rightarrow 40$

$V = \frac{\pi D N}{1000}$

$N_1 = \frac{1000 V}{\pi D} = 318.31$

$N_2 = 280.86$

$N_3 = 251.29$

$t_1 = \frac{l}{.1 \times N_1} = 3.14$

$t_2 = \frac{l}{.1 \times N_2} = 3.56$

$t_3 = \frac{l}{.1 \times N_3} = 3.979$

$t_{total} = 10.68$ min

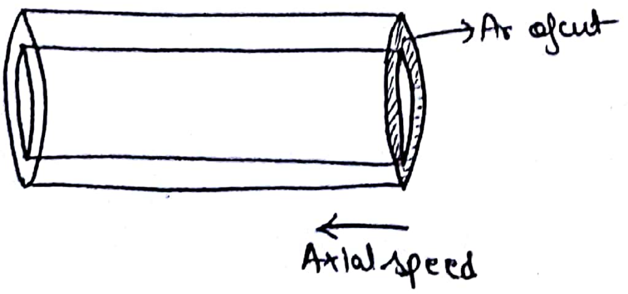
Note: $t_m = \frac{l}{fN}$ here $fN \Rightarrow \frac{mm}{\cancel{rev}} \times \frac{\cancel{rev}}{min} \Rightarrow \frac{mm}{min}$ ⇒ called as feed velocity

fN = feed velocity or Axial speed [cylindrical turning]

Material Removal rate: (MRR)

1. $MRR = \frac{\text{volume of material removed}}{\text{time of machining}}$ mm^3/min

2. MRR = Area of cut × velocity $= \frac{\pi}{4} \times (D_i^2 - D_f^2) \times$ Axial speed



3. $$MRR = \underset{\frac{mm}{rev}}{f}\ \underset{mm}{d}\ \underset{m/min}{V} \times 1000 \quad mm^3/min$$

Ques ES 2016 | A cylinder workpiece of dia 10 mm is turned down to 9mm using 0.5 mm depth of cut. If the axial speed provided to tool is 175 mm/min, then MRR in mm³/min

a) 2200

b) 2400

[✓ c) 2600]

d) 2800

Soln

$d = 0.5$ mm

$fN = 175$ mm/min

$$MRR = \frac{\pi}{4} \times (10^2 - 9^2) \times 175$$

$$= \frac{\pi}{4} \times 19 \times 175 = \frac{3.14}{4} \times (3500 - 175) = \frac{3.14}{4} \times 3325$$

$$\simeq .8 \times 3325 \simeq 2660.0$$

WB P-18 Q9

$v = 50$ m/min

$f = 0.8$ mm/rev

$d = 1.5$ mm

MRR = 60,000 mm³/min

P-18 Q11

$$time = \frac{215}{1.2 \times N_1} + \frac{115}{1.2 \times N_2} + \frac{115}{1.2 \times N_3}$$

$$V = \frac{\pi D N}{1000}$$

$$N_1 = \frac{1000 V}{\pi D} = 106.103$$

$$N_2 = \frac{1000 V}{\pi D_2} = 117.89$$

$$N_3 = \frac{1000 V}{\pi D_3} = 132.63$$

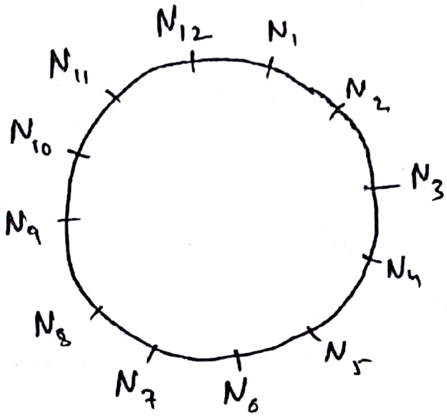
$$t_{total} = 3.224 \text{ min}$$

23/8/16

Speed selection

To obtain a wide range of speed in automobile and m/c tools generally the speeds are arranged in a geometric progression.

GP ⇒ $a, ar, ar^2 \text{ ---- } ar^{n-1}$



$l = ar^{n-1}$

$l = N_{max}$ & $a = N_{min}$

$$\boxed{N_{max} = N_{min} \times r^{n-1}}$$

Ques

$N_{min} = 100$ rpm

$N_{max} = 1000$ rpm

$n = 8$

find N_5

Soln

$1000 = 100\, r^{n-1} \Rightarrow r = (10)^{1/7}$

$N_5 = N_{min} \times r^{5-1} = 100 \times (10)^{4/7} = 372.75$ rpm

- $$\boxed{\frac{N_{max}}{N_{min}} = r^{n-1}}$$

$\frac{N_{max}}{N_{min}}$ = Speed range ratio

$N = \frac{1000\,V}{\pi D} \Rightarrow N_{max} \propto \frac{V_{max}}{D_{min}}$ & $N_{min} \propto \frac{V_{min}}{D_{max}}$

$$\Rightarrow \boxed{\frac{N_{max}}{N_{min}} = \frac{V_{max} \cdot D_{max}}{V_{min} \cdot D_{min}}}$$

Ques
T-1
P-18

$\frac{N_{max}}{N_{min}} = \frac{\overset{3}{\cancel{120}}}{\cancel{40}} \times \frac{\cancel{200}}{\cancel{100}} = 6 = r^{6-1} \Rightarrow (6)^{1/5} = r$

$N_1 = \frac{1000 \times 40}{\pi \times 200} = 63.66$; $N_6 = \frac{1000 \times 120}{\pi \times 100} = 381.97$

$N_2 = 91.095$

$N_3 = 130.35$

$N_4 = 186.53$

$N_5 = 266.92$

Ques
T2
P-18

$$\frac{N_{max}}{N_{min}} = \frac{120}{40} \times \frac{25}{5} = 15$$

Q1
P-17

$n = 6$

$$\frac{N_{max}}{N_{min}} = \frac{25}{6.25} = 4 = \gamma^5$$

$$\Rightarrow \gamma = 1.319$$

P-17
Q6

$D = 100$ m

$N = 500$ rpm

$$f = \frac{\cancel{500}^{100}}{\cancel{60}_{\cancel{5}}} \text{ rps} \times \cancel{12} = 100 \text{ Hz}$$

Various machining operations

1. Cylindrical turning

The feed provided to the workpiece is parrallel to axis of w.p. i.e. Axial feed is provided.

A)

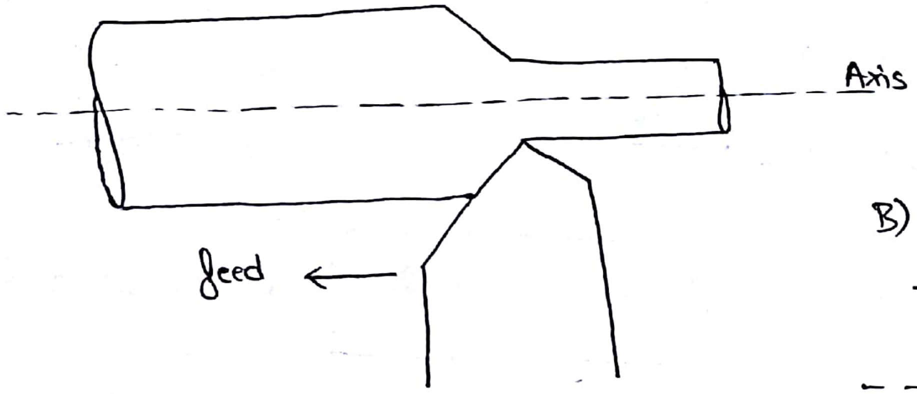


Fig:- Turnig

B)

$$t_m = \frac{R}{fN}$$

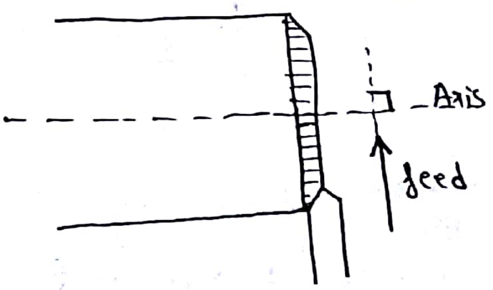


Fig:- Facing

C)

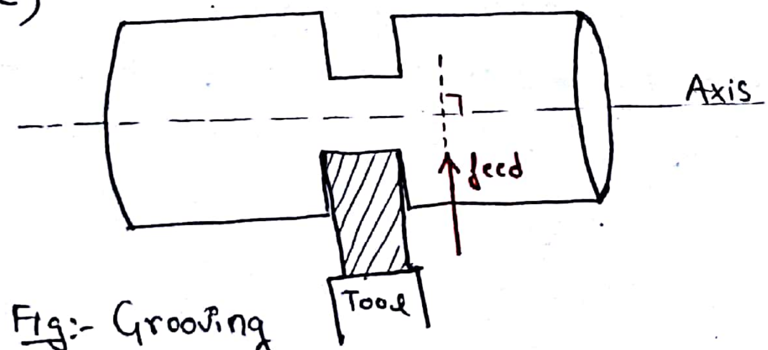
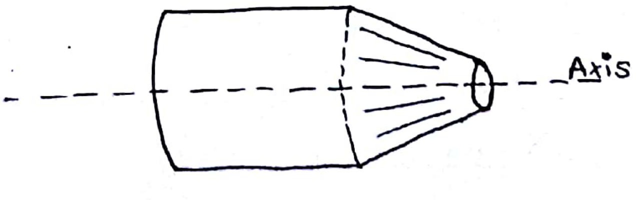
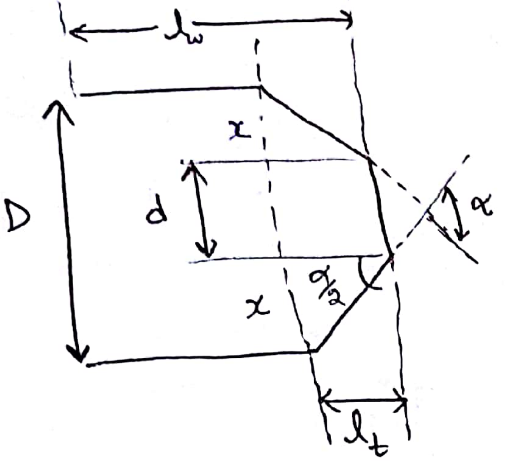


Fig:- Grooving

D) Taper turning



For the taper turning,



$$D - 2x = d$$

$$\Rightarrow x = \frac{D-d}{2}$$

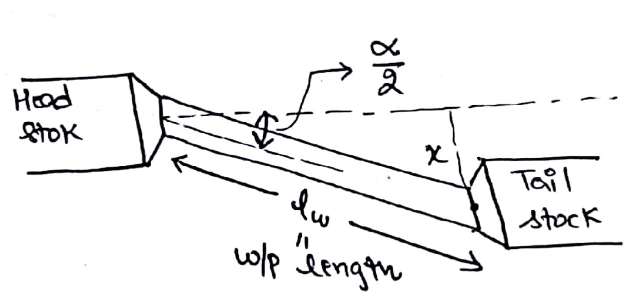
$$\tan\frac{\alpha}{2} = \frac{x}{l_t}$$

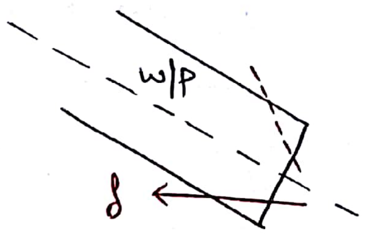
$$\Rightarrow \boxed{\tan\frac{\alpha}{2} = \frac{D-d}{2\,l_t}}$$

α = taper angle or included angle
l_t = length of taper

Taper turning by Tail-stock offset method

In this method the tail stock is placed at an offset from the central lathe axis along the vertical line such that the offset angle is half the taper angle required. The feed provided to the tool is parallel to lathe axis.





$$\sin\frac{\alpha}{2} = \frac{x}{l_w} \Rightarrow \boxed{x = l_w \times \sin\frac{\alpha}{2}}$$

x = offset distance

Ques: ESE 1mark

length of w/p is 400 mm and its taper turned along 100mm length, if the taper angle is 4°, produced by tail stock method, then the tailstock offset required is (mm)

a) 100 sin 4°
b) 100 sin 2°
c) 400 sin 4°
[✓ d)] 400 sin 2°

tail stock offset method

$\boxed{\text{Ques GATE}}$

$l_w = 90$ mm

$l_t = 55$ mm

$D = 80$ mm

$d = 65$ mm

$$\tan\frac{\alpha}{2} = \frac{D-d}{2l_t}$$

$\Rightarrow \alpha = 15.53^\circ$

$= 15^\circ 31.8'$

$= 15^\circ 31' 48''$

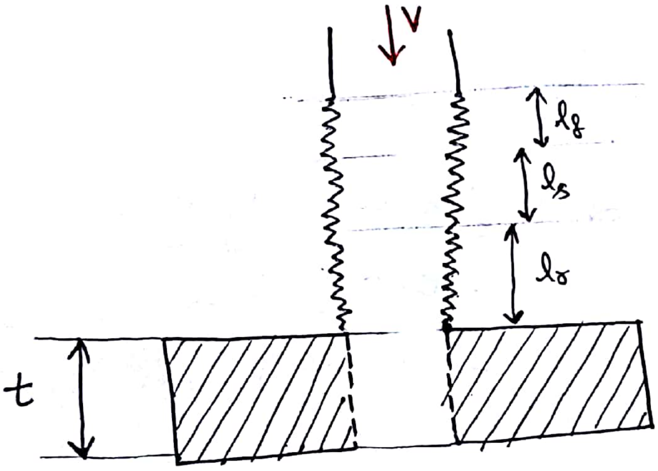
offset $\Rightarrow 90 \times \sin\frac{\alpha}{2}$

$= 12.16$ mm

$\Rightarrow \boxed{1 \text{ Degree} = 60 \text{ minute}}$ and $\boxed{1 \text{ minute} = 60 \text{ second}}$

2. Broaching

- multipoint cutting
- Operates at least cutting speed
- cut slots, grooves, cut gears, can machine both circular and non circular holes.
- Accuracy is good.



machining time $= \boxed{t_m = \frac{l_c}{V}}$

here, $l_c = t +$ total length of broach tool

$\Rightarrow \boxed{l_c = t + l_r + l_s + l_f}$

1) l_r = length of rough teeth

It remove maximum material & is maximum in number

2) l_s = length of semi finished teed

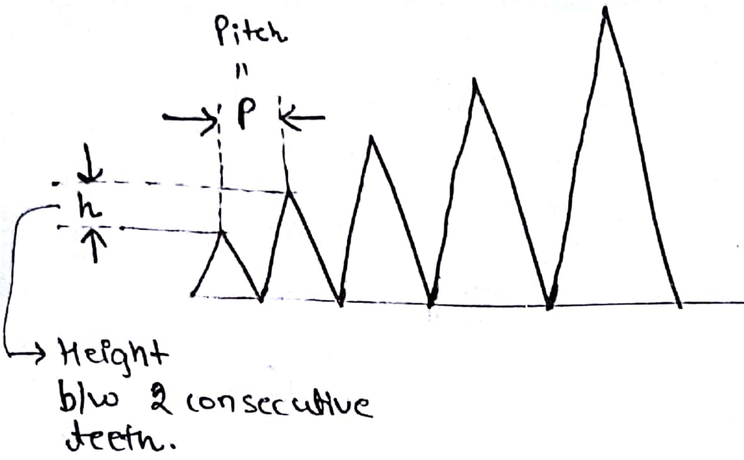
It removes very less material and involve partial finishing

3) l_f = length of finishing teeth

It will not remove any material & strictly involve finishing

It has least no. of teeth

$$\boxed{n_r > n_s > n_f}$$



h = rise per tooth

D_i = initial dia

D_f = final dia

$d = \frac{-D_i + D_f}{2}$

$\boxed{d = nh}$ ⇒ $n = \frac{d}{h}$

$\boxed{L = nP}$

⇒ $\boxed{L = \frac{d}{h} \times P}$

1) $\boxed{L_r = \frac{d_r}{h_r} \times P_r}$

2) $\boxed{L_s = \frac{d_s}{h_s} \times P_s}$

Also,

$\boxed{d_{total} = d_r + d_s}$

3) $\boxed{L_f = n_f \times P_f}$

$\boxed{\begin{matrix} \text{WB} \\ \text{P-18} \\ \text{Q10} \end{matrix}}$

Power = $F \times V$ = 10 kW

$t = 50$ mm

$d = \frac{8 \text{ mm}}{2} = 4$ mm

$d_i = 40$ mm $\quad d_f = 48$ mm

$h = 0.01$ mm

$P = 15$ mm/tooth

$n = \frac{4}{0.01} = 400$

$l_r = 400 \times 15 = 60{,}000$ mm

$t_m = \frac{l_e}{V}$

$l_e = 6.05$ m

$= \frac{6.05}{0.35} = 17.28$ min

$4.5 = n \times 0.1 + 8 \times 0.0125$

$\Rightarrow \boxed{n = 44}$

$\boxed{\begin{matrix} \text{WB} \\ \text{P-18} \\ \text{Q17} \end{matrix}}$

$t = 4.5$ mm

$n_f = 4$

$n_s = 8$

$L_f = 4 \times 20 =$

$L_s = 8 \times 20 =$

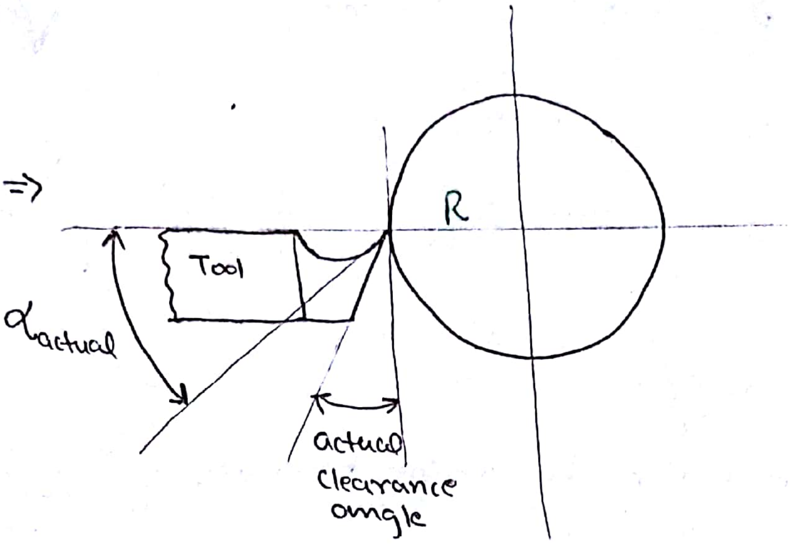
$+ \; 12 \times 20 = \overset{1}{240}$ mm

$l_r = 44 \times 22 = 968$

$\underline{1208}$ mm

Tool Setting Error

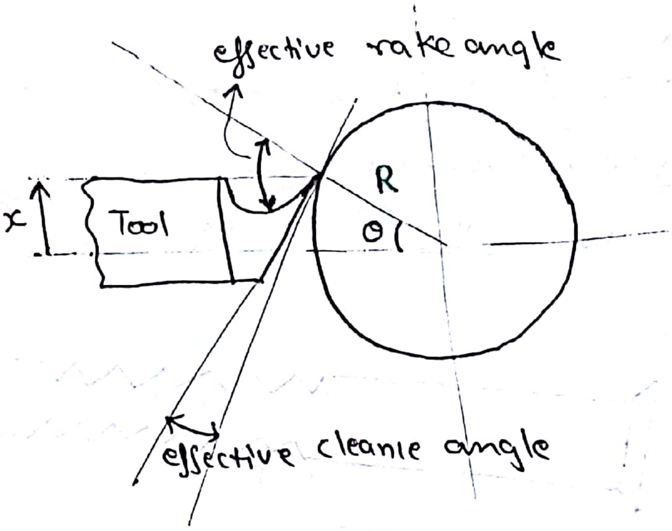
ideal condition ⇒



1) Tool offset above

$$\alpha_{effective} = \alpha_{actual} + \theta$$

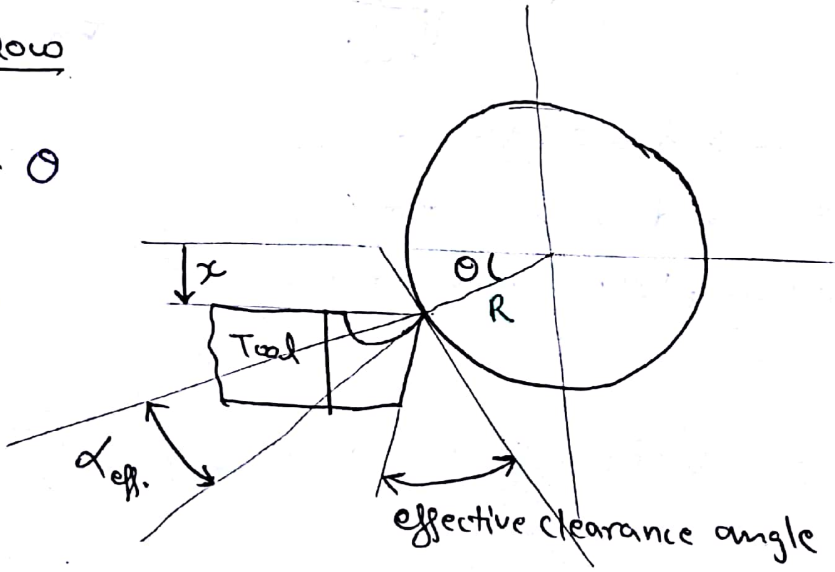
effective clearance angle = actual clearance − θ



2) Tool offset below

$$\alpha_{eff} = \alpha_{act.} - \theta$$

$$\gamma_{eff.} = \gamma_{act.} + \theta$$



Calculation of θ

$$\sin\theta = \frac{x}{R} \Rightarrow \boxed{\theta = \sin^{-1}\frac{x}{R}}$$

x = Offset
R = Radius of cylindrical w/p

P-18
Q16

$R = \frac{90}{2} = 45$ mm

$x = 5$ mm

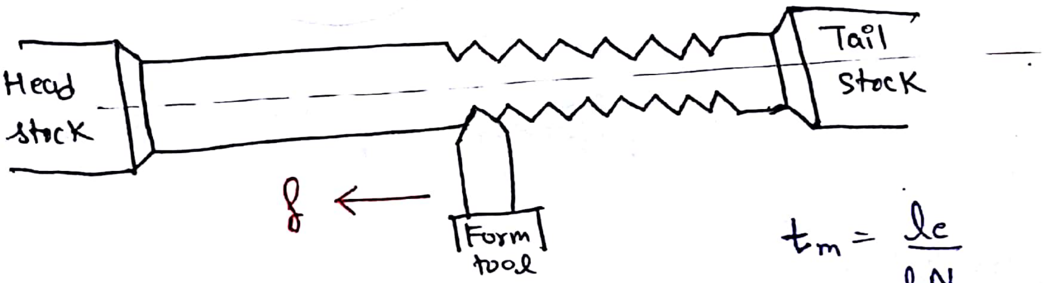
$\theta = \sin^{-1}\left(\frac{5}{45}\right) = 6.379$

$\gamma_{eff} = 14.379°$

$\alpha_{eff} = 10 - 6.379$
$= 3.62°$

3. Threading

- External threads can be produced by "thread chasing"
  $\Downarrow$
  High Quality screw thread
- In thread chasing operation, arrangement is similar to turning operation
  ⇒ Single point form tool is used.
  ⇒ The lathe used for threading operation is known as swiss Automat..



$t_m = \frac{l_e}{f N}$

$f = P$ ⟶ single start threads
$f = 2P$ ⟶ double start threads
$f = 3P$ ⟶ tripple start threads

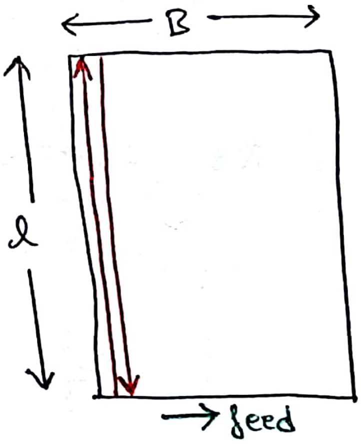
Ques.
WB
Q8

$f = 2 \times P = 2 \times 2 = 4$ mm/rev

SHAPING

- It is a machining operation in which a layer of material is removed from the surface by using A single point reciprocating tool such that the feed is provided to the work piece.
- In the forward stroke material is removed whereas in return stroke no material is removed and hence it is also known as ideal stroke
- Feed is obtained in return stocke. by "Ratchet & Pawl" mechanism.
- Reciprocation of tool is obtained by " whitworth QRMM".

$$\boxed{t_m = \frac{B}{fN}}$$



f = mm/stroke

N = Stroke/min

1 forward stroke + 1 Return stroke = 1 complete stroke (N)

or

1 Double stroke

Time per stroke (min/stroke) = forward time + return time

$$= t_f + t_r = \frac{L}{V} + \frac{L}{V_r}$$

{V = cutting velocity
V_r = return velocity

~~Let, $\frac{V_r}{V} = 1/m$ i.e. $\frac{V}{V_r} = m$ $\Rightarrow V=$~~

$V_r > V$

m = ratio of forward to return speed

$$\boxed{\frac{V}{V_r} = m} \Rightarrow V_r = \frac{V}{m} \Rightarrow \text{Time per Stroke } (1/N) = \frac{L}{V} + \frac{mL}{V}$$

$$\Rightarrow \boxed{V = \frac{NL(1+m)}{1000}}$$

V = m/min
L = mm

- 1 $\frac{\text{rev}}{\text{min}}$ of crank = 1 complete $\frac{\text{stroke}}{\text{min}}$ of tool

rpm of crank = spm of tool

So, $\boxed{\text{rpm of crank} = \frac{1000\, V}{L(1+m)}}$

Q4 P-18

$l = 600$ mm ; $B = 30$ mm

$l_e = 640$ mm

$V = 8$

$$N = \frac{\cancel{1000}^{25} \times \cancel{8}}{\cancel{8}_{2}\ \cancel{640} \times (1 + .5)} = \frac{25}{3}$$

$$= \frac{25}{3}$$

$$t_m = \frac{30 \times \cancel{3}^{10}}{\cancel{.3} \times 25} = 3 \times 4 = \underline{12 \text{ min}}$$

P-20 Q8

$m = \frac{2}{3}$

$V = 18$ m/m

$d = 200$ mm

$$\cancel{8} \times 18 = \frac{N \times \cancel{200}\left(\cancel{8}/3\right)}{\cancel{1000}}$$

$$90 \times \frac{3}{5} = N \quad \cancel{8} \quad \Rightarrow N = 18 \times 3 = \underline{54 \text{ rpm}}$$

P-20 Q9

$B = 100$ mm

$V = ?$

$m = .5$

$d = 150$

$$10 = \frac{B}{fN}$$

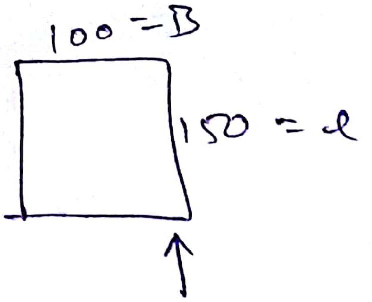
$f = 0.001$

$$N = \frac{100}{\cancel{10} \times \cancel{0.001}} = 10000$$

$$V = \frac{\cancel{10000} \times 150\,(1.5)}{\cancel{1000}} = 2250 \ \underline{\text{m/min}}$$

$= 37.5$ m/s

P-20
Q13



m = 0.7

tm = ?

MRR = ?

v = 20 m/min

d = 3 mm

f = 0.3 mm/stroke

$$v = \frac{NL(1+L)}{1000}$$

$$N = \frac{20 \times 1000}{150 \times 1.7} = 78.43$$

$$t_m = \frac{100}{.3 \times N} = \underline{4.25 \text{ min}}$$

$$MRR = \frac{Vol.}{time} = \frac{100 \times 150 \times 3}{4.25} = 10588.05 \ mm^3/\underline{min}$$

P-20
Q12

l = 2m   v = 1 m/sec = 60 m/min

m = 0.5

f = 1 mm/stroke

B = 305+5 = 310

$$t_m = \frac{B}{fN}$$

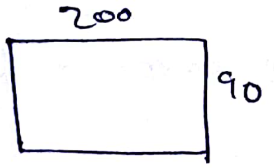
$$N = \frac{\cancel{1000}\ v}{2(1+0.5)} = \frac{\overset{20}{\cancel{60}}}{\underset{3}{\cancel{2 \times 1.5}}}$$

= 20 rpm

$$t_m = \frac{305+5}{1 \times 20} = \frac{31\cancel{0}}{2\cancel{0}} = 15.5 \ \underline{min}$$

$$(t_m)_{per\ piece} = \frac{15.5}{2} = 7.75 \ \underline{min}$$

P-19
Q6



v = 13.5 m/min

f = 0.57 mm/str   m = 0.83

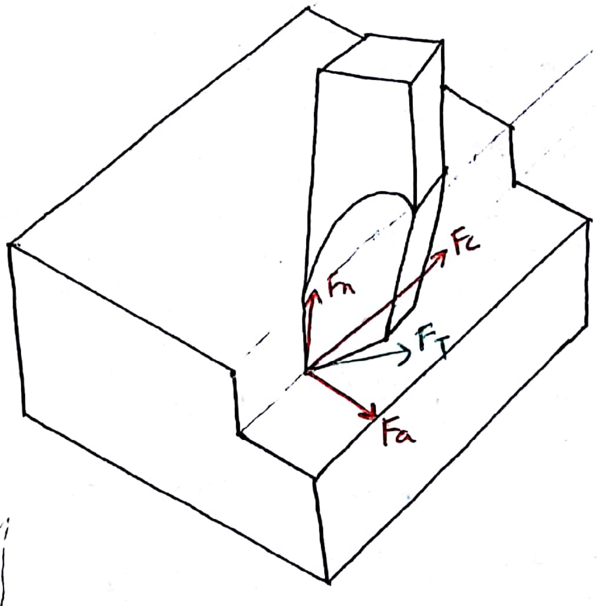
OT = AL = 20mm

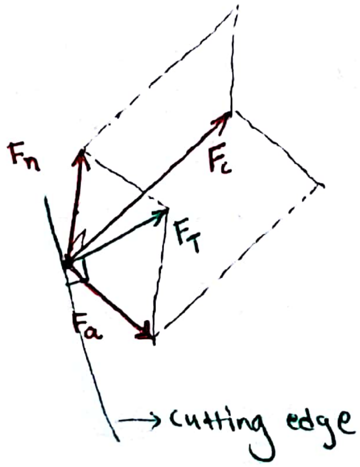
lateral = 4mm

$$N = \frac{1000 \times 13.5}{240 \times 1.83}$$

$$t_m = \frac{98}{.57 \times N} = \mathbf{5.59} \ \underline{min}$$

Force analysis in shaping





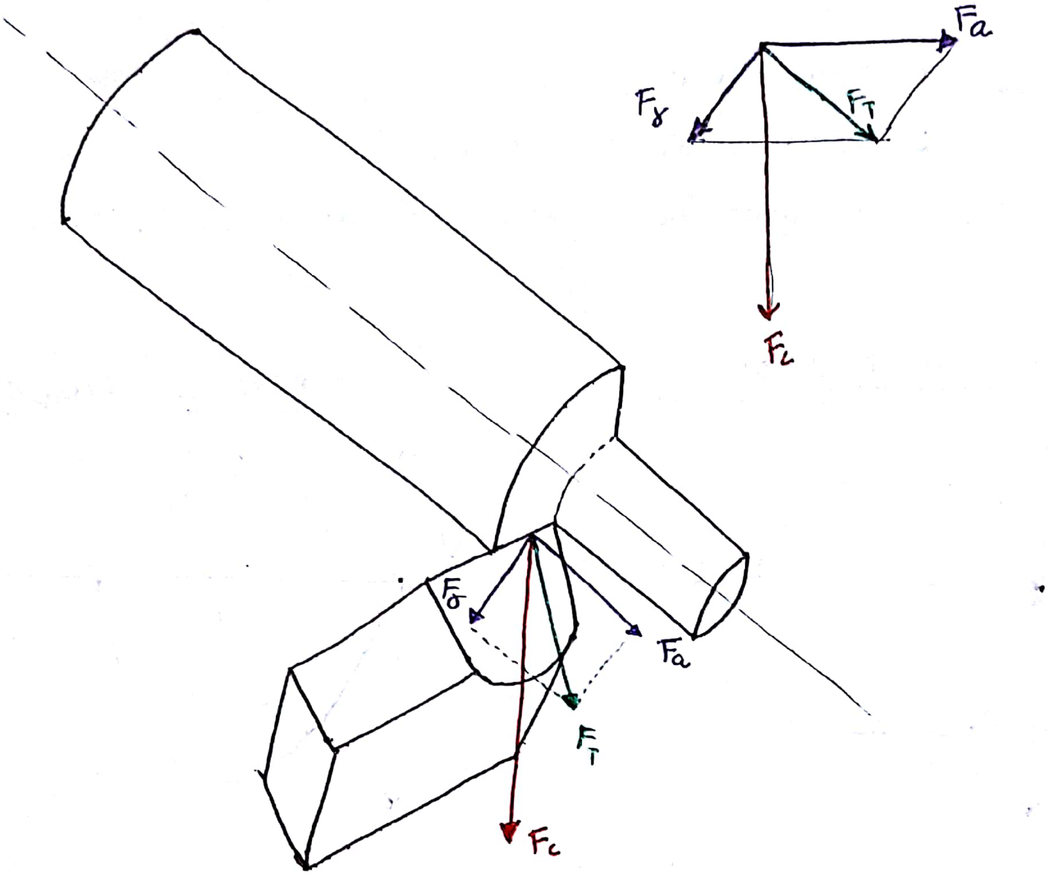
Ques:

Assertion :- In shaping process, the axial force component & cutting force lies on horizontal plane.

Reason :- Axial force and normal force are component of thrust force.

Ans B

Force Analysis in turning



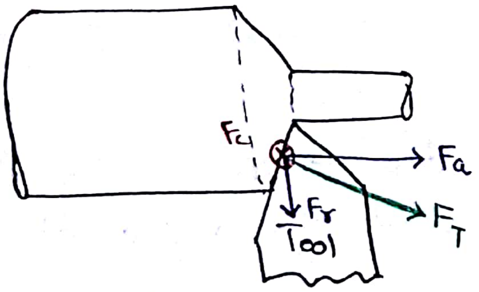
Ques: Assertion :- In turning process, the axial force component, radial force component & thrust force lies on horizontal plan

Reason :- Axial force & radial force are components of thrust force

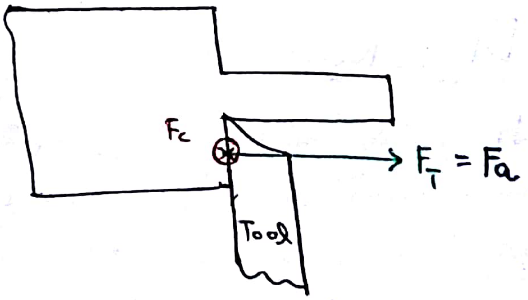
Ans A

oblique turning
($C_s \neq 0$)

orthogonal turning
($C_s = 0$)



$F_c, F_r, F_a \Rightarrow$ 3 forces exists

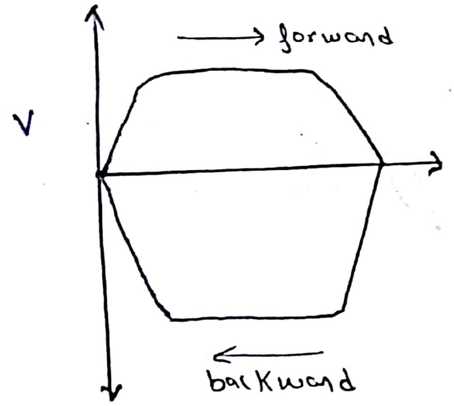


F_c , $F_T = F_a \Rightarrow$ 2 forces exists

Shaping:
1) small flat work piece
2) feed is given to w/p
3) Tool reciprocates

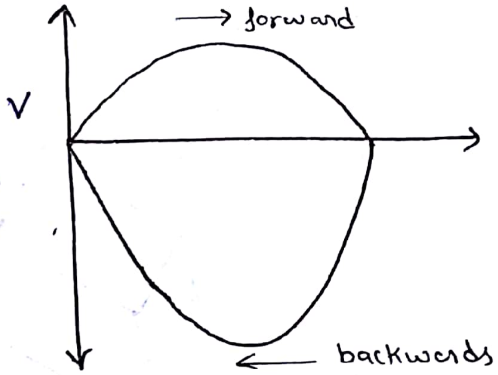
Planning:
1) w/p reciprocates
2) feed is given to tool
3) Planner is havier and more rigid than shaper.

Hydraulic shaper



- It can withstand heavy loads
- It involves constant speed throughout the stroke
- more number of strokes can be obtained at a given cutting speed
- It can withstand the vibrations induced due to intermittend motion

Mechanical shaper

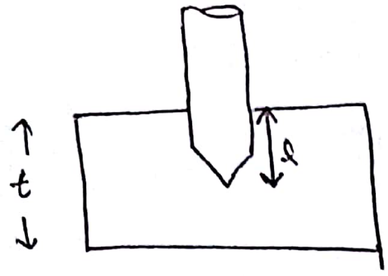


- Speed is max. at mid stage of the stroke.
- It is simple in construction

DRILLING

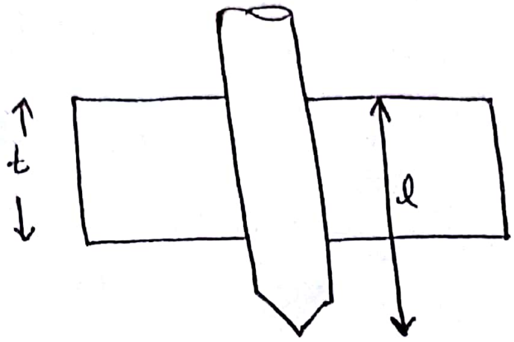
- It is a m/cing operation in which a multipoint rotating tool is used to produce holes such that both cutting motion and feed motion is provided to the tool itself.
- If the length of tool travel is greater than the ~~wo~~ thickness of the workpiece then through hole will be produced whereas

If the length of tool travel is less than the thickness of work piece then the blind hole will be produced.



Blind hole

$l < t$



through hole

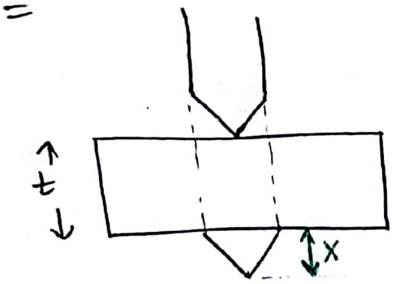
$l > t$

$$\boxed{t_m = \frac{l_e}{f N}}$$

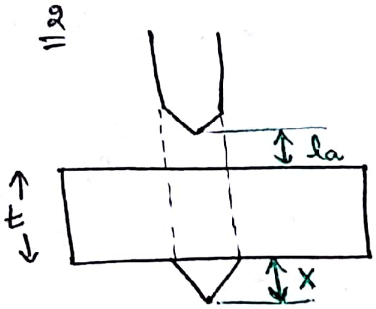
f → $\frac{mm}{rev.}$

N → $\frac{rev}{min}$

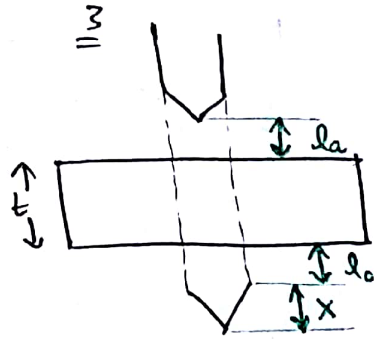
1



2



3



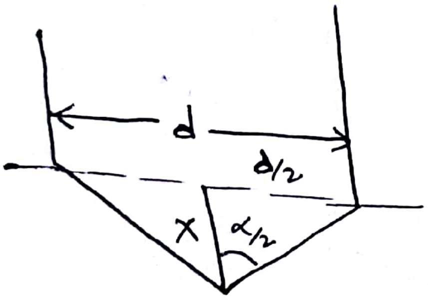
$l_e = t + X$

$l_e = t + X + l_a$

$l_e = t + X + l_a + l_o$

here, X = compulsary approach
l_a = Approach length
l_o = Overtravel

Calculation of Compulsory Approach (X)



$$\tan\frac{\alpha}{2} = \frac{D/2}{X}$$

$$\tan\frac{\alpha}{2} = \frac{0.5\,D}{X} \Rightarrow \boxed{X = \frac{0.5\,D}{\tan\frac{\alpha}{2}}}$$

- if α is not given in the question

$X = 0.3\,D$ for ~~Through hole~~ Blind hole
$X = 0.5\,D$ for through hole

⇒ for steel

P-22
Q 13

$D = 15$ mm
$t = 50$ mm
$N = 500$ rpm
$f = .2$ mm/rev

$\alpha = 118°$
$x = 4.5064$
$l_o + l_a = 4$ mm
$l_e = 58.5064$

$t_m = \frac{l_e}{fN} = 35.1$ sec

P-23
Q 19

$D = 10$ mm
$t = 50$ mm
$N = 600$ rpm
$f = 0.2$
$\alpha = 120°$

$x = 2.88$ mm
$l_e = 52.88$
$t_m = \frac{l_e}{fN} = 0.44$ min

P-23
T1

$D = 20$ mm
$\alpha = 120°$
$t = 30$ mm
$l_o + l_a = 5$ m
$f = .1$ mm/rev

$V = 20$ m/min
$l = 35$ mm
$x = 5.77$
$l_e = 40.77$ mm

$t_m = \frac{l_e}{fN} = 1.28$ min

$N = \frac{1000V}{\pi D} = 318.31$

P-23
Q21

$D = 15$ mm
$f = 0.2$ mm/rev
Drill life = 100 min

$l_e = 45 + 7.5$
$= 52.5$

$N = \frac{20 \times 1000}{\pi \times 15} = 424.41$

~~A~~ H: $l = 45$ mm

time idle = 20 sec.
change time = 300 sec.

$t_m = \frac{l}{fN} = 0.61$ min
$= 37.08$ sec

$n = 161.68$

Avg Production time $= \frac{100 \times 60 + 20 \times 161 + 300}{161} = 59$ sec

Gradual Enlargement Process

- $l_e = t$ [x is also neglected when question asks to neglect approach and overtravel]

WB
P-17
Q5

$l_e = 50$ mm

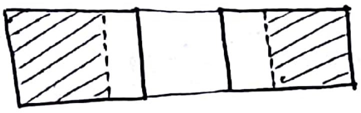
$t_1 = \frac{50}{.2 \times N_1} = .785$ min $N_1 = \frac{1000 \times 10}{\pi \times 10} = 318.3$ rpm

$t_2 = \frac{50}{.2 \times N_2} = 1.57$ min $N_2 = \frac{1000 \times 10}{\pi \times 20} = 159.15$ rpm

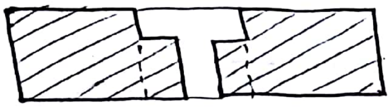
$t = t_1 + t_2 = 2.4$ min

BO~~A~~RING

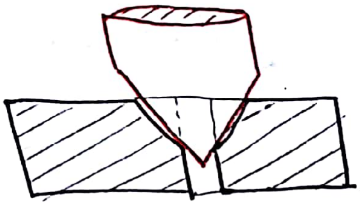
- In this process hole is enlarged uniformly throughout the thickness
- If the enlargement of the hole is performed only at its ends then it is known as counder boring. In other words in counter boaring enlargement of the hole is only upto a certain depth.
- If the enlargement is conical at one of the ends then the process is known as counter sinking.



Boring



Counter boring

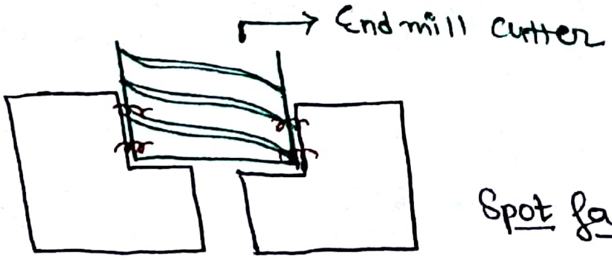


Counter sinking

[here major dia of tool will be greater than max hole size]

Spot facing

It is performed for machining the enlarged portion of the hole for proper seating of bolt heads. In this operation an end mill cutter is used with the drilling machine



Spot facing

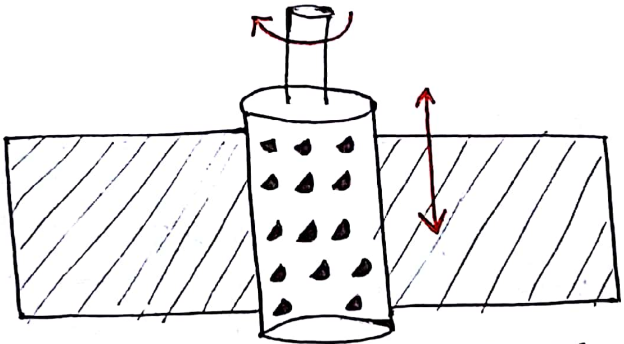
Ques: Arrange in sequence

1. Drilling
2. Counter Boring
3. Boring
4. Spot facing

a) 4-1-2-3
b) 4-3-2-1
c) 1-2-3-4
[✓ d)] 1-3-2-4

HONING

- Best surface finish.
- Surface roughness ⇒ 0.01 μm



↳ abrasive stick [rotates and reciprocates inside the hole]

- Finishing ~~is~~ performed by abrasive action
-

Surface Roughness (R_a) μm		grading	
< 0.025	→	N_1, N_2, N_3	} Honing
0.025 to 1.6	→	N_4, N_5, N_6	
1.6 to 8	→	N_7, N_8, N_9	
8 to 25	→	N_{10}, N_{11}	
> 25	→	N_{12}	

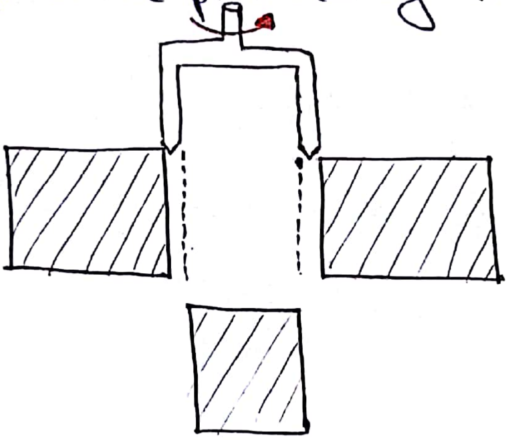
- Application ⇒ finishing cylinders in IC engines

Ques ESE which of foll. holds good for honing surface roughness

[✓ a)] N_1
b) N_5
c) N_7
d) N_{11}

TREPANNING

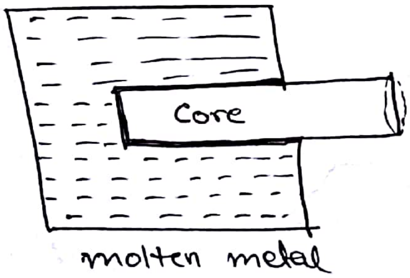
- In this operation large diameter holes can be produced without drilling. Complete material removal doesnot take place.
- The material is diattached only from periphery & only through holes can be produced by trepanning.

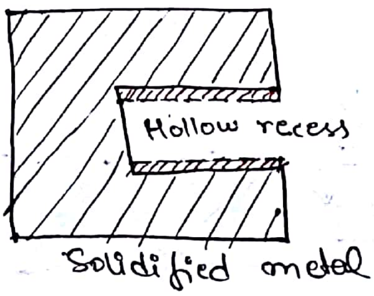


- Used in Post-mortem operations

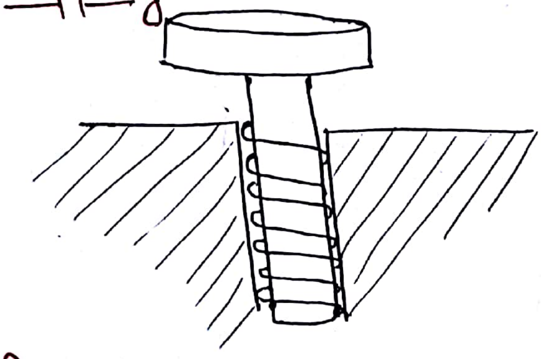
CORE DRILLING

- In core drilling operation an already produced hole in casting will be enlarged.





Tapping



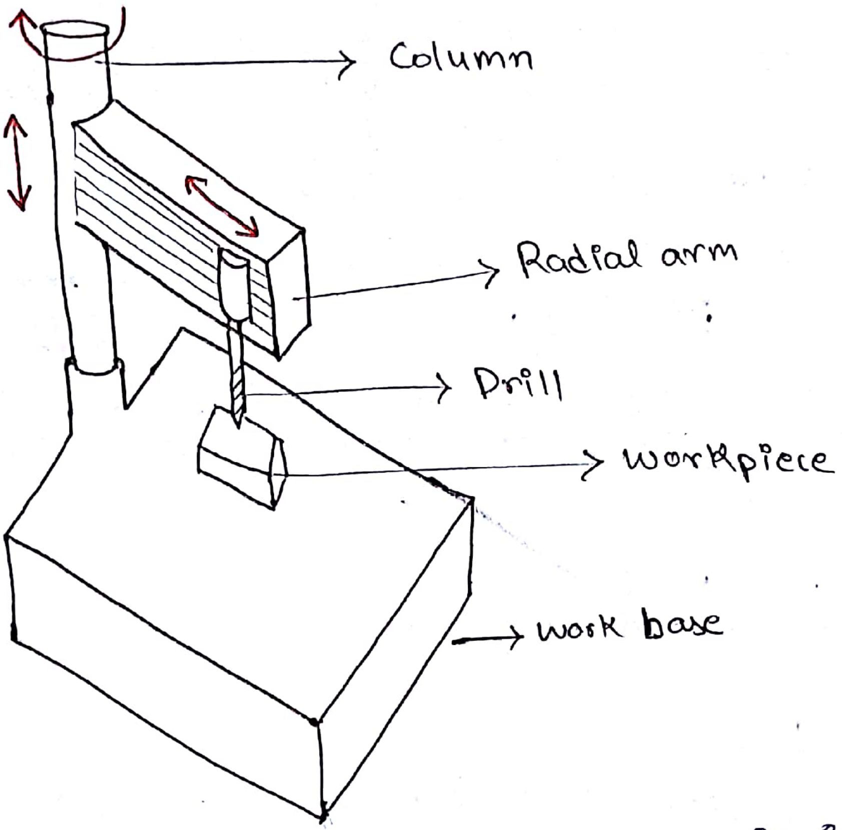
- Used for making internal threads only.

Radial Drilling machine

- Speed of Arm = f(rev. of lead screw)
- Vertical speed of Arm = lead of lead screw × rpm

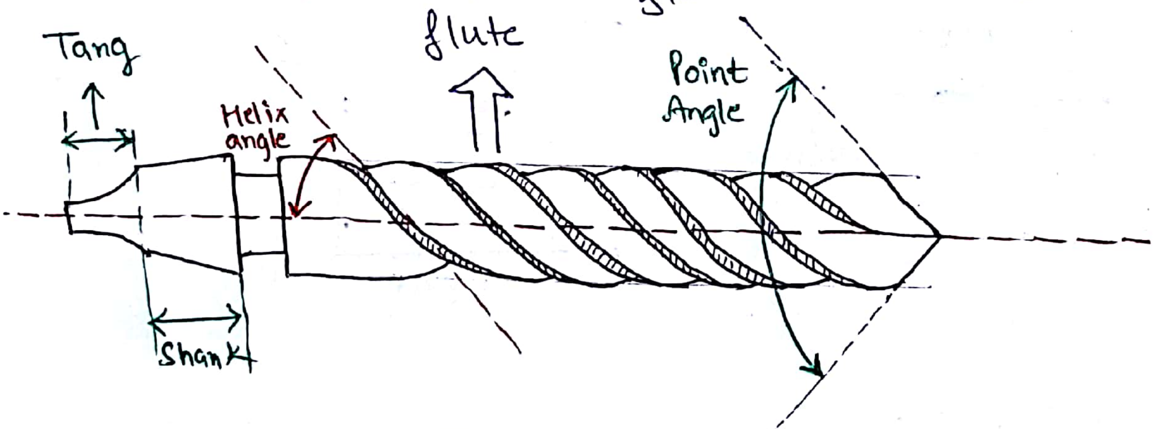
  lead of lead screw = pitch × no. of start

Fig:- Radial Drilling machine



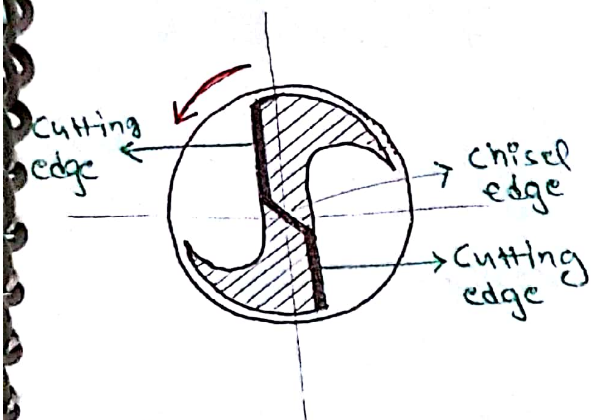
Drill Geometry

→ easy chip flow & oil is pumped which flows over the flute



work material	Point Angle
wood	60–90°
mild steel	118°
High Carbon Steel	120°
Carbide	150°

- Cast iron is exception ⇒ Point Angle = 116°
- In general
  - soft w/p → small Point Angle
  - Hard w/p → large Point Angle



- At the chisel edge more strength is required
- Rake angle is minimum at dead center
- Towards the periphery, the chip flow is maximum therefore rake angle is maximum at the outermost periphery.

- Drill ⇒ variable rake angle
- Chisel edge ⇒ Dead center

- Helix
  - To provide variable rake angle to drill
  - for easy chip flow

- Maximum rake angle = Helix angle [at outer periphery]

$$\alpha_{max} = \psi$$

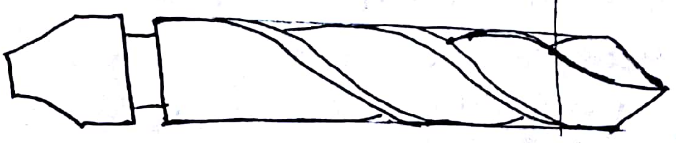
- Soft & Ductile w/p ⇒ Point Angle ↓
  Rake angle ↑

- Hard & strong w/p ⇒ Point Angle ↑
  Rake Angle ↓

- On the basis of Helix Drills can be classified as
  1) Slow helix drill
  2) Regular helix drill
  3) fast helix drill

Slow helix drill

$\psi = 12-22°$



- Hard & strong material (wp)
- Low twist (high strength)

fast Helix Drill

$\psi = 34-38°$

- soft & Ductile w/p material
- high twist (low strength)

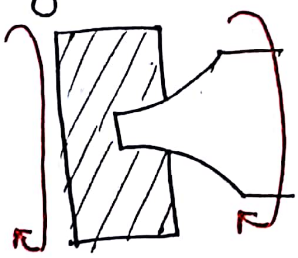
- Irregular helix drill ; $\psi = 24-32^\circ$

Drill strength
Chip lifting capacity
Helix rate
} moderate

Shank

- Straight
  - D < 12.5 mm
  - ex:- 3 Jaw Chuck
- Tapered
  - D > 12.5 mm
  - self locking tendency

Tang



Tang Portion center into a slot and gets fixed.

REAMING

- It is an operation performed for sizing and finishing the hole
- It improves dimensional tolerance and accuracy.

Reamers

- Left hand Spiral reamer
- Right hand Spiral reamer
- Straight reamer

- Right hand spiral reamer will be used to machine blind holes.
- left hand spiral reamer will be used to machine through holes.
- Right hand spiral reamer will pull the chips towards back of the reamer (i.e. towards shank)

- LH spiral reamer will push the chip towards front of the reamer
- In straight reamers flutes are parallel to the reaming axis.
- In case of a soft and Ductile workpiece if blind hole is to be machined then right hand spiral reamer will be prefered due to presence of helix.
- Reamers will have even number of teeth to balance the cutting forces
- In straight reamers rake angle will be zero ($\psi = 0$)

Inverted Drilling operation

- In this operation deep holes are drilled with high feed and heavy depth of cut. Generally an oil hole drill is used through which oil can be pumped along the flute.

Q22

$D = 20$ mm

$t = 30$ mm

$\alpha = 120°$

$l_a = 3$ mm

$l_o = 2$ mm

$N = 500$ rpm

$f = 0.01 \times 2 = 0.02$ mm/rev

$$X = \frac{0.5D}{\tan 60} = 5.7735$$

$$l_e = X + 30 + 5 = 40.77$$

$$t_m = \frac{l_e}{fN} = 4.077 \text{ min}$$

$$= 244.64 \text{ sec.}$$

5. MILLING

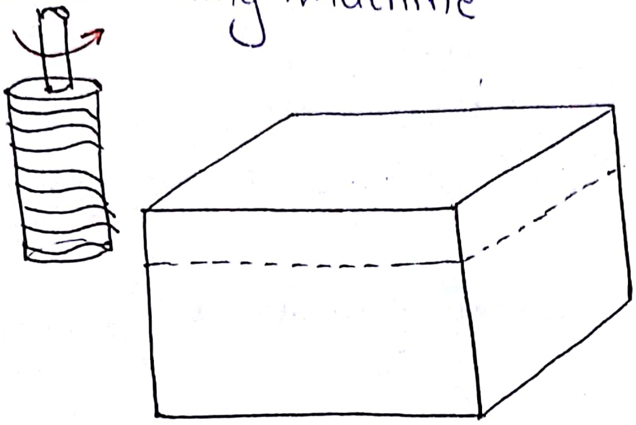
It is a machining operation in which a rotating multipoint cutter is fead past the workpiece in order to remove a layer from the surface, to cut gears for making slots, for external or internal machinings.

Types of milling cutter

1). End-mill cutter
2) Peripheral mill cutter
3) Side mill cutter
4) straddle mill cutter
5) form mill cutter

1. End mill cutter

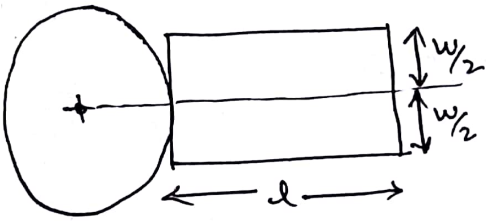
- Vertical milling machine

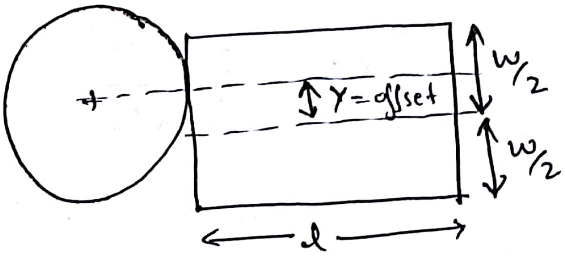


face milling

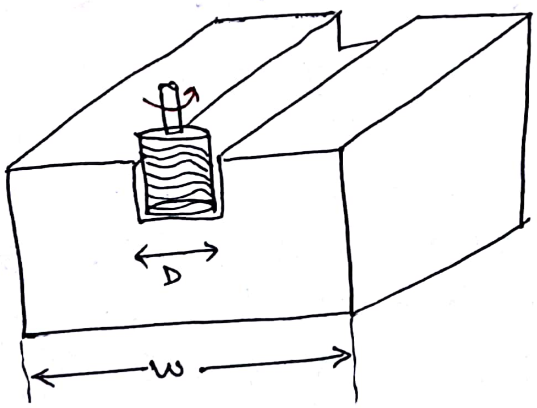
Symmetrical

Asymmetrical

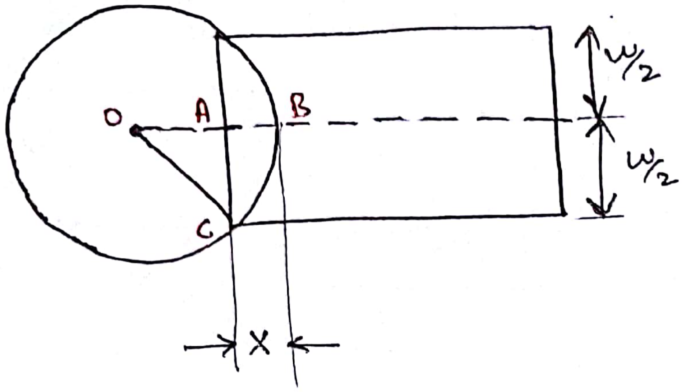




Slot milling



Calculation of compulsary Approach in Symmetrical face milling



$X = OB - OA$

$OA = \sqrt{OC^2 - AC^2}$

$= \sqrt{\left(\frac{D}{2}\right)^2 - \left(\frac{w}{2}\right)^2}$

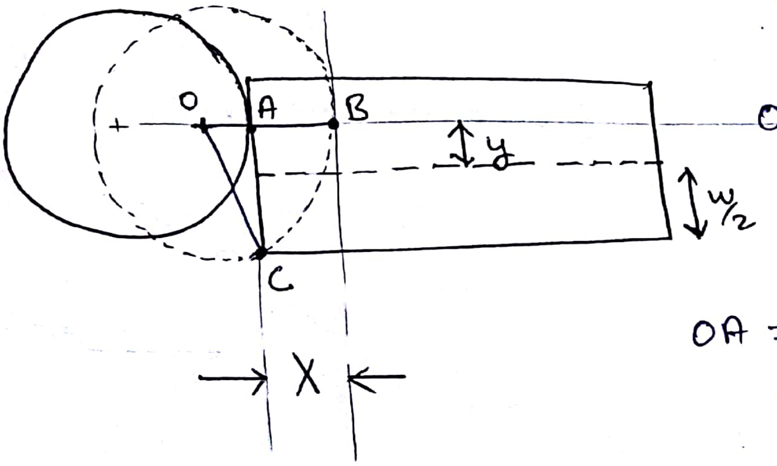
$OA = \frac{1}{2}\sqrt{D^2 - w^2}$

$X = OB - OA = \frac{D}{2} - \frac{1}{2}\sqrt{D^2 - w^2}$

$$\Rightarrow \boxed{X = \frac{1}{2}\left[D - \sqrt{D^2 - w^2}\right]}$$

- Compulsory Approach in face milling is defined as the distance travelled by the end mill cutter after which complete width of w/p is under the cutter

Calculation of Compulsory Approach in Asymmetrical face milling



$Y = OB - OA$

$OA = \sqrt{\left(\frac{D}{2}\right)^2 - \left(\frac{w}{2} + y\right)^2}$

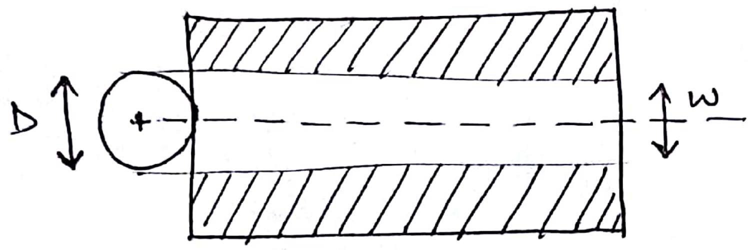
$OA = \frac{1}{2}\sqrt{D^2 - (w + 2y)^2}$

$X = OB - OA = \frac{D}{2} - \frac{1}{2}\sqrt{D^2 - (w + 2y)^2}$

$$\Rightarrow \boxed{X = \frac{1}{2}\left[D - \sqrt{D^2 - (w + 2y)^2}\right]}$$

Special case

- End mill cutter used for slot making



$$X = \frac{1}{2}\left[D - \sqrt{D^2 - w^2}\right]$$

here $D = w$ = width of slot

$$\boxed{X = \frac{D}{2}}$$

machining time calculations

① $$\boxed{t_m = \frac{l_e}{f_t \cdot z \cdot N}}$$

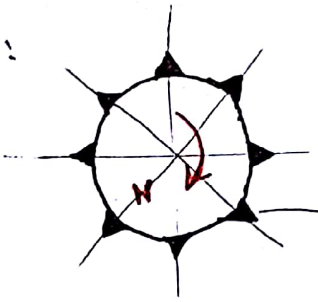
$$\frac{mm}{\cancel{tooth}} \cdot \frac{\cancel{teeth}}{\cancel{rev}} \cdot \frac{\cancel{rev}}{min} = \frac{mm}{min}$$

② $$\boxed{t_m = \frac{l_e}{f_m}}$$

Table feed $\left(\frac{mm}{min}\right)$

$$\Rightarrow f_m = f_t \, z \, N \Rightarrow \boxed{f_t = \frac{f_m}{zN}}$$

ex:



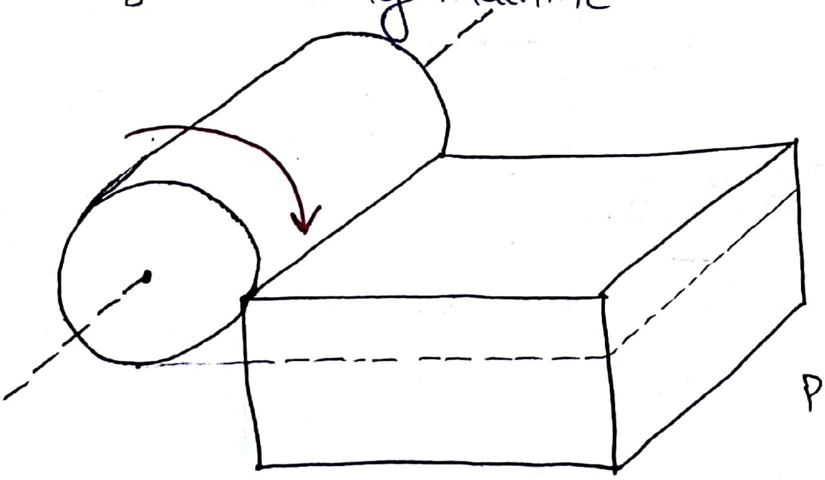
$f_t = 0.01$

$z = 8$

$f_t \times z = 0.08$ mm/rev

2. **Peripheral Cutter**

- Horizontal milling machine



Plane milling

or

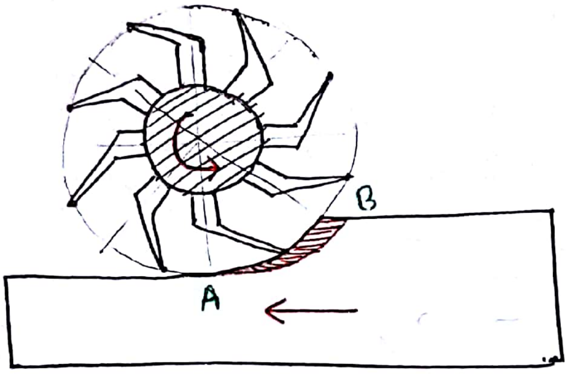
Slab milling

Peripheral cutter

Milling

Up-milling

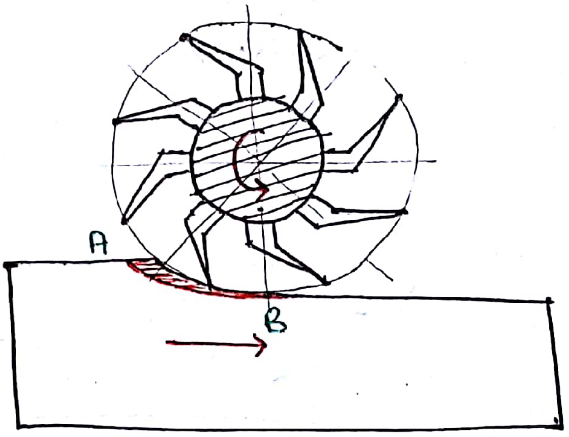
- Dirⁿ of cutter & w/p will be opposite



- The chip thickness varies from minimum to maximum
- Tool life is less
- Surface finish is poor
- The cutter tend to lift the w/p above the table
- w/p require strong clamping

Down milling

- Dirⁿ of cutter & w/p are same.



- The dirⁿ of cutter & w/p are same.
- The chip thickness varies from maximum to minimum
- tool life is high
- Surface finish is better
- Cutter tends to push the w/p towards table
- strong clamping not required

⇒ minimum chip thickness $= t_{min} = 0$

⇒ maximum chip thickness $= \boxed{t_{max} = \frac{2 f_m}{N z}\sqrt{\frac{d}{D}}}$

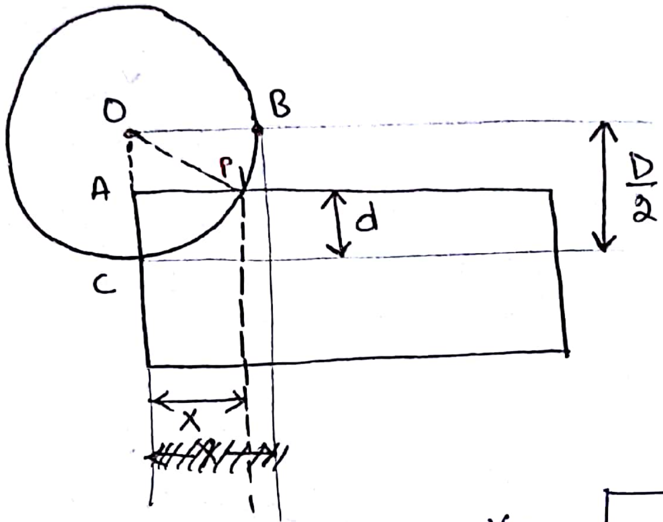
f_m = table feed (mm/min)

d = depth of cut

D = dia of cutter

$$\Rightarrow \boxed{t_{avg} = \frac{t_{min}+t_{max}}{2} = \frac{f_m}{N z}\sqrt{\frac{d}{D}}}$$

Calculation of compulsory Approach for Peripheral milling cutter



$$x = \sqrt{OP^2 - (OA)^2}$$

$$OA = OC - AC$$

$$= \frac{D}{2} - d$$

$$x = \sqrt{\left(\frac{D}{2}\right)^2 - \left(\frac{D}{2} - d\right)^2}$$

$$x = \sqrt{\left(\frac{D}{2}\right)^2 - \left(\left(\frac{D}{2}\right)^2 + d^2 - Dd\right)}$$

$$\boxed{x = \sqrt{Dd - d^2}}$$

⇒ machining time can be calculated as

$$t_m = \frac{l_e}{f_m} = \frac{l_e}{f_t \cdot z \cdot N}$$

Important formulae for milling

1. $X_{sym} = \frac{1}{2}\left[D - \sqrt{D^2 - w^2}\right]$
2. $X_{Asym} = \frac{1}{2}\left[D - \sqrt{D^2 - (w + 2y)^2}\right]$
3. $X_{special\ case} = \frac{D}{2}$

face milling

4. $X_{peripheral} = \sqrt{Dd - d^2}$
5. $t_m = \frac{l_e}{f_m} = \frac{l_e}{f_t \cdot z \cdot N}$
6. Chip thickness in peripheral milling

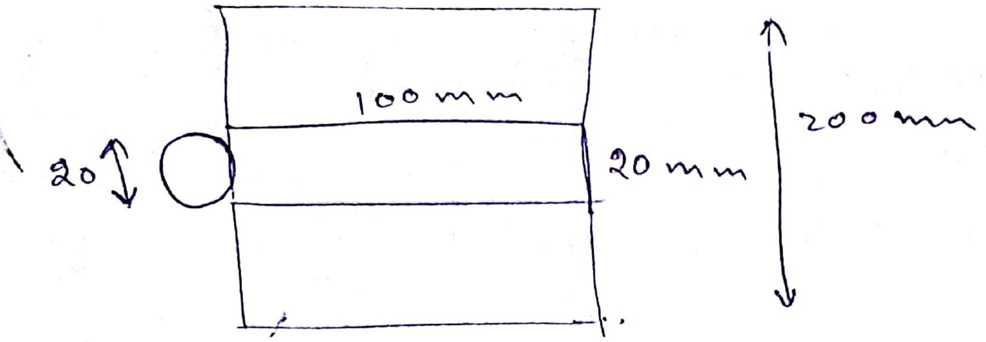
$$t_{max} = \frac{2 f_m}{N z}\sqrt{\frac{d}{D}}$$

$$t_{min} = 0$$

$$t_{avg} = \frac{t_{max} + t_{min}}{2}$$

$$t_{avg} = \frac{f_m}{N z}\sqrt{\frac{d}{D}}$$

WB
P-27
T1



$z = 8$

$f_t = 0.08$ $\quad f_t z = 0.08$ mm/rev

$d = 3$ mm

$V = 60$ m/min

$$V = \frac{\pi D N}{1000}$$

$$N = \frac{1000 \times V}{\pi D}$$

$= 954.929$ rpm

$$t_m = \frac{l_e}{f_t z N}$$

$$= \frac{100 + 10}{.08 \times 954.929}$$ = ~~1.30899 min~~

$= 1.43989$ min

T2

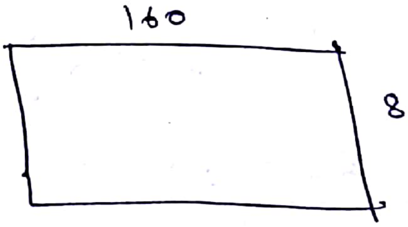
$D = 150$ mm

$z = 10$

$y = 15$ mm

$f_t = 0.25$

$f_t \times z = 2.5$ mm/rev



$$N = \frac{1000\, V}{\pi D} = 42.44 \text{ rpm}$$

$$t_m = \frac{l_e}{f_t z N}$$

$$X = \frac{1}{2}\left[D - \sqrt{D^2 - (w+2y)^2}\right]$$

$=$ ~~11.55~~ 24.01

$$= \frac{160 + \overset{24.01}{\cancel{24.55}}}{2.5 \times 42.44}$$ $= 1.73$ min

WB
P- 26
Q23

$D = 90$ mm

$z = 10$

$V = 30$ m/min $\Rightarrow N = \frac{1000 \times 30}{\pi \times 90} = 106.1032$ rpm

$f_m = 180$ mm/min

$d = 3$ mm

$$t_{max} = \frac{2 f_m}{z N}\sqrt{\frac{d}{D}}$$

$$= \frac{2 \times 180 \times}{\cancel{10} \times 106.1032}\sqrt{\frac{3}{90}} = 0.0619 \text{ mm}$$

$$t_{avg} = \frac{t_{max}}{2} = 0.031 \text{ mm}$$

Q22
WB

$N = 120$ rpm

$t_m = ?$ (2 slot)

$d_e = 10$ mm $\quad d = 20$ mm

$l = 100$ mm

$D = 80$ mm

$f = 0.5$ mm/rev

Clearance = 5 mm

$X \neq \frac{D}{2} \nless 40$ mm

$X = \sqrt{Dd - d^2}$

$= ~~34.64~~ \; 26.45$ mm

$l_e = 34.64 + 100 + 5$

$= 131.45$

$t_m = 2 \times \frac{l_e}{f N} = ~~4.65~~ \; 4.38$ min

Q20
WB

$l = 278$ mm

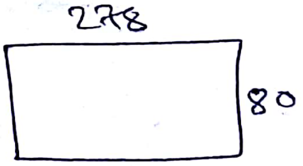
$w = 80$ mm

$D = 120$ mm

$z = 10$

$N = 50$ rpm

$f_t = 0.1$ mm/tooth



$t_{allow} = 2$ min

$l_a + l_o = 2$ mm

$l_e = X + l + l_o + l_a$

$X = \frac{1}{2}\left(D - \sqrt{D^2 - w^2}\right)$

$= 15.2786$

$l_e = 295.278$

$$t_m = \frac{l_e}{f z N} = \frac{295.278}{0.1 \times \cancel{10} \times 50} = 5.9 \text{ min}$$

total time $= 5.9 + 2 = 7.9$ min

Production rate $= \frac{60}{7.9} = 7.589$ Jobs/hr

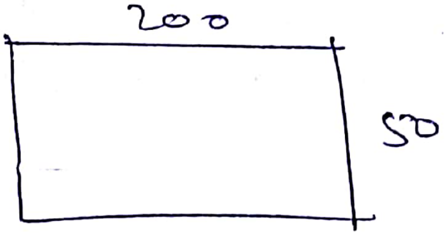
$= 60.71$ Job/8 hr

$\simeq 60$ Jobs/8hr

WB Q19

$w = 50$ mm

$d = 200$ mm



$D = 75$ mm

$x = \frac{1}{2}\left(D - \sqrt{D^2 - w^2}\right) = 9.549$ mm

$d_e = l + x = 209.549$ mm

WB Q18

① $d = d$

② $d = 2d$

$t_{mc} = \frac{f_m}{Nz}\sqrt{\frac{d}{D}}$

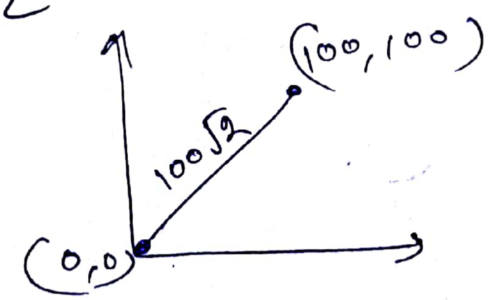
$\frac{t_{max}(1)}{t_m(2)} = \frac{1}{\sqrt{2}} = .707$

WB Q17

$w = D = 10$ mm

$d = 2$ mm

$f_m = 50$ mm/min



$x = 5$ mm

$d_e = 141.4 + 5 = 146.4 \Rightarrow t_m = \frac{146.4}{50}$

$= 2.928$ min

$= 175.68$ sec

WB Q14

$z = 8$

$N = 150$

$f_t = 0.1$ mm/tooth

$f_m = f_t z N$

$= \cancel{0.1} \times 8 \times \cancel{150}$

$= 120$ mm/min

Q10 (A)

06 ⇒ (D)

03 ⇒ D

21 ⇒ 130

WB Q11

$l = 200$

$D = 100$

$z = 4$

$N = 100$ rpm

$f_m = 200$ mm/min

$d = 2$ mm

Clearance = 5 mm

$$t_{avg} = \frac{f_m}{N z}\sqrt{\frac{d}{D}} = \frac{\cancel{200}}{\cancel{400}_{2}}\sqrt{\frac{2}{100}}$$

$= 0.0707$ mm

$= 70.7$ μm

WB Q7

$D = 100$ mm

$z = 10$

$N = 200$ rpm

$d = 3$ mm

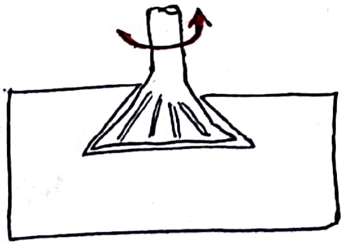
$f_m = 400$ mm/min

$$f_t = \frac{f_m}{z N} = \frac{400}{10 \times 200}$$

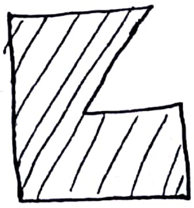
$= 0.2$

Miscellaneous Questions

Numericals ⇒ "form mill cutter"



Double dovetail Recess



Single dovetail Recess

Ques
ESE
2016

The feed in face milling for a width of 70 mm with cutter 160 mm dia having 10 inserts & rotating at 360 rpm with feed rate of 0.5 m/min is nearly

a) 0.21 mm/tooth

b) 0.18 mm/tooth

✓c) 0.14 mm/tooth

d) 0.11 mm/tooth

Soln

$$f_t = \frac{f_m}{zN} = \frac{5\cancel{0}\cancel{0}}{\cancel{10}\times 36\cancel{0}} = \frac{5}{36} = 0.14$$

INDEXING

- it is a process of dividing a circular w/p into equal no. of divisions.
- Its elements are

C → Crank

P → Plate

W → W/p

D → Driving gear | Driver

Direct indexing

- Bevel gear is used
- Gear ratio 24:1

i.e. for rotating w/p by 1 revolution crank has to complete 24 revolution

ex: If 6 divisions are to be made on w/p then, no. of revolution of w/p in 1st indexing = $\frac{1}{6}$ revo.

no. of revolution of crank = $\frac{24}{6}$ = 4 rev.

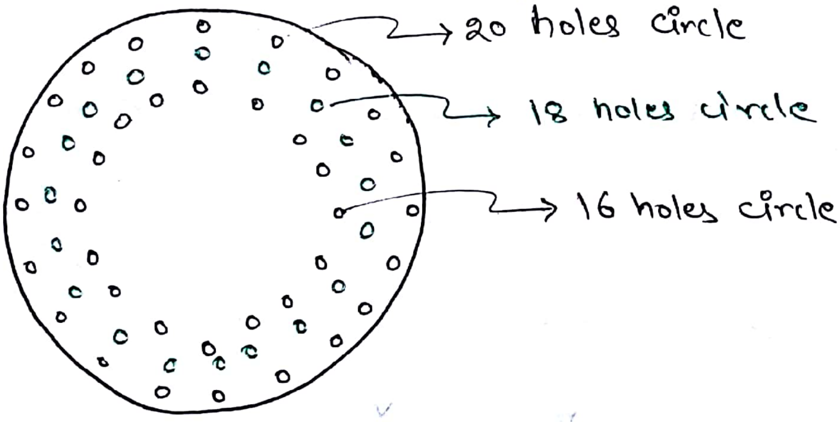
Ques: Divide the w/p into 8 equal divisions using direct indexing, total angle of revolution in (degrees) of crank is ________

Soln: no. of crank rotation = $\frac{24}{8}$ = 3 rev.

angle = 3×360 = 1080°

Index Plate

Index plate is a circular disc that has 'n' no. of holes punched around the periphery to move the crank by fraction of revolution.



Ques: Divide a circular w/p into 14 equal divisions using direct indexing mechanism.

Plate 1 ⇒ 16, 18, 20, 22, 24 holes circles

Plate 2 ⇒ 15, 17, 19, 21, & 23 holes circles

which index plate will be used?

Soln:

$$\text{crank} \Rightarrow \frac{24}{14} = 1\frac{10}{14} = 1 + \frac{10}{14} \times \frac{3/2}{3/2} = \frac{15}{21}$$

1 round & 15 holes movement in 21 hole plate 2

Simple or Plain indexing

- worm gear will be used
- Gear ratio 40 : 1

i.e. 40 revolution of worm will make w/p to move 1 revolution

- So, rotations of worm/crank = $\frac{40}{N}$

N = no. of divisions of w/p reauired

WB
Q16
P-26

crank rotation $= \frac{40}{34} = 1\frac{6}{34} = 1\frac{3}{17}$

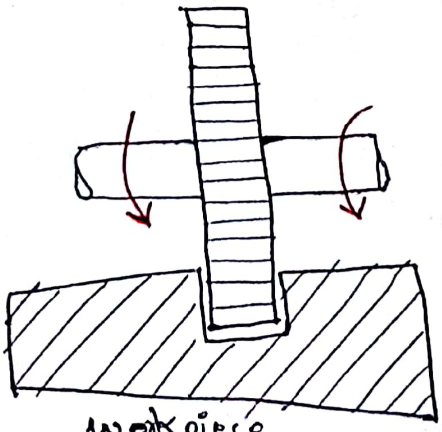
Ques: for 1 division on a w/p the index crank completes one full revolution followed by 10 holes in 30 holes circular plate calculate the angle of revolution of w/p in degrees.

Soln:

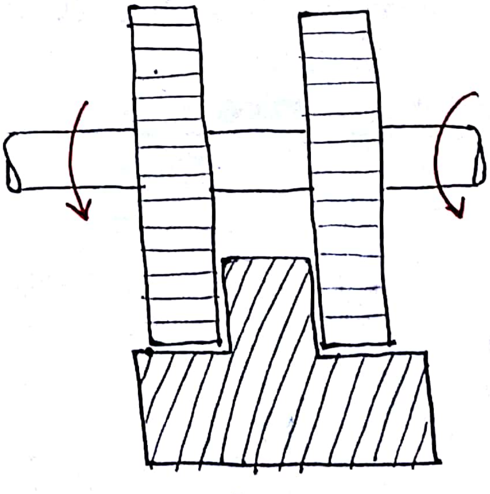
$1\frac{10}{30} \Rightarrow \frac{40}{30}$ 30 divi

$\Rightarrow \cancel{\frac{360}{30}}$ $\boxed{12^\circ}$

3. Side mill cutter



workpiece



Straddle mill

'n'. no. of peripheral cutters combined together for simultenous machining

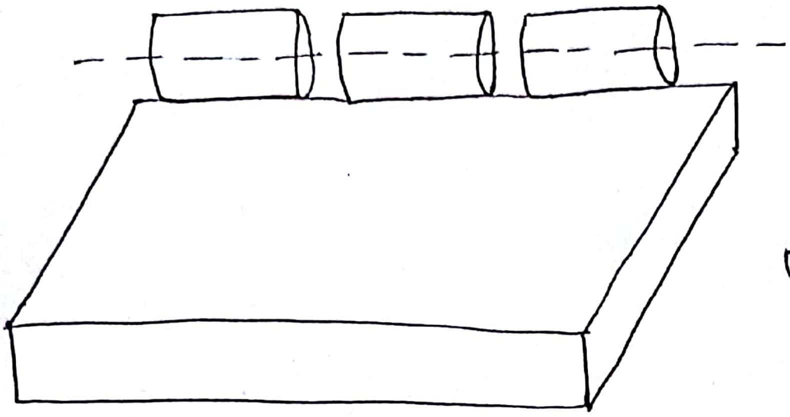
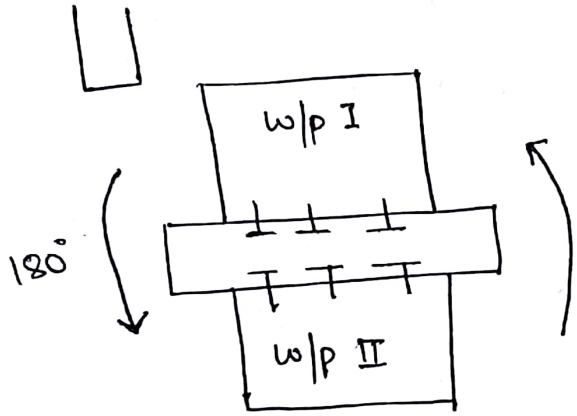


Fig:- Gang milling

Reciprocal milling

- worktable can shift by 180° during machining of 1st w/p, 2nd w/p is being loaded and there is no additional 180° delay after m/c ing of w/p 1.

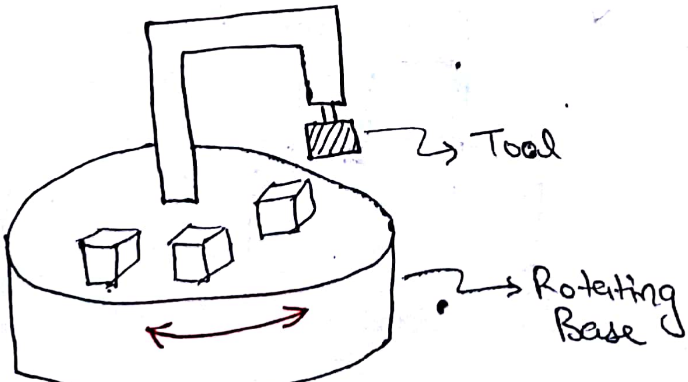


Universal milling machine

- tool can swivel in Various directions
- Complex shapes / contours are machined ex:- 5 Axis mill

Rotating milling machine

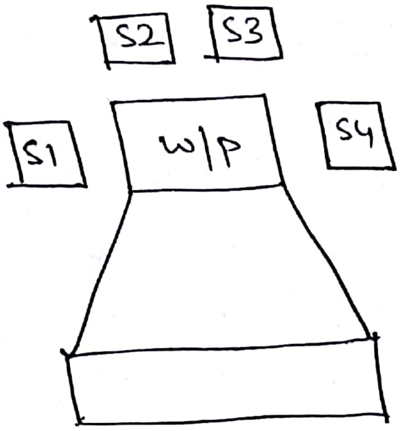
- Rotating worktable exists
- Multiple w/p can be loaded at once.



Helical milling

- It is a process of cutting Helical grooves on a cylindrical w/p or frustum of cone.

Bed type milling m/c
or
Planer milling machine

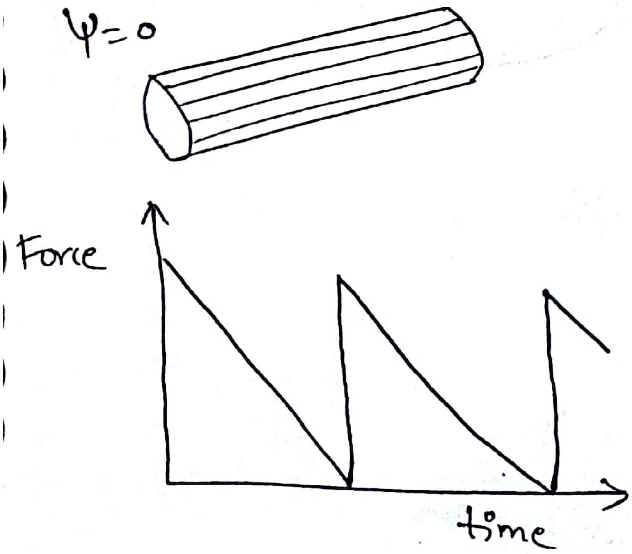


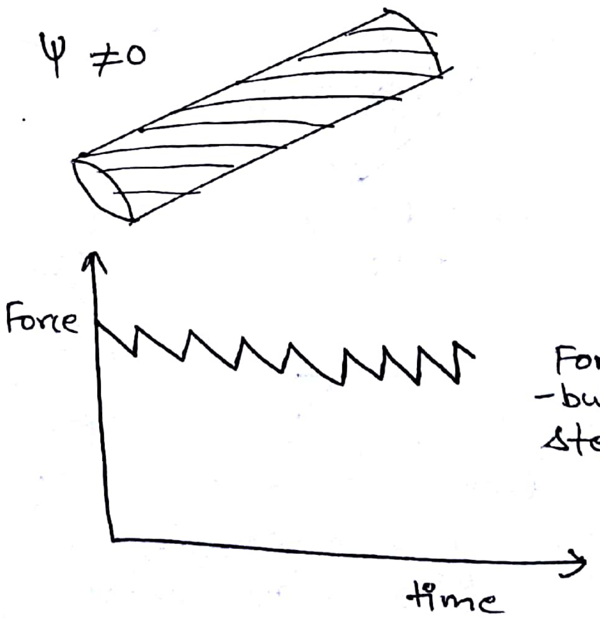
- Multiple horizontal and vertical spindle heads, can be used to m/c a w/p on various faces except the base
- This is capable of withstanding heavy loads & can be used for large w/p.

Ques: what are the reasons for induced vibrations in milling operation ?

Soluⁿ

1) m/c is less rigid
2) If depth of cut is high
3) If zero helix cutter is used

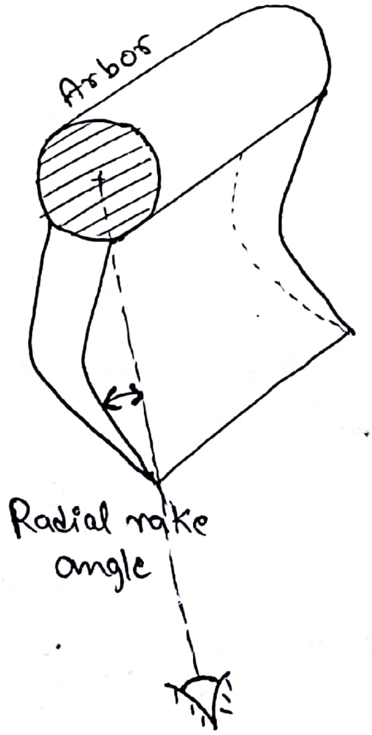


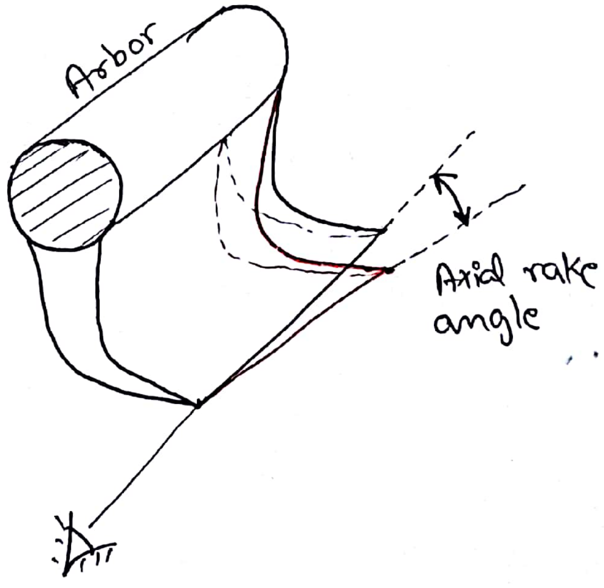


Force distribution is steadier

- If a zero helix cutter is used ($\varphi = 0$) then at one point of time the w/p will be in contact with a single flute. When the flute is in contact the load will be maximum. and the flute will release the contact suddenly lowering the load to zero followed by a sudden contact of another flute. therefore due to this sudden contact and release of the milling tooth, the induced vibrations will be high. To suppress large vibrations impact shocks can be lowered by providing high axial rake angle.
- On the other hand if a non-zero helix cutter is used then at any given time the workpiece is in contact with more than one flute. In this case when one of the flute tries to release the contact, simultenously the adjucent flute will try to make a dominant contact with the workpiece keeping the load steadier.

Axial & Radial rake angles

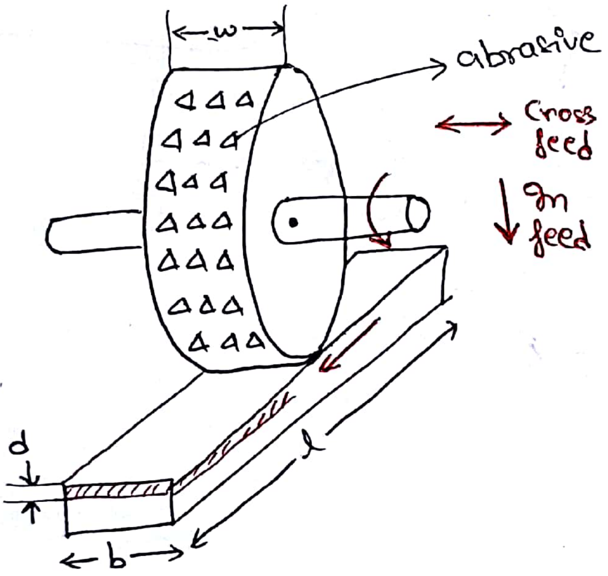


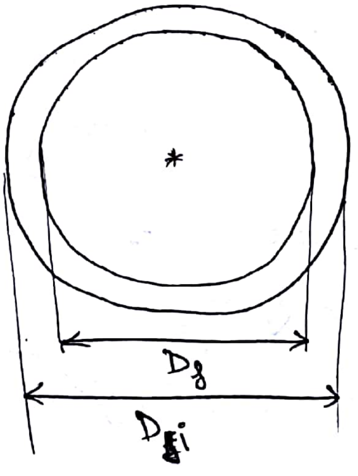


- In upmilling ⟶ Axial rake angle ↑
- In case of intermittent cutting with single point tool large side rake angle is provided

GRINDING

- It is a machining Process which operates at highest cutting speed.
- Grinding consumes highest specific cutting energy
- Highest specific Power consumption..
- It removes material by abrasive action as the abrasives are embeded over the periphery of the wheel.
- During m/cing abrasive layer wears out and due to rubbing force applied by the workpiece, worn out abrasives are pulled out of the wheel giving a fresh layer of abrasive a chance to remove material this is known as self sharpening behaviour of grinding wheel.





- Volume of wheel wear out $= \left(\frac{\pi}{4} D_i^2 - \frac{\pi}{4} D_f^2\right) \times w$
- Grinding ratio $= \dfrac{\text{Vol. of material removed from w/p}}{\text{Vol. of grinding wheel wear}}$

$$GR = \frac{V_{w/p}}{V_{gw}} = \frac{l \times b \times d}{\frac{\pi}{4} w \left(D_i^2 - D_f^2\right)}$$

→ width of w/p

→ width of Grinding wheel

- Specific Cutting energy $= \frac{J/s}{mm^3/s} = \frac{Power}{MRR}$

- Reason for slow MRR

  1) Size effect
  2) welding effect
  3) Negative rake angle

- Specific Power consumption of grinding is higher than that of Turning

	Turning		Grinding
if,	MRR	=	MRR
	C ↓		C ↑

Due to high cutting velocity of grinding

if	Power	=	Power
	C ↓		C ↑

Due to size effect

$$\boxed{\begin{gathered} P = F_c . V \\ C = \frac{F_c . V}{MRR} \end{gathered}}$$

- <u>Size effect</u>

A major Portion of abrasive vol. is embedded inside the wheel & a very small portion of abrasives is allowed to interact with the w/p Due to which MRR is low this is Known as size effect.

- <u>welding effect</u>

Due to high Cutting Speed heat developed at wheel - work interface will be high due to which material once removed may get welded which is to be removed in further passes.

- **Negative rake angle**

Generally the abrasives are randomly oriented in the grinding wheel but due to its cubical X-s/c, it strikes the workpiece with a large -ve rake angle thereby imparting strength to the tool but decrease in penetration.

- Specific cutting energy $= \frac{J}{mm^3} = \frac{F_c . V}{b . d . v}$

v = table speed (mm/min)

Grinding wheel Specification

Attack	GATE	to Get a	seat in	BARC
↓	↓	↓	↓	↓
Abrasive	Grain size	Grade	Structure	Bond
⇓	⇓	⇓	⇓	⇓
Alphabet	Numeral	Alphabet	Numeral	Alphabet

1) **Abrasive**

CBN / Carbide — SiC → Hard w/p
— B_4C

Al_2O_3 → soft & medium hard w/p
⇓
HSS, Bronze, Brass, MS, CI etc

Dimond

CBN → very hard w/p

Ques: A grinding wheel is specified as A 27 K 12 V. the letter K represents

a) Hardness
b) Abrasives
c) Structures
d) Grain size

2) Grain Size

Grain Size Number	Type of grains
10 – 24 →	coarse grains
30 – 60 →	medium grains
80 – 180 →	fine grains
220 – 600 →	very fine grains

- Grain size $\propto \frac{1}{GSN}$
- Rough Grinding → Coarse or medium grains
- finish grinding → fine or very fine grains
- $\boxed{\text{Grain size} = \frac{1}{GSN}}$ inches

1 inch = 25.4 mm

Ques: A 27 K 12 V
find grain size

Soln

$$\text{grain size} = \frac{1}{GSN} = \frac{1}{27}\ \text{Inches} = \frac{25.4}{27}\ \text{mm}$$

3) Grade or Hardness

Hardness of a grinding wheel can be defined as the ability of the bonds to retain its abrasive

A to H ⇒ soft wheels

I to P ⇒ medium wheel

Q to Z ⇒ Hard wheel

- If w/p is soft ⇒ Hard wheel
  If w/p is medium ⇒ medium wheel
  If w/p is Hard ⇒ soft wheel

- Let us consider a hard w/p to be grinded by hard wheel (H-H combination)
  - Since the w/p is hard the rubbing force will be be high and therefore the abrasives will wear out Quickly.
  - But since the wheel is also hard, it will not allow the abrasives to be pulled off and worn out abrasives will involve rubbing action without giving any chance to fresh layer of abrasives. This is known as glazing or blunt wheel grinding.
  - After glazing is observed on the grinding wheel, a single point tool will will be used to remove worn out abrasive forcefully from the wheel this operation is known as dressing which takes 15 to 20 minutes.
  - In H-H combination glazing takes place after 3-4 minutes and large idle time will be followed which is not productive therefore H-H combination must not be prefered.

- If soft w/p is grinded by hard wheel then the abrasives will wear out slowly and glazing will be observed after 3-4 hours followed by dressing operation. So small idle time after long productive time is justified.

4. Structure

Structure of a grinding wheel refers to the average gap b/w two consecutive abrasives.

Structure no.	Structure
0 – 7	Dense structure
8 – 16	open structure

- Rough grinding ⟶ open structure
- finish grinding ⟶ Dense structure
- Hard w/p ⟶ Dense structure
- Soft w/p ⟶ open structure

- $$\boxed{\text{Average gap b/w 2 consecutive abrasive} = \frac{\text{Structure no.}}{1000}}\ \text{inches}$$

Ques: find the average gap b/w abrasives

A 27 K 12 V

Solu^n

$$\text{Avg gap b/w abrasive} = \frac{SN}{1000}\ \text{inches}$$

$$= \frac{12}{1000} \times 25.4\ \text{mm}$$

$$= 0.3\ \text{mm}$$

- Let us consider a soft and ductile work piece to be rough grinded by a dense structure wheel.
  - Since the w/p is soft and ductile the chip flow will be continous and if rough grinding is performed then the material removed will be high but since the structure is dense, the material will not flow out easily and will be clogged within the abrasive. This is known as loading of grinding wheel.

Reasons for loading

1) mismatch of structure
2) if grinding wheel has low rpm then also loading happens
3) If cutting fluid is not properly supplied.
[mist application :- Cutting fluid in spray form of discharge, used for finish m/cing
flood application :- High discharge of cutting fluid used for rough machining]
4) If the w/p is too soft (like rubber)

- Hard workpiece will apply high rubbing force and therefore abrasives must be close to each other therefore dense structure must be prefered.

5. Bond

a) Vitrified bond (V) :- Vitrified is derived from the word Vitrieum which means glass like. therefore this bond is very very hard but brittle. Calcium hydroxide along with some flux will be fired at a very high tempr and will be then cooled to obtain a hard glass like bond. [1380°c] This process is known as vitrification

Properties of vitrified bond

- it is very hard and brittle
- it is innert to chemical reactions with cutting fluids
- it has high tempr withstanding capacity
- it has high thermal stability.

Limitation

- it cannot be used for high speed grinding bcz Vitrified bond is hard and brittle to when

when subjected to high speed grinding, under high centrifugal force the bond may break.

b) <u>Rubber bond</u> :- it is soft and is used for manufacturing flexible wheels, it is also used for polishing operations and in centerless grinding.
(R)

c) <u>Silicate bond</u> :- it is also known as water glass. it is made up of sodium silicate which can be used for medium or high speed grinding.
(S)

- it has low chemical innertness as compared to vitrified bond

Note:- Grinding wheel life can be defined as the time period b/w two successive dressings operations.

Q14
P-30
WB

volume removed from w/p

$= 200 \times 2.5 \times 5 = 2500 \text{ mm}^3$

$V_{gw} = \frac{\pi}{4}(D_i^2 - D_f^2)\,w$

$= \pi/4 \times (300^2 - 299.986^2) \times 25$

$= 471.2 \text{ mm}^3$

Grinding ratio $= GR = \frac{2500}{471.2}$

$= 5.305$

27/2/16

Q15
WB

$$C = \frac{F_c . V}{d . b . v}$$

$$F_c = \frac{C \times d \times b \times v}{V}$$

$$V = \frac{\pi D N}{1000} = \frac{\pi \times 22\cancel{0} \times 36\cancel{00}}{1\cancel{000}}$$

$$= 2488.14 \ m/min$$

$C = 40 \ J/mm^3$

$d = 0.04 \ mm$

$b = 22 \ mm$

$f_m = v = 1180 \ mm/min$

$$F_c = \frac{40 \times 0.04 \times 22 \times 1180}{2488.14} = 16.7 \ N$$

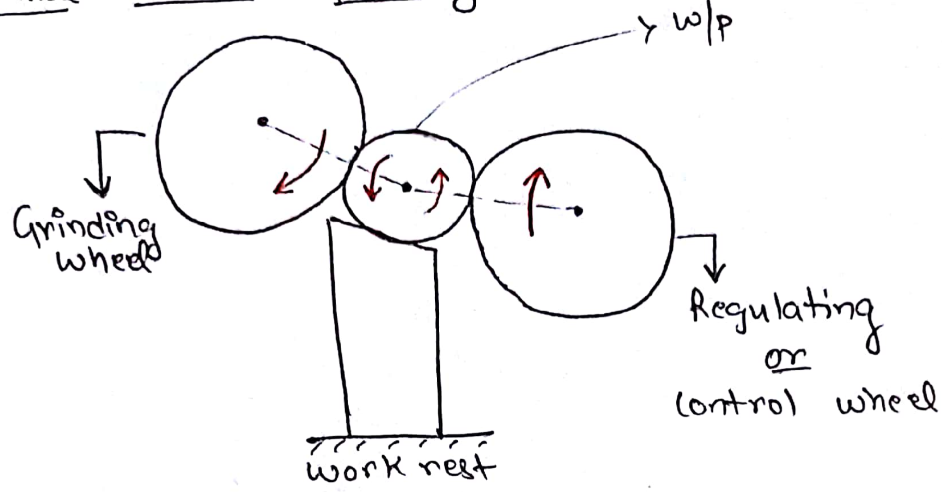
Centerless Grinding

- The w/p will not be provided with any fixed center.
- there will be no seperate motion attachement for the w/p bcz motion to the w/p will be provided by the regulating wheel.
- The dirⁿ of rotation of regulating wheel and grinding wheel are same
- The dirⁿ of w/p will be opposite to grinding wheel & Regulating wheel

Functions of regulating wheel

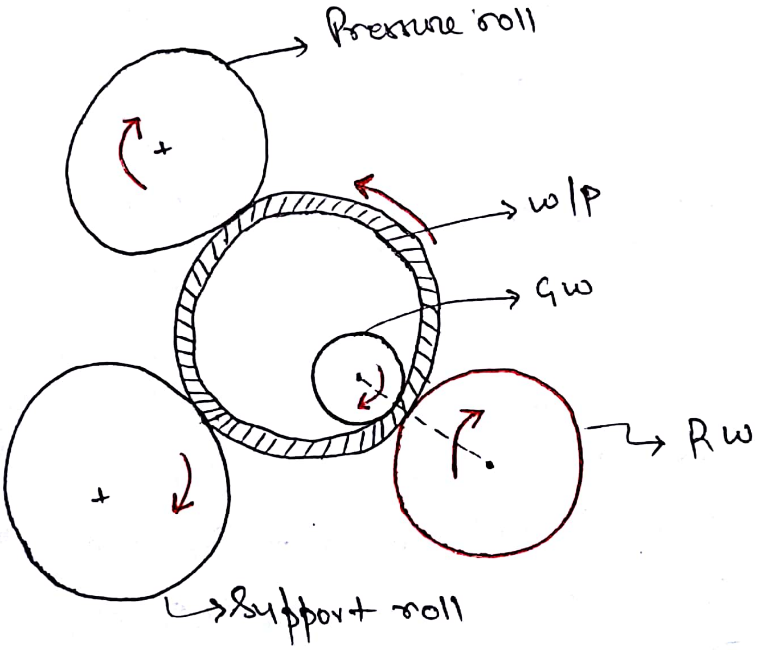
→ Position the w/p
→ Provide motion to w/p
→ apply lateral pressure on w/p.
→ feed is given to w/p

External centerless Grinding.



Solid cylinder ⇒ External C.G. [RW is smaller than GW]

Hollow Cylinder ⇒ Internal C.G. [RW is longer than GW]



Limitations:

1) long flat w/p cannot be machined by centerless grinding
2) initial setup time is high.

Advantages

1) m/cing time per job is less
2) High productivity
3) High accuracy & improved dimensional tolerance
4) minimised loading & unloading time
5) no fixed centers required like chuck in lathe

Non- Traditional machining methods

Limitations of traditional method

1) Tool & w/p must be in direct physical contact.
2) Tool must be 30% stronger than the w/p.
3) It is very diff. to m/c very hard materials.
4) It is very diff. to m/c very soft materials due to clogging.
   ex:- Rubber.
5) It is diff. to machine complex contours.
6) It is very diff. rather inpossible to produce holes on hard & brittle material like glass.

Non traditional methods

1. mechanical method

Source → Tool | work motion

mechanism of material removel ⇒ Shear ⇒ Traditional method

Source → fluid / particle motion
ex:- WJM, AJM, USM

mechanism ⇒ Errosion

2. Electrochemical method

Source → Electric current

mechanism → Ionic Dissolution
ex:- ECM

3. Chemical method

source → Corrosive Agent

mechanism → Corrosion ex:- chemical machining

4. Thermal method

mechanism → fusion & Vaporisation

Source
1) High Speed Electrons → ex: EBM
2) Powerful radiations → ex: LBM
3) High tempr ionised gas → ex: PAM
4) Electric spark → ex: EDM

1. Electrochemical machining (ECM)

- It is high current low voltage process.
- It follows law of electrolysis. [Faraday's law]
- According to Faraday's law mass of material removed will be directly proportional to charge flow through the electrolyte.

$$m \propto q \qquad \left(\because I = \frac{q}{t}\right)$$

$$m \propto It$$

$$m = zIt \qquad [\because z = \text{electrochemical equivalent}]$$

$$z = \frac{e}{F}$$

e → gram equivalent

F → Faraday's const.

$$e = \frac{\text{Atomic wt.}}{\text{Valency}} = \frac{A}{Z}$$

$$m = \frac{e}{F} It \Rightarrow \frac{m}{t} = \frac{eI}{F}$$

$$\dot{m} = \frac{eI}{F} \Rightarrow \boxed{\dot{m} = \frac{AI}{ZF}} \Rightarrow \boxed{\rho\dot{Q} = \frac{AI}{ZF}}$$

gm/s

ρ = gm/cm³

$\dot{Q}$ = cm³/s

- Specific material removal rate $= \frac{MRR}{I} = \frac{\rho Q}{I} = \frac{A}{ZF} = s$
- J = Current density $= \frac{I}{A}$

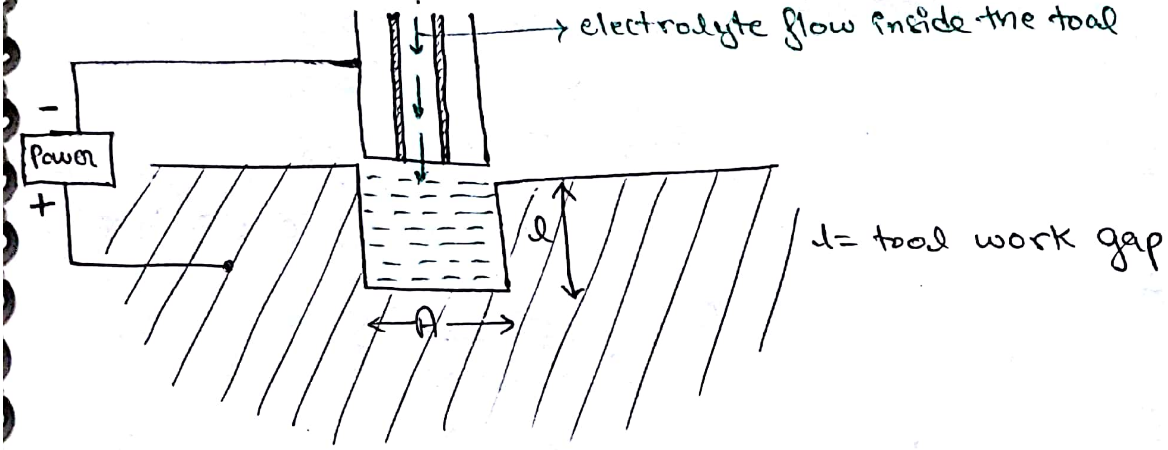
Resistance = $\frac{\rho_s l}{A}$ ⇒ $\frac{V}{I} = \frac{\rho_s l}{A}$ ⇒ $\frac{I}{A} = \frac{V}{\rho_s l}$

So $\boxed{J = \frac{I}{A} = \frac{V}{\rho_s l}}$ [∴ ρ_s = resistivity (Ω cm)]

- feed rate = $\frac{MRR}{A}$ (mm/s) $= \frac{\rho Q}{A_r} = \frac{AI}{FZ(A_r)} = \frac{AJ\cancel{(A_r)}}{FZ\cancel{(A_r)}}$

feed = $\frac{AJ}{ZF}$

feed rate = $\delta \times J = \frac{A}{ZF} \times \frac{V}{\rho_s l}$



Q28
P-34
WB

$MRR = \rho Q = \frac{AI}{FZ}$

$7.6 \times Q = \frac{56 \times 480}{96500 \times 2}$ ⇒ $Q = 0.0183$ cm³/s

Q29

MRR = ?

$A_r = 2.5 \times 2.5$ cm²

$y = 0.025$ cm

$V = 12$

$K = 3\ \Omega$-cm

$I = JA$

$= 1000$ A

$A = 55.85$

$Z = 2$

$\rho = 7.86 \times 10^{-3}$ gm/cm³

$\boxed{\delta = \frac{MRR}{A} = 0.0588 \text{ mm/s}}$

$J = \frac{KV}{y} = \frac{12}{3 \times 0.025} = 160$

$\rho Q = \frac{AI}{FZ} = \frac{55.85 \times 1000}{96500 \times 2} = 0.289$ ~~cm~~ gm/s

$= 36.768$ mm³/s

$\boxed{030}$

Ans

$v = 13.78$

$y = 0.2$ cm

$v = ?$

$\Delta v = 2.5$ v

$K = 50\ \Omega$ – mm

$= 5\ \Omega$ cm

$f = 0.25$ mm/min

$= \frac{0.025}{60}$ cm/s

$\rho = 7.86$ gm/cm³

$A = 56$

$Z = 2$

$f = \frac{MRR}{A_r}$

$I = JA$

~~Ar H~~

$$\boxed{\rho\theta = \frac{AI}{FZ}}$$

$$J = \frac{K(v - \Delta v)}{y}$$

$$\rho \times f(A_r) = \frac{AI}{FZ}$$

$$A_r = \frac{\boxed{56} \times \boxed{I} \times 60}{.025 \times \boxed{96500} \times \boxed{2} \times 7.86}$$

$$\boxed{A_r = \frac{I}{0.08859}}$$

~~0.69637~~

$I = JA$

$J = \frac{I}{A}$

$$\Rightarrow \frac{1}{0.08859} = \frac{(v - 2.5)}{5 \times 0.2}$$

~~0.69637~~

$\Rightarrow v = 11.28 + 2.5$

$= 13.787$ V

Alloy equation

① Two / Binary alloy

A → X %

B = (100 − X) %

$$\boxed{\left(\frac{Z}{A}\right)_{alloy} = \frac{X}{100} \times \left(\frac{Z}{A}\right)_A + \frac{(100 - X)}{100} \times \left(\frac{Z}{A}\right)_B}$$

② for composition of 3 elements

$$\left(\frac{Z}{A}\right)_{alloy} = \frac{X}{100} \times \left(\frac{Z}{A}\right)_P + \frac{Y}{100}\left(\frac{Z}{A}\right)_Q + \frac{(100 - X - Y)}{100} \times \left(\frac{Z}{A}\right)_R$$

TI
-34

$$\left(\frac{Z}{A}\right)_{alloy} = 0.18\left(\frac{2}{58.93}\right) + .62\left(\frac{2}{58.71}\right) + .2\left(\frac{6}{51.99}\right)$$

$= \cancel{0.02937}$ 0.0503

$$\rho Q = MRR = \frac{AI}{ZF} = \frac{500 \times \overset{19.876}{\cancel{34.0154}}}{96500}$$

$= \cancel{0.17624}$ 0.1029

$$\dot{Q} = \frac{0.17624}{\rho} = \cancel{0.021}\ 0.012437$$

cm^3/s

WB
P-31
Q6

$\rho_{alloy} = 6\ gm/cm^3$ $\dot{Q}_{alloy} = 0.05\ cm^3/s$

$I = 2000A$

$$\left(\frac{Z}{A}\right)_{alloy} = \frac{x}{100}\left(\frac{2}{56}\right) + \frac{(100-x)}{100}\left(\frac{4}{24}\right)$$

$$= \frac{x}{100}\,\frac{2}{56} + \frac{\cancel{100}}{\cancel{100}} \times \frac{4}{24} - \frac{x}{100} \times \frac{4}{24}$$

$$\rho Q = \frac{AI}{FZ} \Rightarrow \left(\frac{Z}{A}\right)_{alloy} = \frac{I}{F} \times \frac{1}{\rho Q}$$

$= 0.069084$

$$0.069084 = x \times 3.57 \times 10^{-4} + $$

$$-0.069084 + \frac{4}{24} = \frac{x}{100}\left(\frac{4}{24} - \frac{2}{56}\right)$$

$\Rightarrow x = 74.51$

$\cancel{\frac{6000 \times 10^3}{10^6}}$

P % ⇒ $100 - x = 25.48$ %

Important points about ECM

- ECM will provide excellent surface finish
- Tool wear will be negligible
- It can be used for removing layers from the surface, m/cing circular or square holes, m/cing steam turbine blades.
- MRR is high

MRR order

PAM > ECM > EDM > USM > EBM > LBM

⇒ PAM will have poor accuracy and if high MRR is required with accuracy then ECM will be prefered

⇒ Electrolytes used in ECM can be classified as
  1) Passivating electrolyte [stock material removal, Rough m/cing]
  2) Non-Passivating electrolyte [used for less material removal, finishing operation]

⇒ The material removal in ECM is layer by layer therefore surface finish is excellent.

Electro chemical Grinding

- material removal will be by electrolysis
- grinding wheel will be electrode (copper bonded)
- Excellent surface finish.

Electric Discharge Machining

- It is high voltage, low current source
- It uses R-C circuit in which a capacitor is charged upto threshold voltage for charging time t_1. Then in the 2nd cycle the capacitor is discharged to dissipate the discharging voltage. The discharging process will be spontaneous and hence it will produce an electric spark. This electric spark will result into intense heating of the work piece.
- The work material removed will be flushed away by the flow of dielectric fluid like mineral oil or Kerosin. This is known as spark erosion

$$V_d = V_0\left(1 - e^{-\frac{t_1}{RC}}\right)$$

t_1 = charging time

V_d = discharged potential

V_0 = charged voltage

R = Resistance (Ω)

C = Capacitance (F)

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

$$P = \frac{E}{t_1 + t_2} \Rightarrow P = \frac{E}{t_1}$$

$$\underset{\substack{\downarrow \\ \text{discharge} \\ \text{time}}}{t_2} <<< \underset{\substack{\downarrow \\ \text{charging time}}}{t_1}$$

$$P = \frac{1}{2}\frac{C V_d^2}{t_1}$$

Old formulay

1) $MRR = \dfrac{40 I}{T_m^{1.23}}$ cm³/min

T_m = melting pt. tempr of wp (°C)

2) idle time or cycle time

$$t_c = RC \ln\left(\frac{V_s}{V_s - V_c}\right)$$

R = charging resistance

C = charging capacitance

V_s = Supply/open circuit voltage

V_c = charging voltage

3) Avg Power input = $\dfrac{\text{Total Energy consumed}}{\text{Cycle time}}$

$$P = \frac{RC\, V_0^2 \left(1 - e^{-\frac{t_1}{RC}}\right)^2}{2 t_1 R}$$

$\frac{t_1}{RC}$ = time variable = N

$$P = \frac{V_0^2 \left(1 - e^{-N}\right)^2}{2RN}$$

for maximum power

$\frac{dP}{dN} = 0$

$\Rightarrow \quad V_d = 0.716\, V_0$

Q T2 WB

Dia = 12 mm

thickness = 50 mm

$R = 40\ \Omega$

$C = 20 \times 10^{-6}$ F

$V_s = 220$ V

$V_d = 110$ V

~~$V_c = .716\, V_s$~~

~~$= 157.52$ V~~

$t_c = RC \ln\left(\frac{V_s}{V_s - V_c}\right)$

$\neq$

$= 40 \times 20 \times 10^{-6} \ln\left(\frac{220}{220-110}\right)$

$= 0.5545$ ms

$$\text{Avg. Power} = \frac{\boxed{\frac{1}{2} C V_d^2}}{t}$$

$= 218.2$ W

$\simeq .2182$ KW

Q17
P-33
WB

$V_d = 100V$

$t_c = 0.025$ Sec.

$$P = \frac{1}{2}\frac{CV_d^2}{t_c} = 1000$$

$$\cancel{\frac{1}{2}} \times \frac{C \times (100)^2}{\cancel{0.025} \times 10^{-3}} = \cancel{1000}\ \cancel{25}\ 50 \times 10^{-3}$$

$$C = 0.005\ F \times 10^{-3}$$

$$= 5\ \mu F$$

Important Points for EDM

- Similar to ECM, EDM will require both tool and work material to be conducting in nature
- Tool wear exists
- It is used for producing blind cavities, narrow slots, m/cing nozzles in diesel engines.
- EDM process is also known as diesinking process or spark erosion process.
- Some copper is added in the graphite electrode used in EDM to increase the electrical conductivity.
- MRR is lower than ECM.
- MRR and tool wear depends upon process parameters like thermal conductivity and specific heat capacity.

Case-1 if tool has low thermal conductivity and w/p has high thermal conductivity then w/p will have a higher heat transfer rate and heat will not be accumulated at the maching zone and therefore it will be difficult for the tempr to rise upto fusion ~~state~~ hence MRR will decrease.

Case-2 If specific Heat capacity of w/p is high then more sensible heat energy will be required for melting. and therefore MRR will be low.

On the other hand if specific heat capacity of tool is low and if thermal conductivity of tool is also less then tool wear will be high.

Favarable conditions

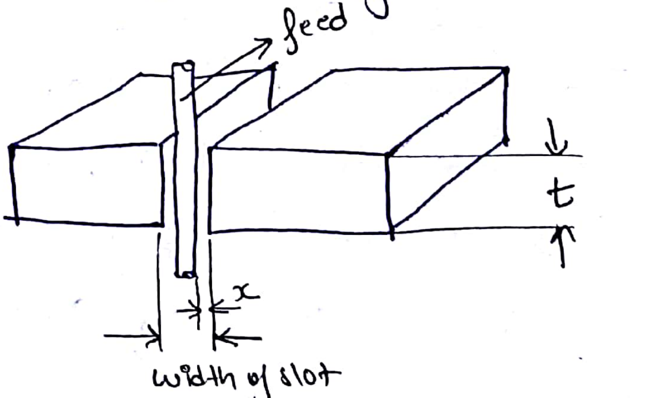
- MRR ↑
- Tool wear ↓
- Tool ⇒ K ↑ , C ↑
- w/p ⇒ K ↓ , C ↓

Wire EDM

- Deep cutting
- MRR = Area × Velocity

  = width of slot × feed rate of wire × thickness

width = D + 2x



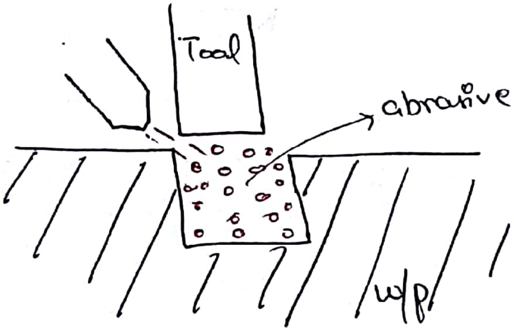
Ques GATE A titanium plate of 8 mm thickness is cut by wire cut EDM process using a wire of dia 1 mm with a uniform spark gap of 0.4 mm maintained on both sides of wire. If wire feed ~~rate~~ is 20 mm/min

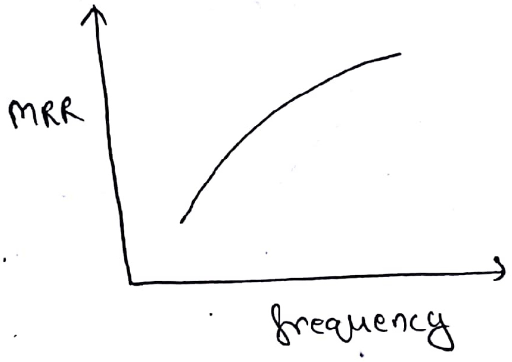
Solⁿ

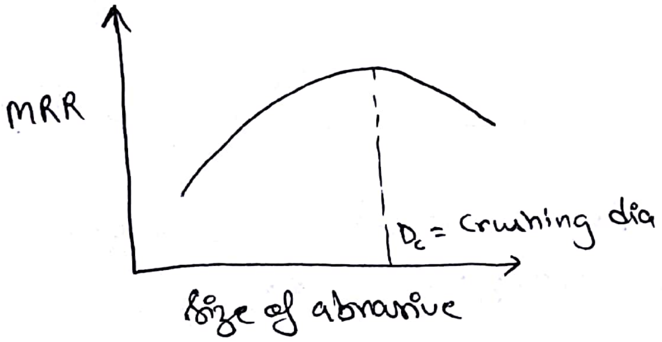
$$MRR = 8 \times (1 + 0.8) \times 20 = 288 \text{ mm}^3/\text{min}$$

Ultrasonic Machinig (USM)

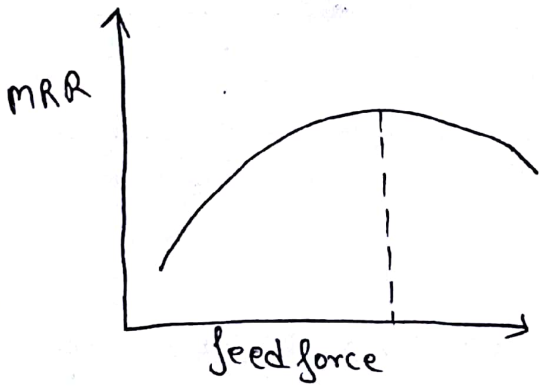
- In this process the tool vibrates at high frequency, an slurry of abrasives is placed b/w the tool and the work. The abrasives recieves the impact load from the tool and transfers it further on to the work piece. The work material being hard undergoes ~~a brittle~~ a brittle fracture. The material once removed will be erroded by the continous flow of slurry.
- USM doesnot require material to be conducting in nature
- USM can be used to m/c refractory materials. It can also be used to produce holes on hard & brittle material like glass
- USM will undergo high tool wear and MRR is generally low







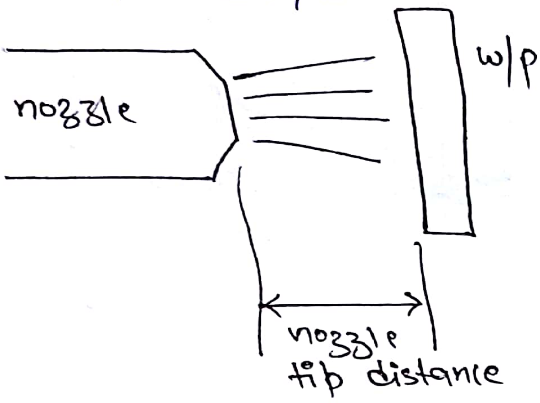
on increasing the size of abrasives MRR will start increasing due to more transfer of loads to the w/p. But after a limiting size the impact load received by the abrasiv mass will be used in crusing its own size & the left magnitude of load will be transfered ahead thereby decreases MRR.

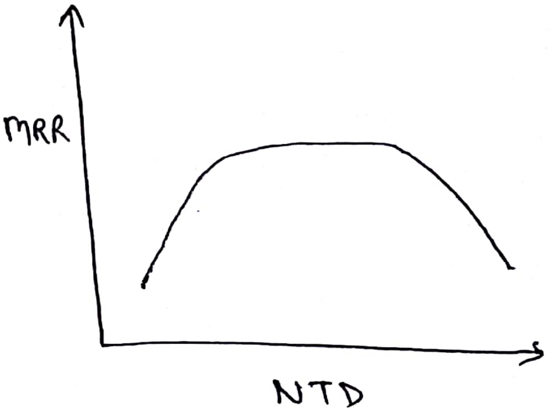


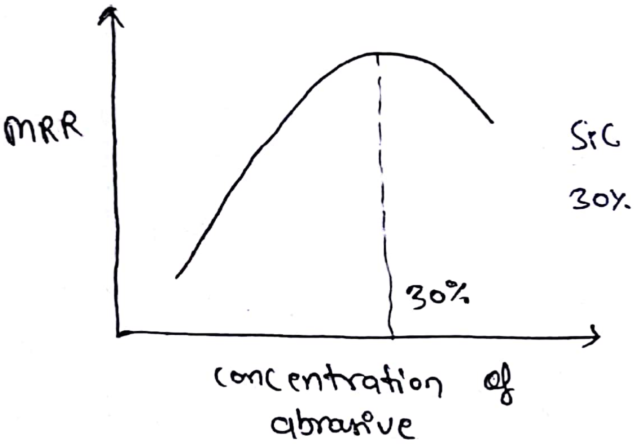
- USM can be used for producing holes in human teeth in dental operations.

Abrasive Jet machining (AJM)

- In this process a jet of abrasives will be released from a nozzle and will strike the work material such that the abrasives impinges on the work material to undergo a brittle fracture. This process is generally used for deburring the internal surfaces and to machine materials like Gallium, Germanium, Silicon, etc.







SiC : water
30%   70%

Ques: In AJM process if Q is the abrasive flow rate & d is mean dia of abrasives then MRR is Proportional to

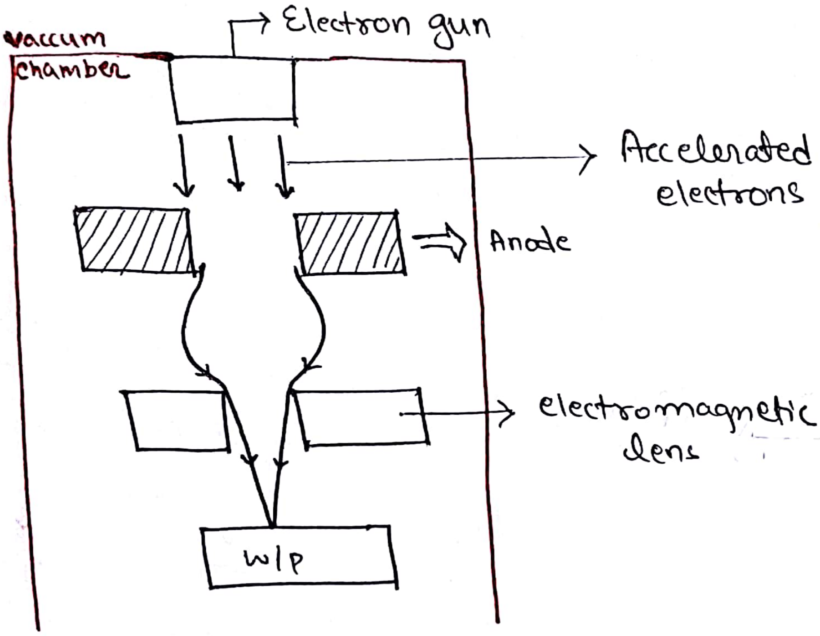
↳a) Qd^3
b) Qd^2
c) Qd
d) $\frac{Q}{d}$

Solu^n abrasive rate = $\frac{\text{no. of abrasive}}{\text{time unit}}$

Electronic Beam machining (EBM)

- In this process high speed electrons will strike the w/p thereby converting the kinetic energy into heat energy. The material then undergoes fusion and vapourisation.

- In this process a vaccum chamber is required such that electron beam will not be disturbed by the atmospheric gases and the accuracy will be high.
- Electrons will get released by an electron gun which will be accelerated by the attraction of anode. These accelerated electrons will be converged by an electromagnetic lense and therefore it will be focused onto very small area
- EBM can be used to machine complex contours as the beam can be maneuvered into complex positions



- Limitations
  1) It cannot m/c large w/p bcz of difficulty to maintain Vaccum.
  2) Both EBM and LBM must not be used for material which are highly reflective and which has high thermal conductivity.
- Both EBM & LBM can be used to produce fine holes on thin sheet

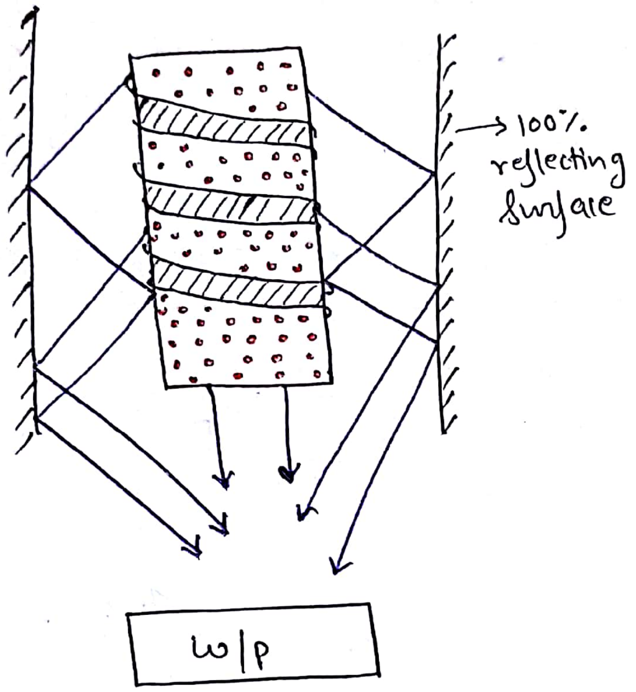
Laser Beam machining (LBM)

LASER ⇒ Light amplification by stimulated emission of radiation.

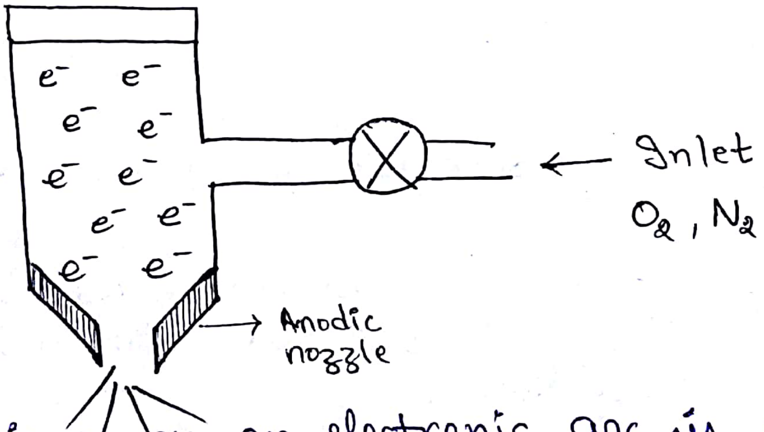
- In LBM ruby rod is used as a solid state laser source Xenon flash tube be coiled around the ruby rod to energise and exit the ~~state~~ after emitting light which falls on solid state laser source.

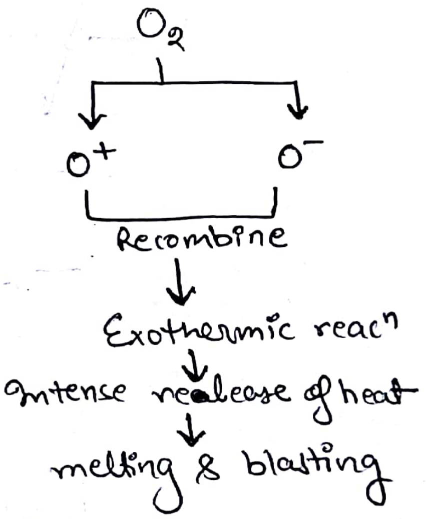
Thereby releasing powerful radiations which when interacts with the w/p, rises the tempr followed by melting and vapourisation this process of material removal is known as <u>abilation</u>

- LBM have least MRR



<u>Plasma Arc machining</u> (PAM)





- In this process an electronic arc is created b/w cathode and anodic nozzle within which diatomic molecules such as O_2, N_2, H_2 will be made to enter such that they collide with the electrons and gets ionised. Further on recombination they follow an exothermic process thereby releasing intense amount of energy due to which material undergoes melting and blasting.
- This process is used for profile cutting on stainless steel and other hard alloys. It has <u>highest MRR</u> but poor accuracy.

JIGS - FIXTURES

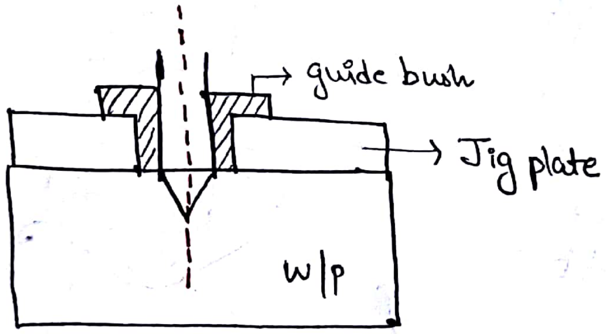
functions of jigs & fixtures

Chris Strikes Long Raining Sixes

- Chris → Clamping
- Strikes → Supporting
- Long → Locating
- Raining → Resistance to forces
- Sixes → Safety factors

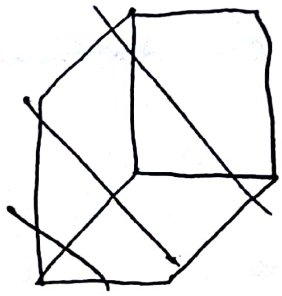
- **Jigs** is used to hold & support the w/p
- it is lighter in construction
- it guids the tool for machining
- it is not fixed with m/c tool system

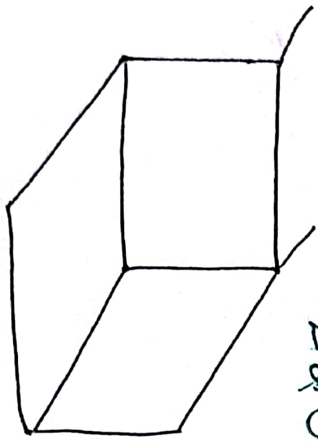
- **Fixture** is used to hold & support the w/p but it doesnot guide the tool for machining
- fixture will provide reference for the tool wrt. w/p.
- it is heavier in construction
- it is fixed with the machine tool

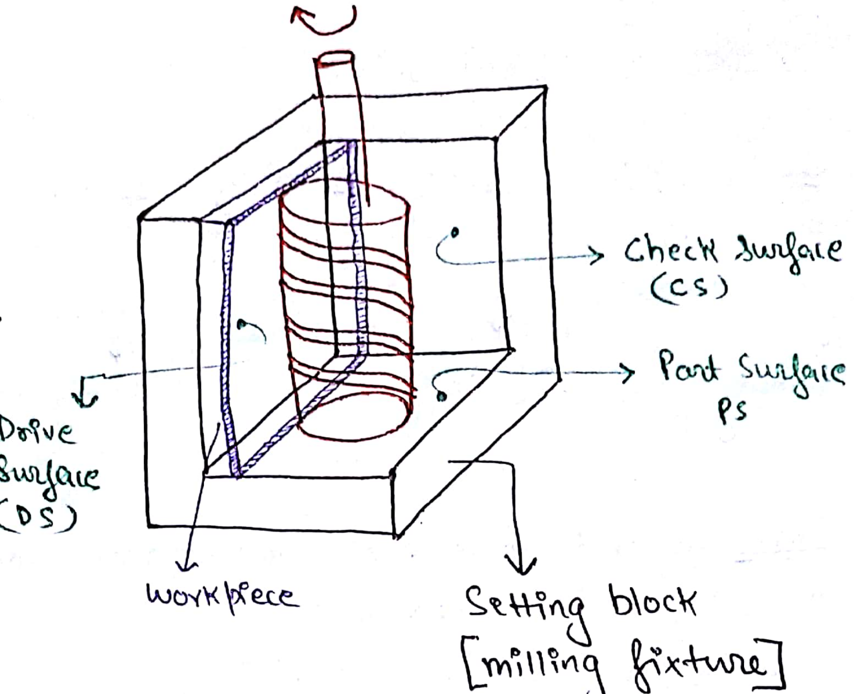


Drill Jig

- interence fit b/w guid bush & Jig plate
- Jig plate size will be corresponding to size of w/p



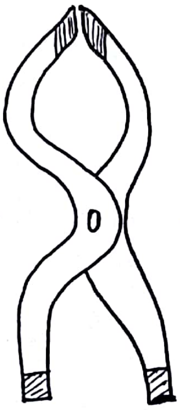




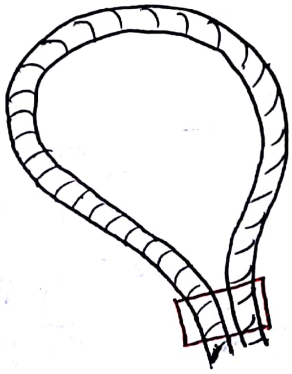
- 3-Jaw chuck ⇒ Turning fixture

Clamps

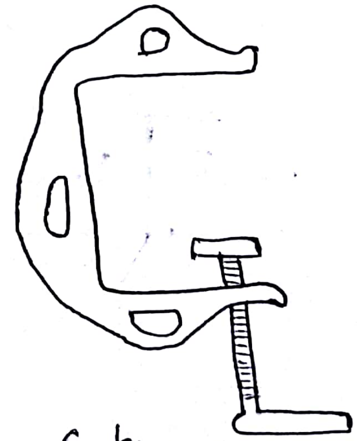
- it is also used to hold and support the workpiece when other elements are unable to perform the requisite



A-type clamp



Rope clamp



C-type clamp

~~Supporting pins~~ Locating pins

- These Pins are used to support the w/p which ~~doesnot~~ carry holes

1) round or circular pins

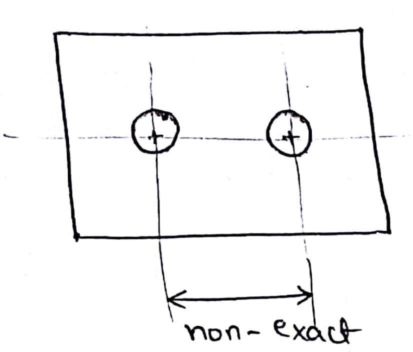
→ it is used to support heavy w/p
→ it makes surface content.

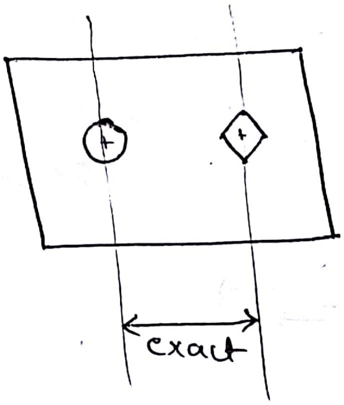
2) **Conical Pins**

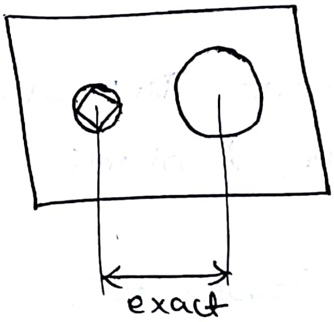
→ it is used to support lighter w/p.
→ it maks a line contact.

3) **Diamond Pin**

→ it is used to control any variations in center to center distance
→ it is used along with round pin.

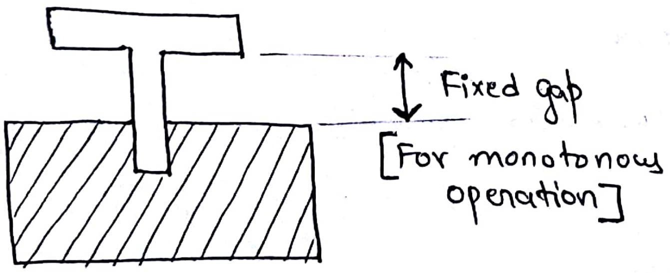


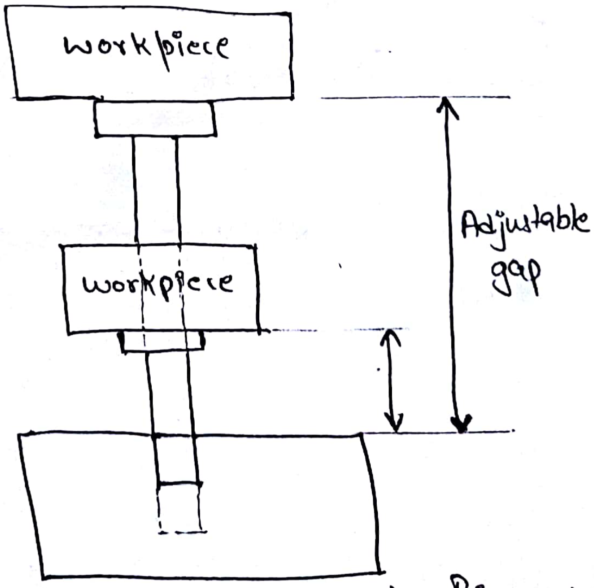




Supporting Pins

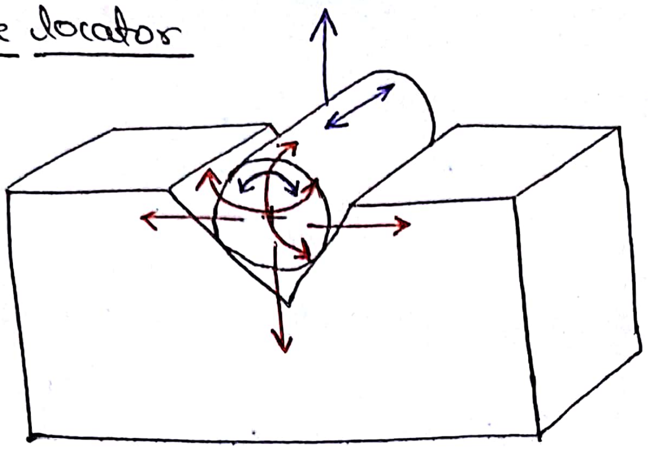
- These are used to support w/p which doesnot carry holes
- Supporting Pins → fixed Pins
  → Adjustable Pins





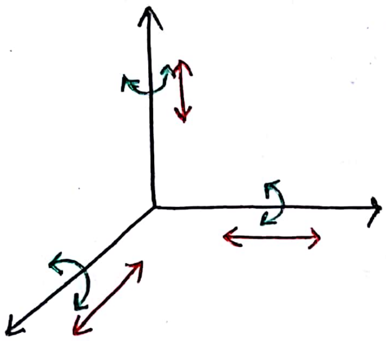
Adjustable Pin → jac Pin
variable dimention w/p ↵

V- type locator



D.O.F. = 5

DOF arrested = 7

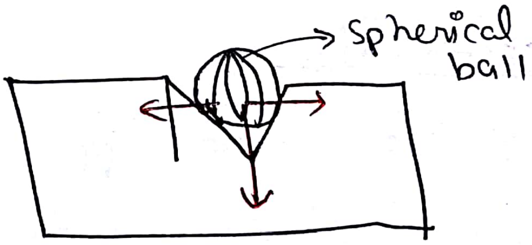


Total degree of freedom = 6T + 6R

= 12

Ques: Find ~~a~~ the DOF allowed when a spherical ball is placed on V block

Soln DOF allowed = 9



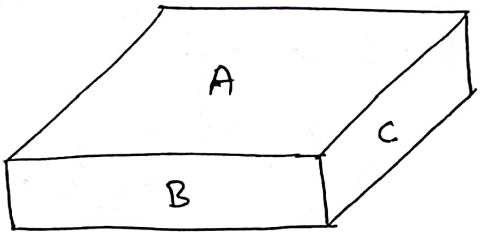
Ques ESE Statement -I : A cylindrical w/p can be located on V- locator

Statement - II : The cylinder placed on V- locator cannot have translatory motion along X- axes.

(c)

3-2-1 Principle

- The numerals 3, 2, 1 refers to the number locating positions. Let us consider a cuboidal w/p with primary datum, Secondary datum & tertiary datum.



A = Primary datum
B = Secondary datum
C = Tertiary datum

- Support A by 3 locating Pin
  - → Translation along -ve Z axis restricted
  - → Rotational along 'x' & 'y' axis restricted
  - → So 5 DOF arrested
- Support B by 2 locating Pin
  - → Translation along -ve Y axes restricted
  - → Rotational about z axis restricted
  - → So, 3 more DOF arrested
- Support C by 1 locating Pin
  - → Translation along x axis restricted
  - → So, 1 more DOF arrested

Note: By using 3-2-1 principle 9 DOF are arrested

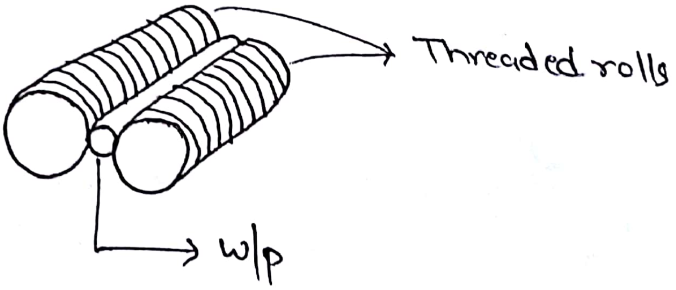
Ejector

- It is used for easy removal of w/p after machining
- It will improve safety parameters

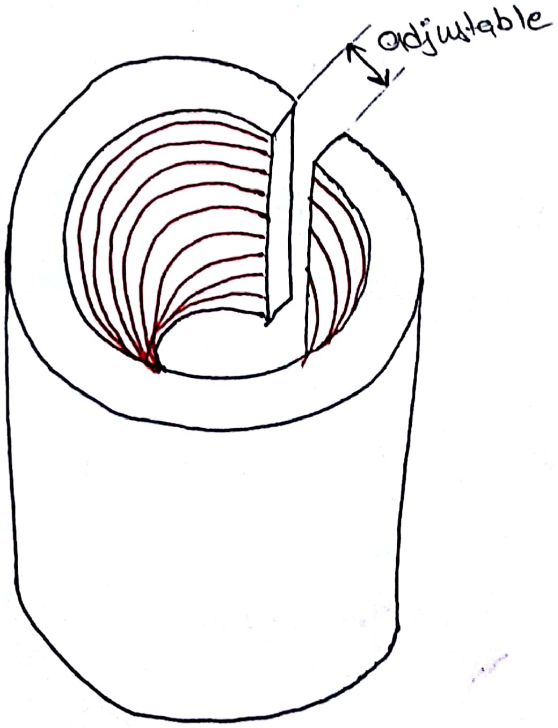
Screw thread & Gear Manufacturing

Screw thread

- Screw thread can be manufactured by
  1) Thread chasing → High Quality threads (only external threads)
  2) Thread rolling → Strong threads (no material removed)
  3) Thread grinding → only external threads
  4) Thread milling → Produces both internal & external threads Both
  5) Tapping → only internal threads
  6) Open die threading → external threads only [mechanism is same as tapping]
- Thread rolling will require threaded rolls.



- Open die threading



Tapping → die threading
Shapping → Planning
Honig → Lapping
Turning → Boring

Gearmanufacturing Process

1) Gear shaping → Both internal & external Gears

2) Gear Planning
3) Gear Hobbing
4) Gear milling
5) Gear Broaching

→ only external Gears

- Gear shaping [it uses both reciprocating & rotating cutters]
  - Rack type cutter ⇓ External gears
  - Pinion type cutter ⇓ Internal Gears

- Gear hobbing
  - it uses a rotating circular cutter known as HOB.
  - it can be used only for external gears
  - it is highly accurate due to continous indexing mechanism

Ques: Single start HOB used for cutting 60 teeth on a circular blank. Find the speed ratio of HOB to circular blank.

Solu^n 60 : 1

Note:
- for double stent HOB ratio will be 30 : 1 for cutting 60 teeths.
- for 3 stent HOB
  ratio ⇒ 20 : 1 for cutting 60 teeths

other manufacturing methods

1) Casting

a) Sand casting : large size gears can be produced.

Application :- Cement mixer.
- farm machinary
- Hoist gearbox
- lifts

b) Die casting : Small size gears can be produced

Application :- Lawn movers
- Cameras
- Toys

c) Injection moulding : light Gears can be produced

Application :- Speedometer
- washing m/c
- Xerox machine
- wind shield vipers

Note: Circular blanks for gear manufacturing can be produced by semi-centrifugal casting.

2) Forming

a) Roll forming : In this process circular blanks are mounted on a shaft and is pressed b/w hard rolled dies, both spur & helical gears can be produced

b) Extrusion : light gears can be produced through extruded rods.

Application - wall clock
- type ~~righter~~ writter

3) Sheet metal operations

Thin metallic gears can be produced by sheet metal operation.

Application :- wrist watches
- electric meters

METAL CUTTING

Book :- Manufacturing Engineering & technology
[Kalpakjian]

CHAPTER - 1

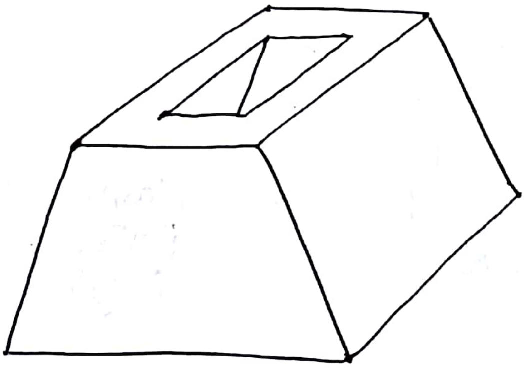
THEORY OF METAL CUTTING

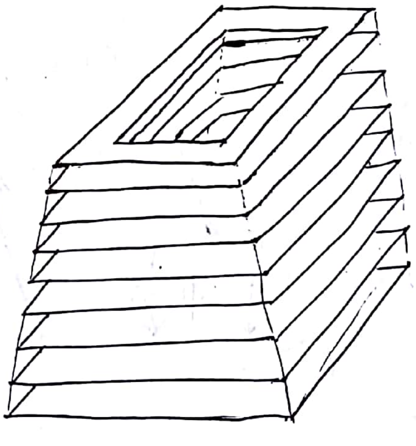
Classification of manufacturing Process

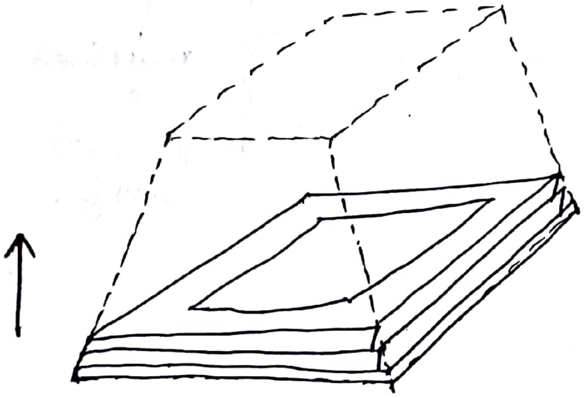
1) Shaping or forming (Shape) Zero process
2) Joining process +ve process
3) Removal Process -ve process
4) Regenerative manufacturing

Ques: what is regenerative manufacturing or rapid Prototyping?

Ans: Production of solid Products in layer by layer from raw materials in different forms.







Machining

It is essential Process of finishing by which jobs are produced to the desired dimensions by gradually removing the excess material from the preformed blank in the form of chips with the help of cutting tools moved past the work Surface

- machining is a removal process.

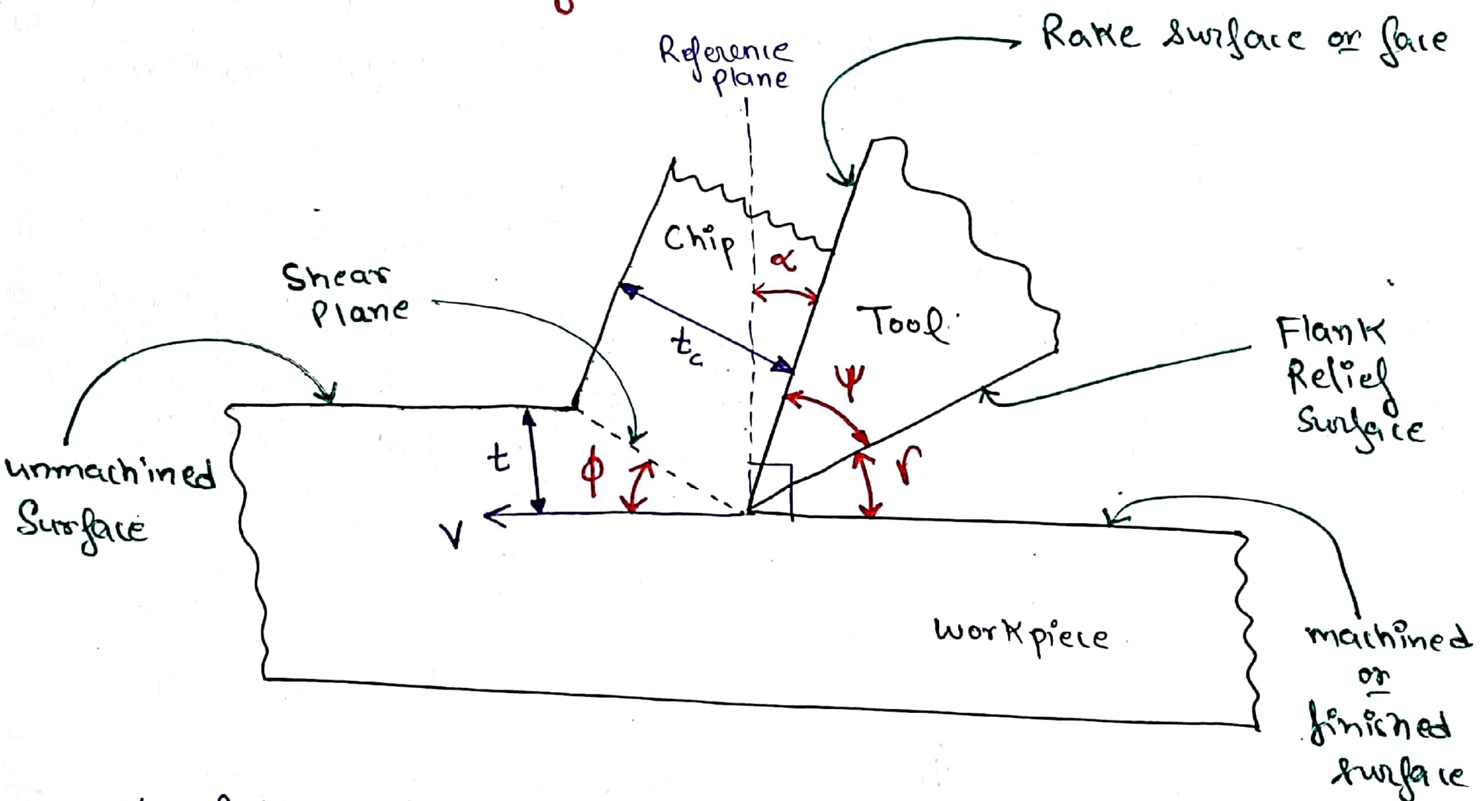
machining aim to

- fulfill its functional requirements
- improve its performance
- Prolong its service

Draw back of machining

- loss of material in the form of chips.
- slow Process [slow Productivity]

Orthogonal Machining



α = Rake angle

γ = Clearance angle

V = Cutting velocity

ϕ = Shear angle

ψ = lip angle or wedge angle or cutting angle or Knife angle

t = uncut chip thickness

t_c = chip thickness $t_c > t$ [always]

- Due to plastic deformation of the material thickness will increase [shear failure]. Practically "t_c" will be 2 to 3 times of "t". Due to temp^r increase of the chip thickness will increase in some microns

important Point

$t = d$ (depth of cut) → for orthogonal cutting

$t = f \sin \lambda$ → for turning

↓ feed

→ Principle cutting edge angle

⇒ b = width of cut → orthogonal cutting

Rake surface or face

The surface along which the chip moves upwards is called rake surface of tool.

Flank or relief surface

The other surface which is relieved to avoid rubbing with the machined surface is called flank or flank surface

Rake angle (α)

- Angle of inclination of rake surface from reference plane i.e. normal to horizontal machined surface.
- it allows chip flow direction.
- it reduces the cutting force required to shear the metal and reduce the power consumption.

$\alpha \uparrow \Rightarrow$ cutting force $\downarrow$

- It provides keenness (sharpness) to cutting edge.
- $\alpha \uparrow \Rightarrow$ surface finish $\uparrow$; $\alpha \uparrow \Rightarrow$ sharpness $\uparrow$

Clearance angle or relief angle (γ)

- angle of inclination of clearance or flank surface from the finished surface.
- it reduces friction and tool wear.
- it improves tool life.
- Excessive clearance angle weakens the tool.
- It must be +ve [3° to 15°]

Turning [oblique cutting]

Speed - feed - depth of cut

⇒ tangential velocity or cutting velocity or cutting speed

$V = r.\omega$

$V = \frac{d}{2} \times \frac{2\pi N}{60} = \frac{\pi D N}{60}$ m/s [when D in m]

$V = \pi D N$ m/min (when D in m)

$V = \frac{\pi D N}{1000}$ m/min (when D in mm)

S = SI units ex :- m/s

Sec = CGS units ex :- cm/sec

⇒ feed

for proper positioning of the tool

$f =$ mm/rev

feed in a minute $= fN$ mm/min

- feed or feed velocity or axial speed $= V_f = fN$ mm/min ex:- Axial speed = 0.4 m/min

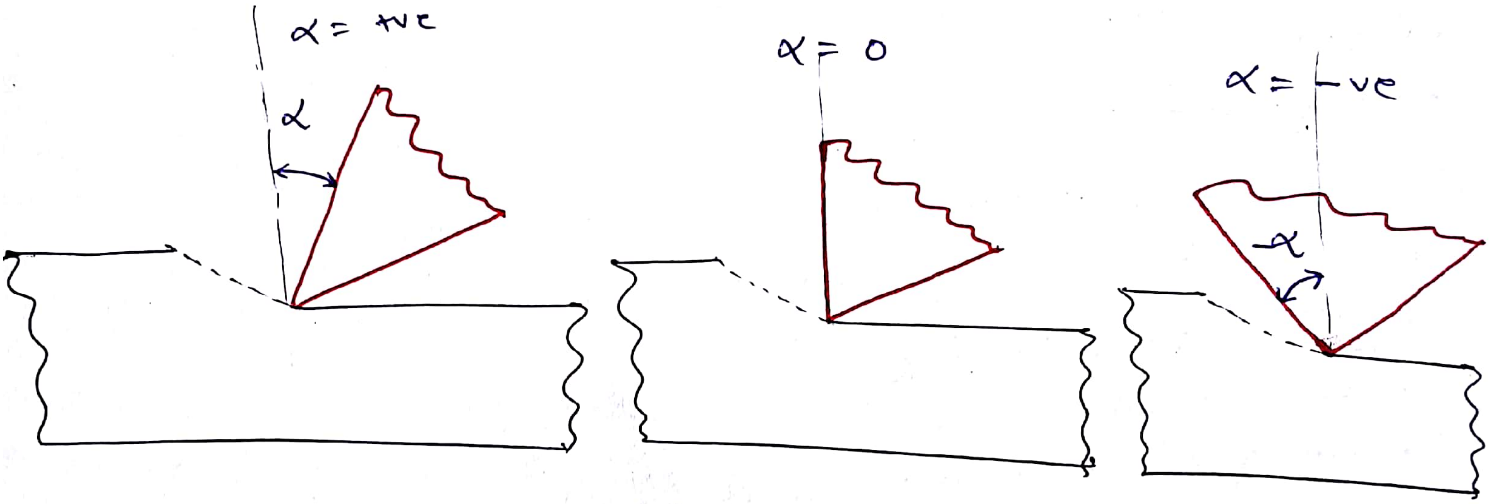
i.e. $fN = 0.4 \times 1000$ mm/min

depth of cut

$$d = \frac{D_1 - D_2}{2}$$

Rake Angle

- rake angle can be +ve, -ve, 0



Positive rake (5° - 30°)

- Reduce cutting force
- Reduce cutting power

⇒ Positive rake angles are reccomended

- m/cing low strength material
- low power machine
- long shaft of small diameter [Due to low stiffness]
- m/c set-up lacks strength and rigidity.
- Low cutting speed
- Cutting tool material → (HSS)

HSS ⇒ 18 - 4 - 1 ⇒ 30 m/min
W Cr V

- High carbon Steel → 7.5 m/min
High speed steel → 30 m/min [Ductile tool]
Carbides → 150 m/min
Ceramics → 600 m/min

Negative Rake

- Increases edge strength (mechanically & thermally)
- it will increase tool life.
- Increases cutting force
- Requires high cutting speed
- Requires very high power
- Heavy impact load.

⇒ negative rake angles are reccomended when
- m/cing high strength alloy
- High cutting speeds
- with rigid set-up
- Cutting tool material : Ceramic , carbide

Zero rake

- To simplify design and manufacturing of the form tool.
- increases tool strength
- Avoids digging of tool into the workpiece
- Brass & C.I. are machined by zero rake.
[work piece]

Brass ⇒ due to long continous chip formed during +ve rake
CI ⇒ poor surface finish during -ve rake
]⇒ So zero rake are given

example of form tools
1) Gear cutting in milling m/c.
2) thread cutting in lathe m/c.

Types of machining

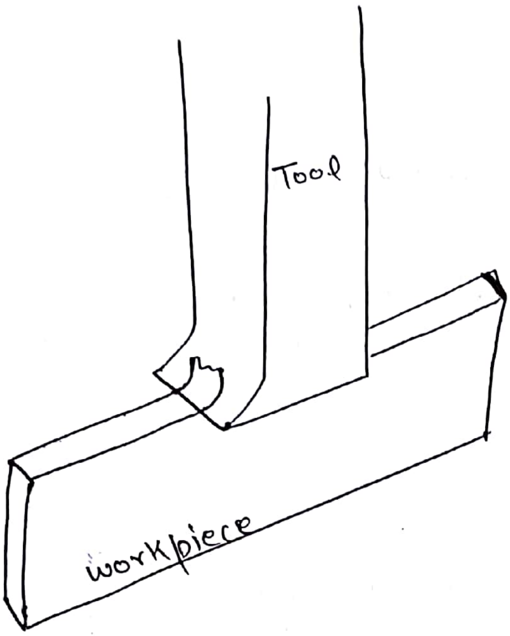


Fig:- orthogonal Cutting

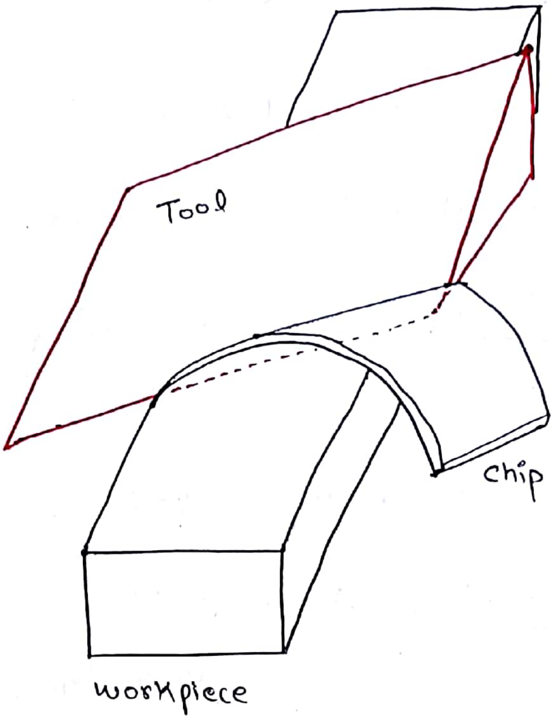


Fig: oblique cutting

Orthogonal Cutting

1. Cutting edge of the tool is ⊥ar to the dir^n of cutting velocit
2. Cutting edge is wider then the w/p width and extends beyond the w/p on either side. Also the width of w/p is much greate than depth of cut.
3) The chip generated flows on the rake face of the tool with chip velocity perpendicular to the cutting edge.
4) The cutting forces act along two direction only.

Note: During metal cutting (Any), an increase in cutting speed causes cutting forces to remain uneffected or slightly reduced. But Power, Heat, temp^r, will increase therefore material strength will decrease, cutting force will slightly reduce.

Geometry of Single Point turning tool

Classification of tool

According to the number of major cutting edges (points) involved

- **Single Point** : turning, shaping, planning, slotting tools, parting tools
- **Double Point** : Drilling tool
- **Multi Point** : milling, broaching, hobbing tools, saw, grinding wheel

System of Description of tool Geometry

1) machine reference system : ASA or ANSI
2) Tool reference system : ORS (ISO old) and NRS (ISO ~~old~~ new)
3) work reference system : WRS

ORS ⇒ orthogonal rake system

(A)

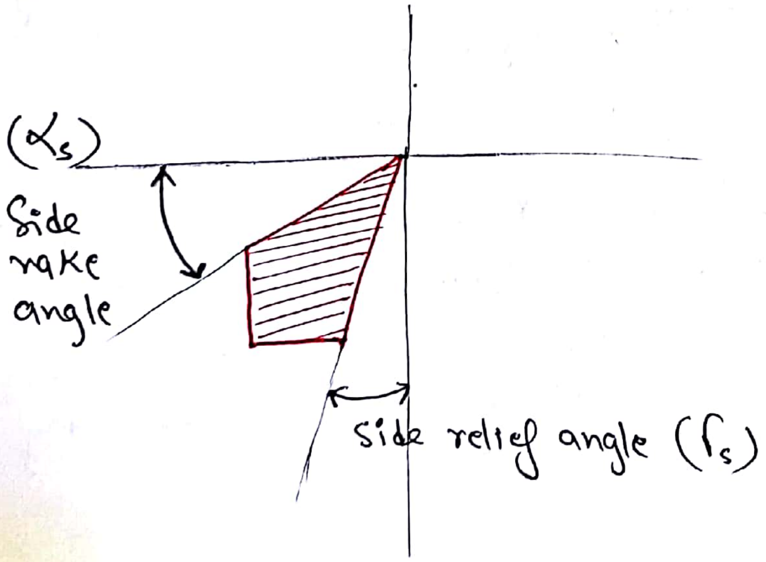


Fig:- X-S/C ⊥ar to base & || to width

(B)

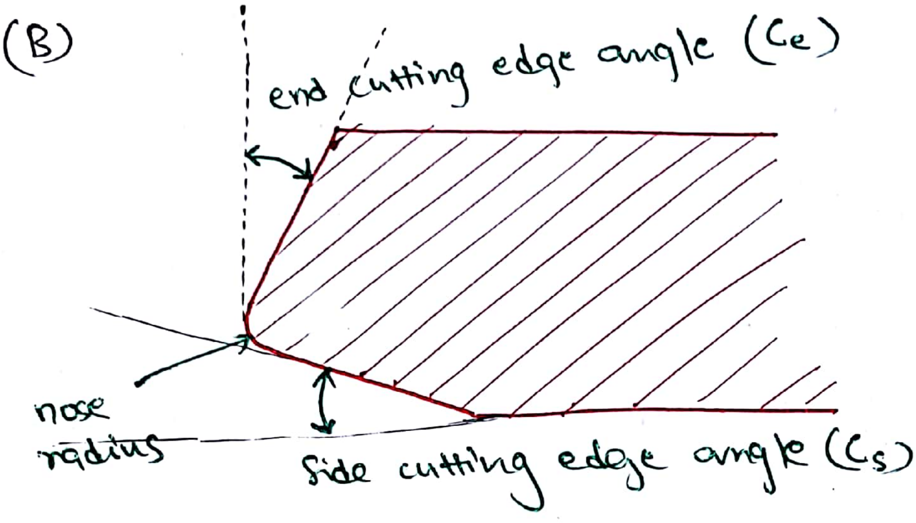


Fig:- X-S/c parallel to base

(C)

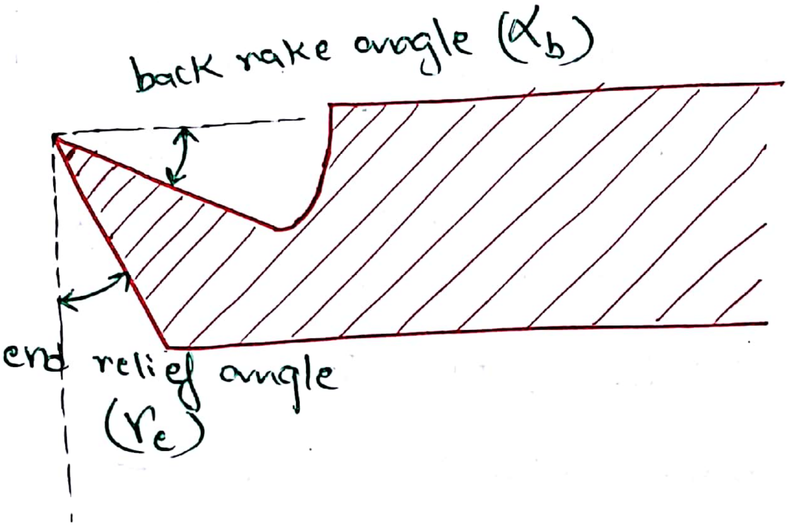


Fig:- X-S/c ⊥ar to base and parallel to length

Back rake angle (α_b)

- it is the angle b/w the face of the tool and the base of the shank or holder, and is usually measured in a plane ⊥ar to base and Parallel to the length of tool.
- it effects the ability of tool to shear the work material and form the chip.
- in turning +ve α_b takes the chips away from the machined surface whereas -ve α_b takes the chips on to the machined surface.

Side rake angle (α_s)

- it is the angle b/w the face of the tool and the base of shank or holder and is usually measured in a plane ⊥ar to base and parallel to width.
- increase in the side rake angle reduces the chip thickness in turning

End relief angle (γ_e)

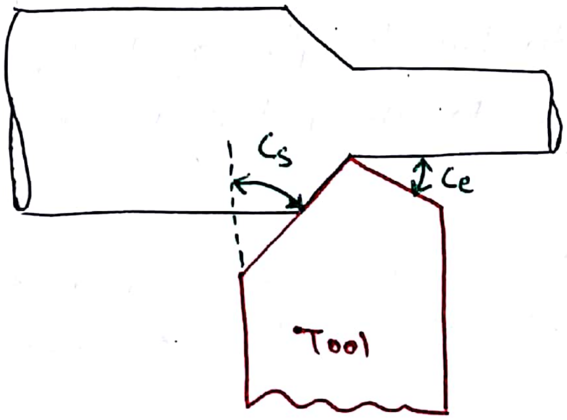
- It is the angle b/w the portion of end flank immediately below the end cutting edge and a line drawn through this cutting edge ⊥ar to the base. It is usually meared in a plane ⊥ar to the end flank
- The end relief angle prevents friction on the flank of the tool.

Side relief angle (γ_s)

- it is the angle b/w the portion of the side flank immediately below the side cutting edge and line drawn through this cutting edge ⊥ar to the base. It is measured in a plane ⊥ar to side flank.

End cutting edge angle, ECEA (C_e)

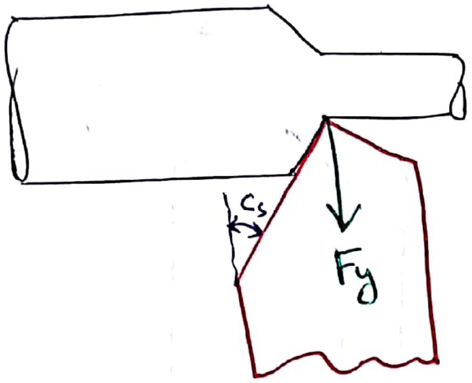
- The end cutting edge angle is the amount that the end cutting edge slopes away from the nose of the tool, so that it will clear the finished surface on the workpiece, when cutting with side-cutting edge.

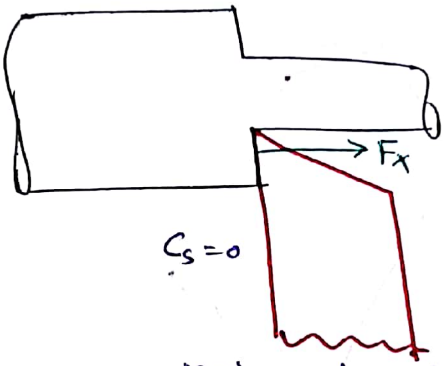


- it prevents the trailing end of the cutting edge of tool from rubbing against the workpiece.
- A larger end cutting edge angle weakens the tool.
- it is usually kept b/w 8° to 15°

**** Side cutting edge angle, SCEA (C_s)

- it is the angle which prevents interference as the tool enters the work materials (normally 15-30°)





not prefered

- larger this angle, the greater the component of force tending to seperate the work & tool. (may induce chatter)
- At its increased value it will have more of its length in action, for a given depth of cut.
- At its increased value it produce thinner & wider chip that will distribute the cutting heat (inc. tool life)
- $C_s = 0$ is desirable when micing Casting and forging with hard and scaly skins, because of the least amount of tool edge should be exposed to the destructive action of the skin.

Note: 1. C_s has no influence on cutting force (F_z) or cutting power consumption.

2. F_y = thrust force or radial force will increase

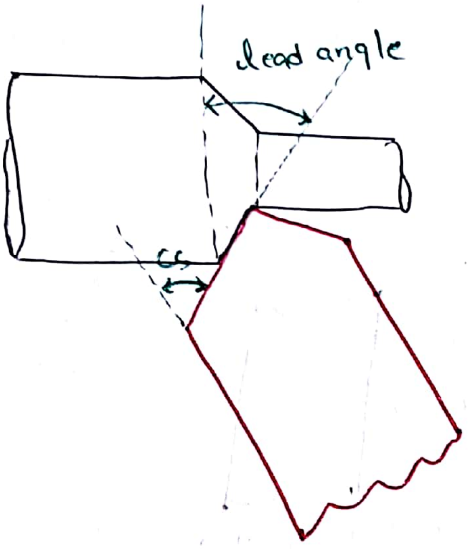
$F_y\uparrow = F_t \sin(C_s)\uparrow$

3. F_x = axial or feed force will decrease

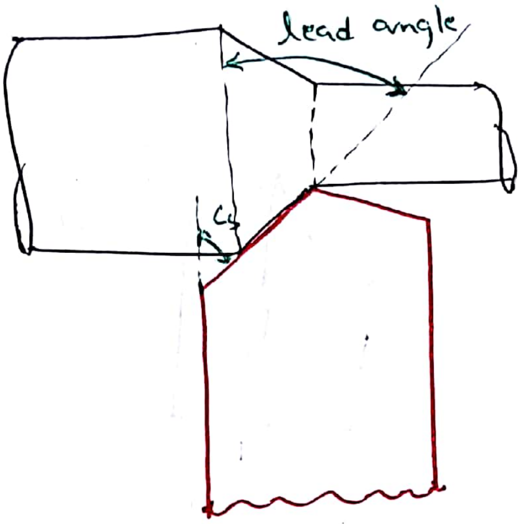
$F_x\downarrow = F_t \cos(C_s)\uparrow$

Lead Angle

$C_s \neq$ lead angle



$C_s =$ lead angle



Lip angle

- Lip angle / wedge angle / Knife angle / cutting angle depends on the rake and clearance angle provided on the tool and determine the strength of the cutting edge.
- A larger lip angle permits machining of harder metals, allow heavier depth of cut, better heat dissipation, increase tool life.

Nose Radius

- it is curvature of the tool tip.
- it strengthen the tool nose by reducing stress concentration
- it provide better surface finish

$$\downarrow h = \frac{f^2}{8R\uparrow}$$

- But too large nose radius will induce chatter
- if nose radius increases, cutting forces & Power increases.
- it increase tool life.

Tool designation or Tool signature (ASA or ANSI)

$$\alpha_b - \alpha_s - \gamma_e - \gamma_s - C_e - C_s - R$$

To remember easily follow the rule

- rake, relief, cutting edge
- Side will come last
- finish with nose radius

Orthogonal rake system (ORS)

$$i - \alpha - \gamma - \gamma_1 - C_e - \lambda - R$$

- Inclination angle (i)
- orthogonal rake angle (α)
- Side relief angle (γ)
- end relief angle (γ_1)
- end cutting edge (C_e)
- Principal cutting edge angle or Approach angle (λ) $= 90 - C_s$
- nose radius (R)
- $i = 0$ for orthogonal cutting
  $i \neq 0$ for oblique cutting

Note:- $i=0$ for turning operation bcz plane is cut at $\perp$ar to Principal cutting edge

$\Rightarrow \lambda = 90^\circ$ for orthogonal turning

Interconversion b/w ASA & ORS

$$\tan i = \sin(\lambda)\tan\alpha_b \mp \cos(\lambda)\tan\alpha_s$$

$$\tan\alpha = \sin(\lambda)\tan\alpha_s + \cos(\lambda)\tan\alpha_b \Longrightarrow \text{GATE}$$

$$\tan\alpha_b = \sin(\lambda)\tan i + \cos(\lambda)\tan\alpha$$

$$\tan\alpha_s = \sin(\lambda)\tan\alpha \mp \cos(\lambda)\tan i$$

*** ** Critical correlation

when $\lambda = 90^\circ \Rightarrow \alpha_s = \alpha$

$i = 0^\circ \Rightarrow \alpha_n = \alpha$

$i = 0$ & $\lambda = 90^\circ \Rightarrow \alpha_s = \alpha_n = \alpha$

λ = Principal cutting edge angle

i = inclination angle

α_n = normal rake angle (NRS)

Shear Angle (ϕ)

$$\boxed{r = \frac{t}{t_c} = \frac{l_c}{l} = \frac{V_c}{V} = \frac{\sin\phi}{\cos(\phi-\alpha)} = \frac{1}{h}}$$

$$\boxed{\tan\phi = \frac{r\cos\alpha}{1 - r\sin\alpha}}$$

r = chip thickness ratio ($r < 1$ always) or cutting ratio

$h = \frac{1}{r}$ = chip reduction factor or chip compression ratio.

~~3178~~

Note: change in velocity does not change shear angle hence no changes in force.

- if $\alpha = 0$

$$\tan\phi = \frac{r\cos\alpha}{1 - r\sin\alpha} = r$$

Cutting shear strain (γ)

**
*

$$\boxed{\gamma = \cot\phi + \tan(\phi - \alpha)} = \frac{\cos\alpha}{\sin\phi\cos(\phi-\alpha)}$$

if $\alpha = 0$ $\left[\text{when } \phi = 45^\circ,\ \underline{\underline{r = 1}}\right] \rightarrow$ condition for minimum

$\gamma = \cot\phi + \tan\phi \geq 2$ $\left[\because x + \frac{1}{x} \geq 2\right]$

γ_{min} will be at $\phi = 45^\circ \Rightarrow \gamma_{min}(\alpha = 0) = 2$

P-7
Q7

$$\gamma = \cot\phi + \tan(\phi - 12)$$

$$\frac{d\gamma}{d\phi} = -\operatorname{cosec}^2\phi + \sec^2(\phi - 12) = 0$$

$$\operatorname{cosec}^2\phi = \sec^2(\phi - 12)$$
$$\sin^2\phi = \cos^2(\phi - 12)$$
$$\cos^2(90 - \phi) = \cos^2(\phi - 12)$$

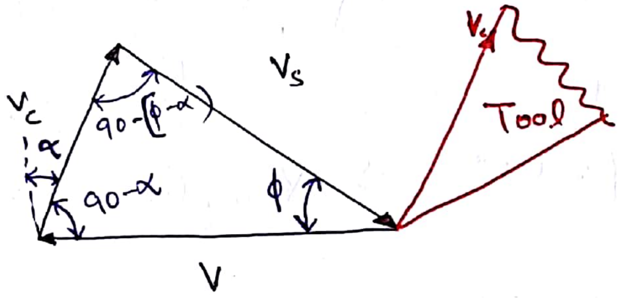
$$\Rightarrow 90 - \phi = \phi - 12$$
$$\Rightarrow 2\phi = 102$$
$$\phi = 51^\circ$$

Note: wheather $\alpha = 0$ or $\alpha \neq 0$, minimum shear strain will occur only and only if $\boxed{r = 1}$

Velocities in metal cutting [orthogonal]

- Velocity of the tool relative to the work piece (V) is called the cutting speed.
- Velocity of the chip relative to the w/p, (V_s) is called the shear velocity.
- Velocity of the chip relative to the tool (V_c) is called chip velocity.

Derive the expression for velocities in metal cutting

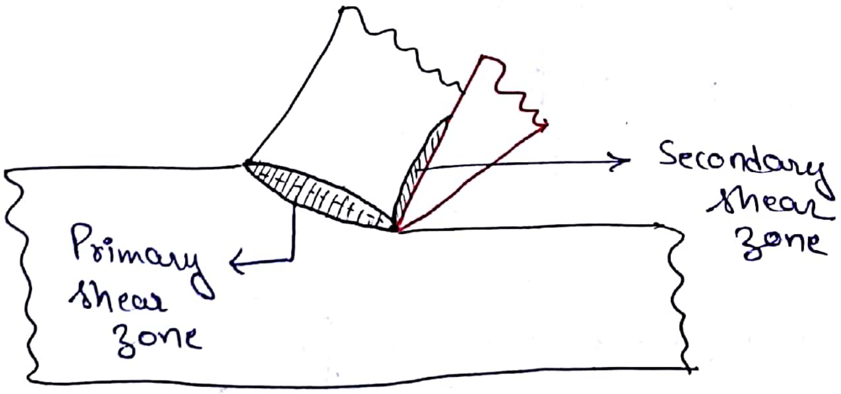


$$\boxed{\frac{V}{\cos(\phi-\alpha)} = \frac{V_c}{\sin\phi} = \frac{V_s}{\cos\alpha}}$$

★ ★ ★
★ ★

$$r = \boxed{\frac{V_c}{V} = \frac{\sin\phi}{\cos(\phi-\alpha)}} \qquad \boxed{\frac{V_s}{V} = \frac{\cos\alpha}{\cos(\phi-\alpha)}}$$

Shear Zone



Shear strain rate ($\dot{\gamma}$)

- it is not shear strain, it is rate of shear strain i.e. flow

$$\dot{\gamma} = \frac{d\gamma}{dt} = \frac{V_s}{\text{thickness of shear zone}} = \frac{V_s}{t_s}$$

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$$r = .75 = \frac{2.4}{t_c} \Rightarrow t_c = \underline{3.2}$$

$V = 60$ m/min

$$\tan\phi = \frac{r\cos\alpha}{1 - r\sin\alpha}$$

$$V_c = V \times \frac{\sin\phi}{\cos(\phi-\alpha)}$$

$$r = \frac{V_c}{V} \Rightarrow V_c = rV = .75 \times 60$$

$$= 45 \text{ m/min}$$

Cause of chip formation

Shear yielding → in ductile material

Brittle fracture → in Brittle material

Types of chip

1) Continous chip
2) Discontinous chip
3) Continous chip with BUE
4) Serrated chip

Conditions for forming Discontinous chip.

1) of irregular shape and size

work material → brittle [Such as grey cast iron]

2) of regular shape and size

work material → ductile but hard & work hardenable

feed → large

Depth of cut → large

tool rake → negative

cutting fluid → absent or inadequate

with multi point cutter like milling, Broaching.

Condition for forming continous chip without BUE

work material → Ductile

Cutting velocity → high

feed → low

rake angle → positive and high

Cutting fluid → both cooling & lubricating

Condition for continous chip with BUE

work material → ductile

cutting velocity → medium

feed → medium

Cutting fluid → absent or inadequate.

Built-up-edge (BUE) formation

- In machining ductile material with long chip tool contact length lot of stress and tempr develops in the 2ndary deformation zone at the chip-tool interface

- Under such high stress and tempr in b/w two clean surfaces of metals, strong bonding may locally take place due to adhesion similar to welding.
- Such bonding will be encouraged and accelerated if the chip tool materials have mutual affinity or solubility.
- The weld material starts forming as an embryo at the most favourable location and thus gradually grows.
- with the growth of BUE, the force also gradually increased due to wedging action of the tool tip along with the BUE formed on it.
- whenever the force exceeds the bonding force of the BUE, the BUE is Broken or Sheared off and taken away by the ~~fat~~ flowing chip. Then agains starts forming and grow.
- Low cutting speed also contributes to forming of BUE. ex:- milling, Broaching.

Effects of Built-up-edge formation

⇒ Harmful effect

- Poor surface finish [fragments of BUE]
- it unfavorably changes the rake angle at the tool tip causing increase of cutting force i.e. power consumption
- Induce vibration.

⇒ Good effect

- BUE protects the cutting edge of the tool i.e. increases tool life.

Reduction or elemination of BUE

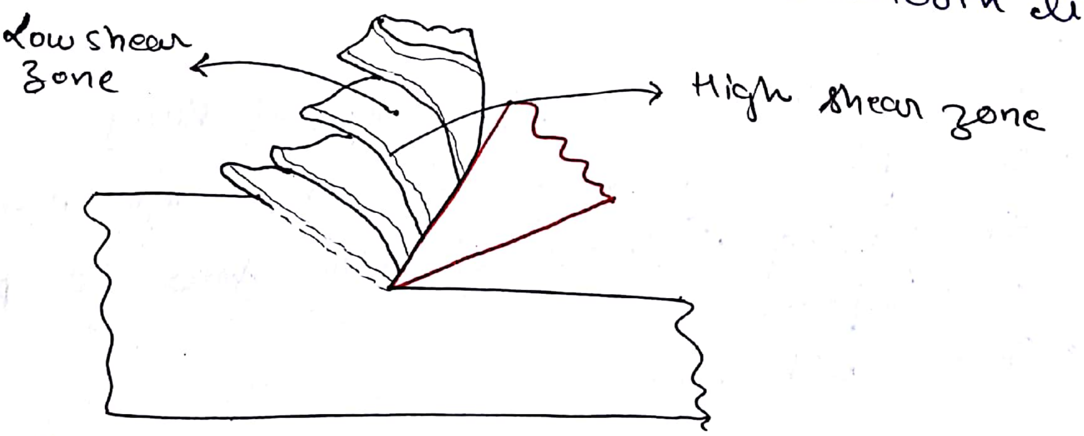
increase → cutting speed ↑
Rake angle ↑ $\Rightarrow F_c \downarrow \Rightarrow P \downarrow \Rightarrow$ heat ↓ ⇒ temp ↓

Decrease → feed ↓
depth of cut ↓

Use → cutting fluid
change cutting tool material (as $\underbrace{\text{cermets}}_{\text{ceramic tool in metal matrix}}$)

Serrated chips

- It is also called segmented or non-homogenous chips are semi-continous chips with zones of low & high shear strain
- metals with low thermal conductivity and strength that decreases sharply with tempr, such as titanium exhibit this behaviour, the chips have sawtooth like appearance

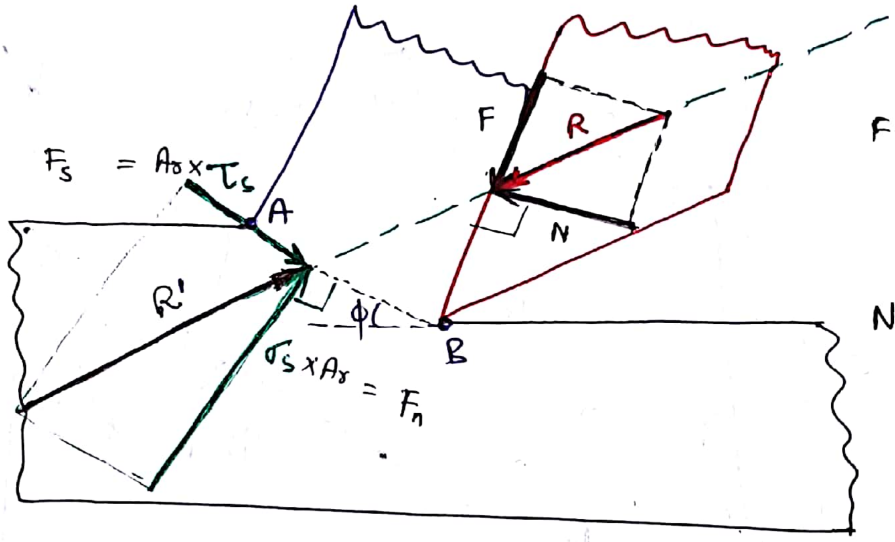


⇒ When is forced chip breaker neccessary and why?
When chips continously form and come out very hot, sharp & high speed
under condition :→ soft ductile work material
→ flat rake surface with positive or near zero rake
for: → safety & convenience of operator
→ easy collection and disposal of chips

CHAPTER-2

ANALYSIS OF METAL CUTTING

⇒ orthogonal cutting



F = friction force
or
shear force on rake surface

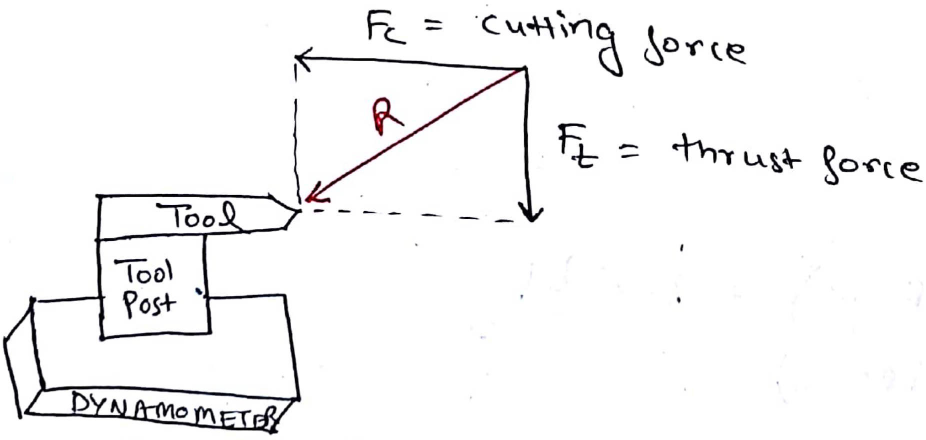
N = normal force

$$\frac{t}{AB} = \sin\phi \Rightarrow AB = \frac{t}{\sin\phi}$$

$$\text{Area of shear plane} = b \times (AB) = \frac{bt}{\sin\phi}$$

$$\boxed{F_s = \tau_s \times \frac{bt}{\sin\phi}}$$

$$F_n = \text{normal force on shear plane} = \boxed{\sigma_s \times \frac{bt}{\sin\phi} = F_n}$$



Merchant force circle Diagram (MCD)

As the chip is moving with constant velocity "V_c", net resultant force on the chip must be zero therefore R & R' must be equal and opposite.

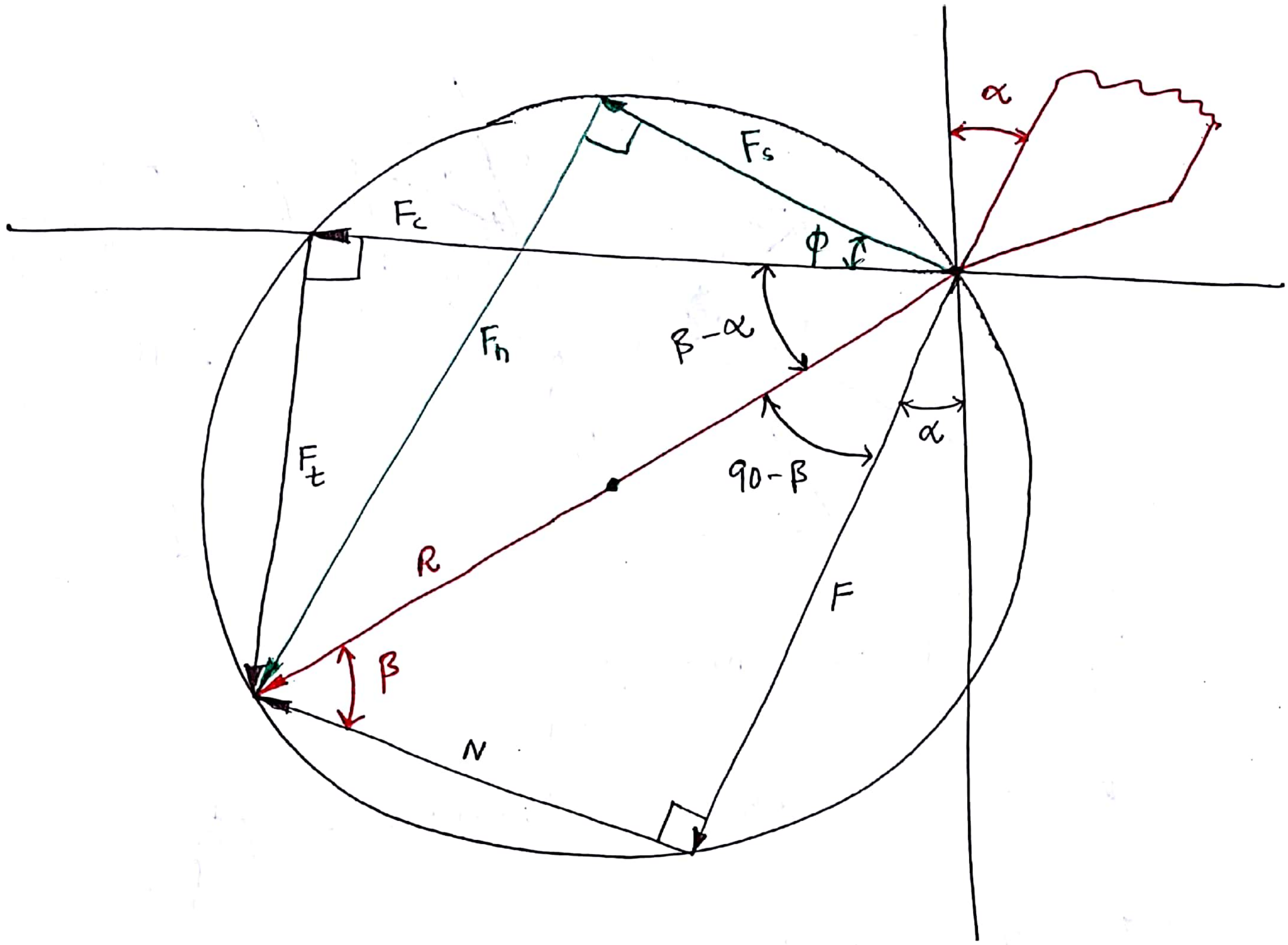


Fig:- Schematic Diagram of MCD

$$\tan\beta = \frac{F}{N} = \mu \Rightarrow \boxed{\beta = \tan^{-1}(\mu)} = \text{friction angle}$$

$F = R\sin\beta$

$N = R\cos\beta$

$F_c = R\cos(\beta-\alpha)$

$F_t = R\sin(\beta-\alpha)$

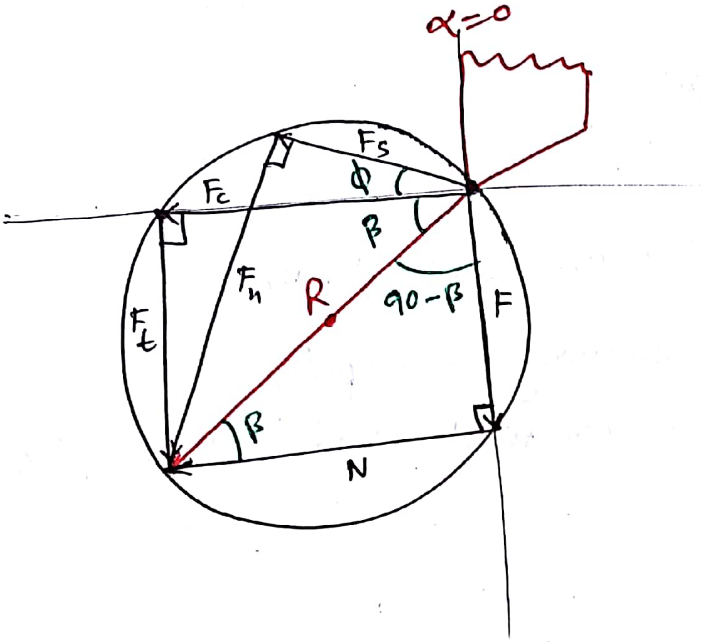
$F_s = R\cos(\phi+\beta-\alpha) = \tau_s \times \frac{bt}{\sin\phi}$

$F_n = R\sin(\phi+\beta-\alpha)$

- if R has to be find out, out of these 6 forces atleast one should be given directly or indirectly.

~~[illegible] Slide 79~~

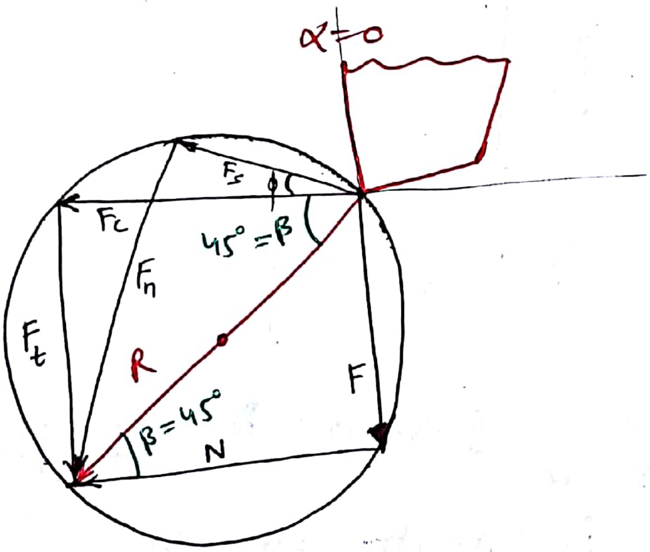
Special case-1 $[\alpha = 0]$



- F, N, F_c, F_t will form a rectangle
  $\Rightarrow F = F_t$
  $N = F_c$

*** F ⊥ar F_c or F ⊥ar V mean $\alpha = 0$

Special case 2 $[\alpha = 0, \mu = 1]$



- $F = N = F_c = F_t$ will form a square

- F ⊥ar F_c or F ⊥ar V means $\alpha = 0$

Slide 80

$F = 402.5 N$

F ⊥ar V $\alpha = 0$

$\mu = 1 \Rightarrow F = N = 402.5 N$

$r = \frac{.2}{.4} = .5$

$v = 2 m/s$

$180.003°$

$F_s = R \cos(\phi + \beta)$

$R = \sqrt{2} \times 402.5 N$

$\tan\phi = r \Rightarrow \phi = 26.565°$

Limitations of use of MCD

1. MCD is valid only for orthogonal cutting.
2. By the ratio $\frac{F}{N}$, the MCD gives apparent (not actual) co-efficient of friction

Merchant theory or Analysis

Asumptions

- work material behaves like an ideal plastic
- theory involves minimum energy principal.
- τ_s & β are assumed to be constant and independent of ϕ

$$\frac{d\tau_s}{d\phi} = 0$$

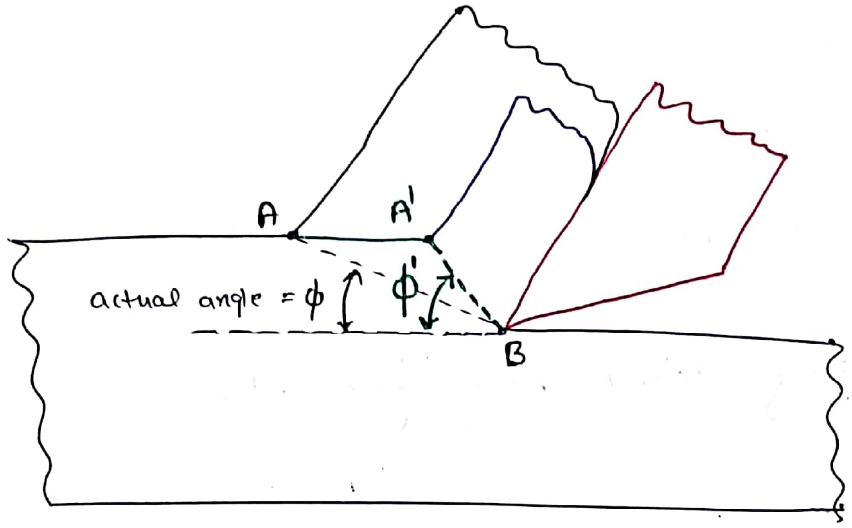
- it is based on single shear plane theory

$$\boxed{\phi = \frac{\pi}{4} + \frac{\alpha}{2} - \frac{\beta}{2}}$$

- for calculation $\boxed{\phi = 45^\circ + \frac{\alpha}{2} - \frac{\beta}{2}}$

- अगर $\tan\phi = \frac{r\cos\alpha}{1 - r\sin\alpha}$ formula से ϕ find out करना possible है तो कभी भी Merchant theory नहीं लगेगा। अगर नहीं होता है तो Merchant theory ही लगेगा।

⇒ Merchant theory gives higher shear plane angle means smaller shear plane which means lower shear force ⇒ lower cutting forces, power, tempr, all of which mean easier m/cing.



ϕ' = shear angle by merchant theory

$\phi' > \phi$

Modified merchant theory

from Xerox

⇒ merchant theory is used for calculating "β" sometimes, but it will be 3rd preference.

1st option ⇒ $\beta = \tan^{-1}(\mu)$

2nd option ⇒ F_c & F_t are given

$$\mu = \frac{F}{N} = \frac{F_c \sin\alpha + F_t \cos\alpha}{F_c \cos\alpha - F_t \sin\alpha} \Rightarrow \beta = \tan^{-1}(\mu)$$

3rd option ⇒ use merchant theory if ① & ② fails

$$\phi = 45 + \frac{\alpha}{2} - \frac{\beta}{2}$$

Slide 129

$F = F_c \sin\alpha + F_t \cos\alpha$
$= 290.73\,N$
$N = F_c \cos\alpha - F_t \sin\alpha$
$= 456.45\,N$
$F_n = F_c \sin\phi + F_t \cos\phi$
$= 355.44\,N$
$F_S = 408.08\,N$

dia = 160 mm
$N = 315$ rpm
$d = 2.5$ mm
$f = 0.16$ mm/rev
$\lambda = 75°$
$\alpha = 10°$
$F_z = 500N$
$F_x = 200N$
$t_4 = 0.48$ mm

$F_c = 500N$
$F_t = \frac{200}{\sin 75} = 207.055N$
$t = f\sin\lambda = 0.1545$
$r = 0.3219$
$\tan\phi = \frac{r\cos\cancel{\alpha}}{1 - r\sin\alpha} = r$
$\phi = \cancel{17.847}\ 18.56$
$\alpha = 10$

~~$F = F_t = 207.055N$~~
~~$N = F_c = 500N$~~
~~$F_n = F_c \sin\phi + F_t \cos\phi$~~
~~$= 350.329N$~~
~~$F_s = F_c \cos\phi - F_t \sin\phi$~~
~~$= 412.48N$~~

$\beta = 32.49°$

$\boxed{S128}$

$\alpha = 22°$

$t_c = 0.8 \text{ mm}$

$V = 48 \text{ m/min}$

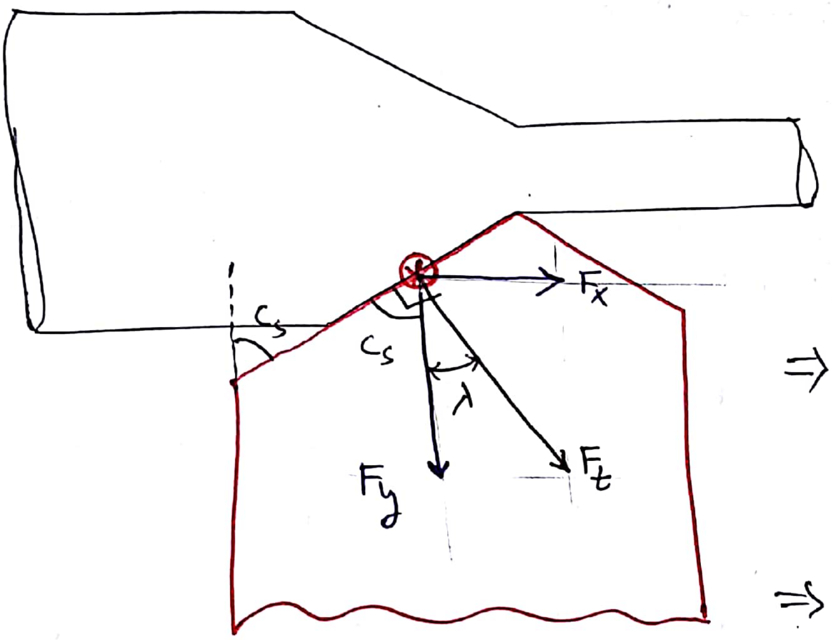
$t = f = 0.4 \text{ mm/rev}$

$$\tan\phi = \frac{r\cos\alpha}{1 - r\sin\alpha}$$

$$\phi = 29.7°$$

Proofs of turning convension formula

Force convension



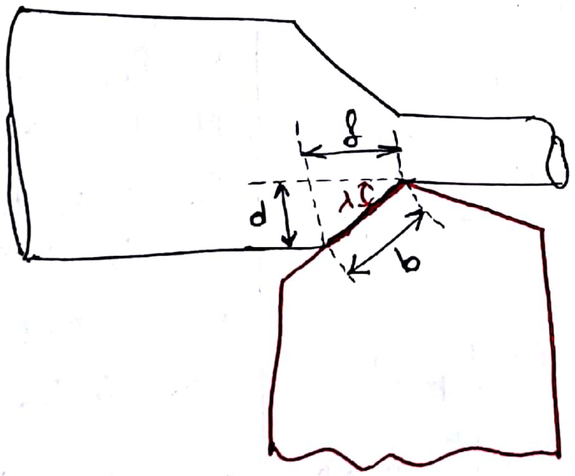
$$\Rightarrow F_t\cos\lambda = F_y$$

$$\Rightarrow \boxed{F_t = \frac{F_y}{\cos\lambda}}$$

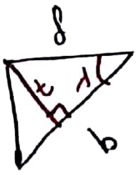
$$\Rightarrow F_t\sin\lambda = F_x$$

$$\Rightarrow \boxed{F_t = \frac{F_x}{\sin\lambda}}$$

Geometry convesion



$$\frac{d}{b} = \sin\lambda \Rightarrow \boxed{b = \frac{d}{\sin\lambda}}$$



$$\frac{t}{f} = \sin\lambda$$

$$\Rightarrow \boxed{t = f\sin\lambda}$$

Power consumption

Total power = Shearing Power + frictional Power

$$F_c V = \underset{65-70\ \%}{F_s V_s} + \underset{30-35\ \%}{F V_c}$$

Specific energy consumption (J/mm³)

$$e = \frac{\text{Power (W)}}{\text{MRR } (mm^3/s)} = \frac{F_c \cdot \frac{V}{60}}{1000\, f d \times \frac{V}{60}} = \frac{F_c}{1000\, f d}$$

Lathe, Drilling, milling ⇒ 2 - 3 J/mm³

Grinding ⇒ 50 J/mm³

ECM ⇒ 500 J/mm³

5143) ~~$Vol = \frac{\pi}{4} \times \left[(200)^2 - (80)^2\right] \times 1 = 26389.378\ mm^3$~~

~~$Power = 200 \times \frac{\cancel{90}^{3}}{\cancel{60}_{2}} = 300\ W$~~

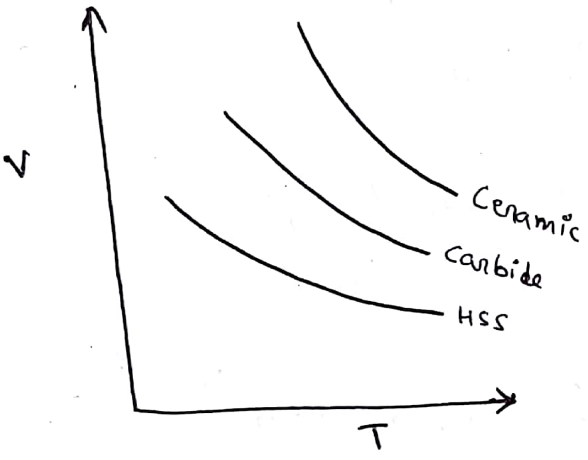
~~$N_1 = \frac{1000 \times 90}{\pi \times 200} = 143.2394$~~

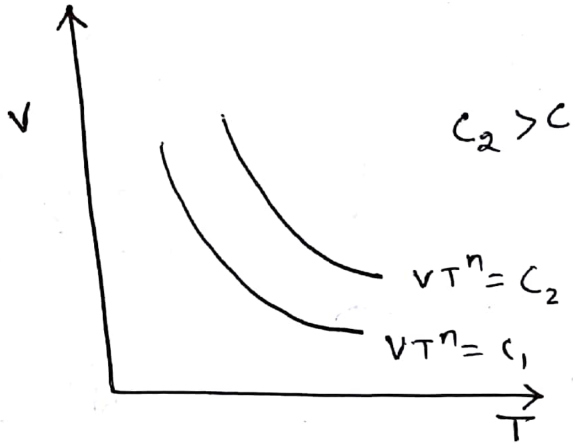
~~$N_2 = \frac{1000 \times 90}{\pi \times 80} = 358.098$~~

247]

$\Rightarrow \boxed{T = 1.0}$ min

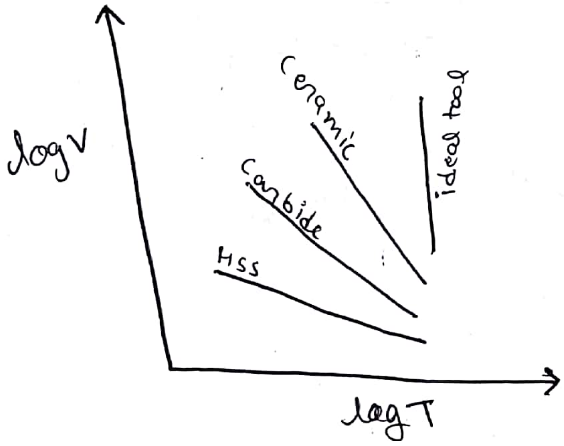
Tool life curves [$VT^n = C$]

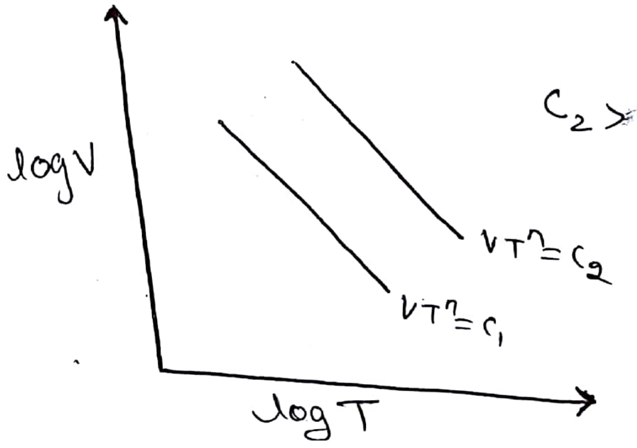




$C_2 > C_1$

curve
ploted
for same
tool





$C_2 > C_1$

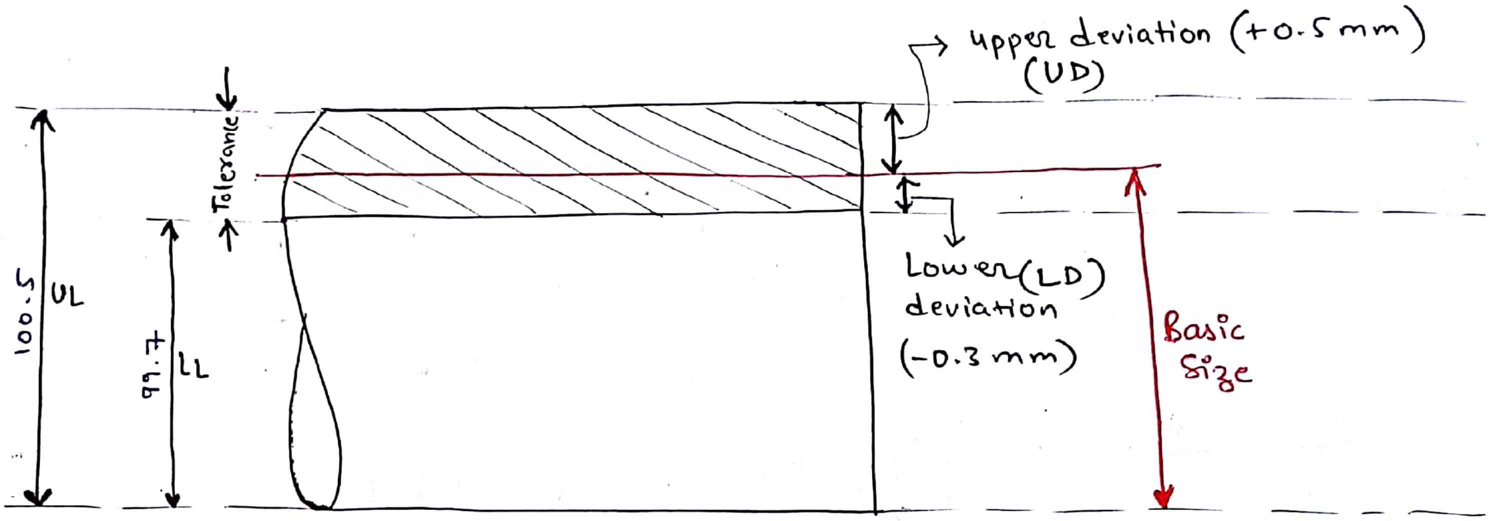
CHAPTER- METROLOGY

Example Shaft $100^{+0.5}_{-0.3}$ mm dia

(UL) Upper limit = 100.5 mm

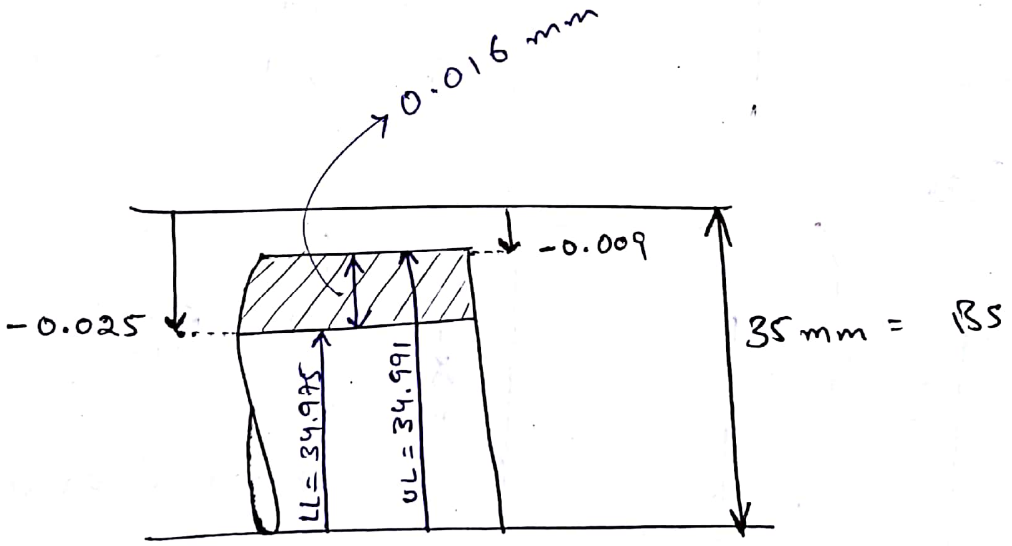
(LL) lower limit = 99.7 mm

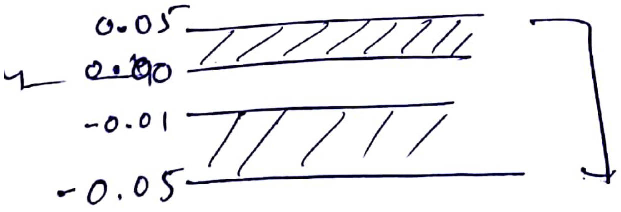
Tolerence = UL-LL = 0.8 mm



fundamental deviation = mini. { Upper deviation , Lower deviation }

P-40
S-13

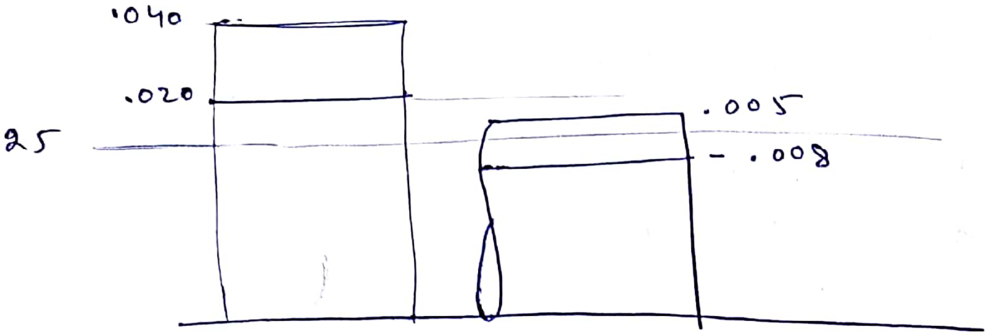




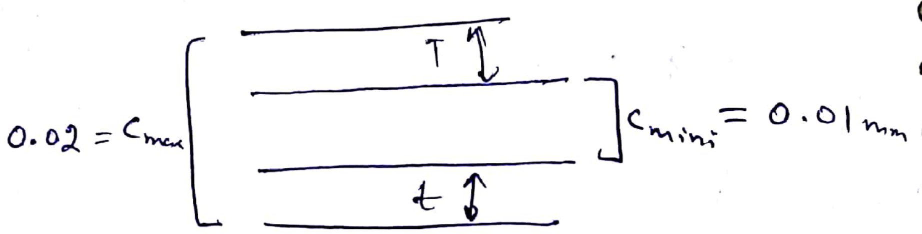
⇒ 0.10 = C max

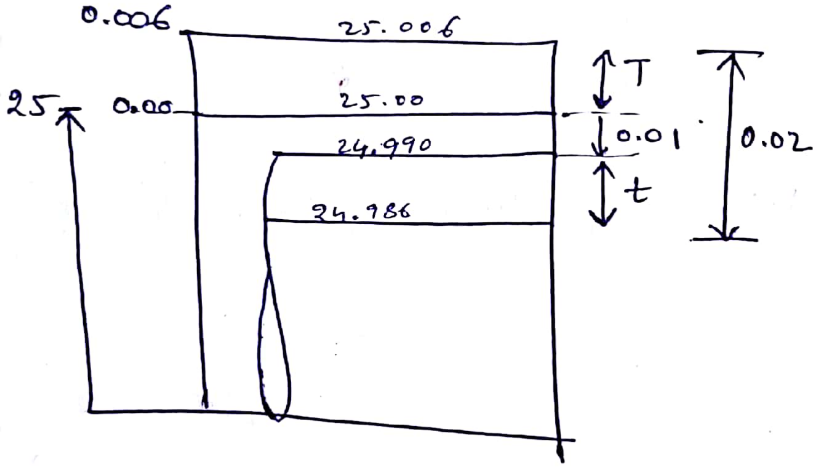
P-41
S-20

$C_{mini} = 0.015$ mm



P-41
S-21





$T = 1.5t$

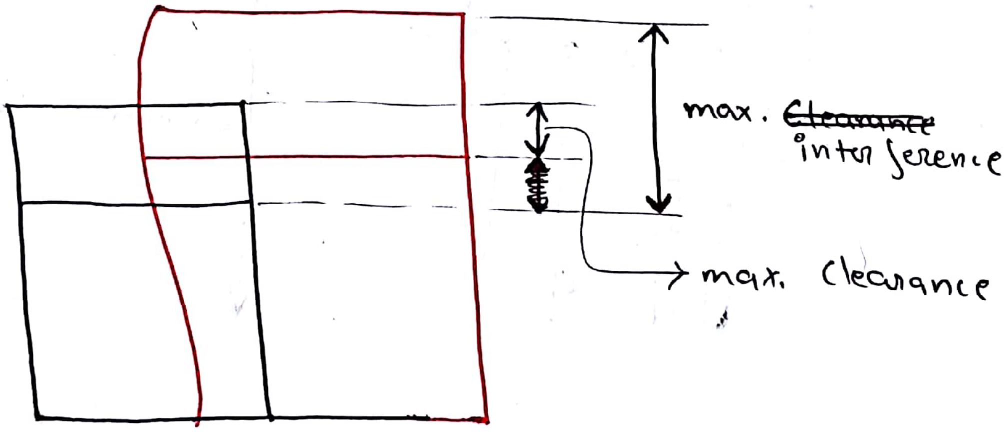
$T + t = 0.01$

$2.5t = 0.01$

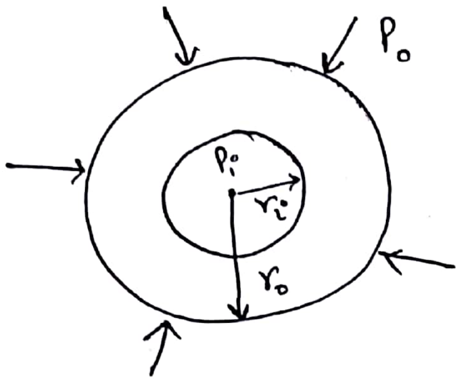
Shaft ⇒ $t = 0.004$ mm

hole ⇒ $T = 0.006$ mm

Transition Fits



Thick cylinder



$P_{outer} = P_o$

$P_{inner} = P_i$

inner radius $= r_i$

outer radius $= r_o$

$x =$ radial distan
from center

$$P_x = -A + \frac{B}{x^2}$$

$$\sigma_r = A - \frac{B}{x^2}$$

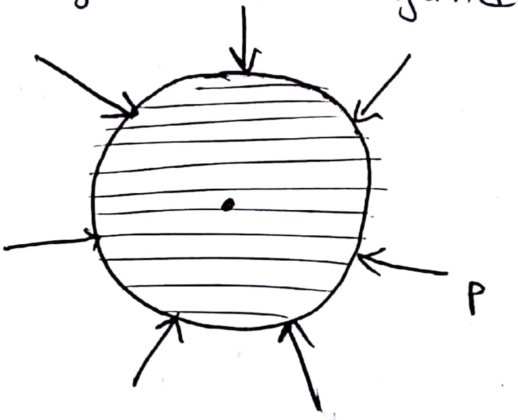
tangential stress $= \sigma_n = A + \frac{B}{x^2}$

Here, A & B are calculated from boundary conditions

$$\boxed{A = \frac{P_i r_i^2 - P_o r_o^2}{r_o^2 - r_i^2}}$$

$$\boxed{B = \frac{(P_i - P_o) r_i^2 r_o^2}{r_o^2 - r_i^2}}$$

for a solid cylindrical shaft under external pressure



$$A = -\frac{Pr^2}{r^2} = -P$$

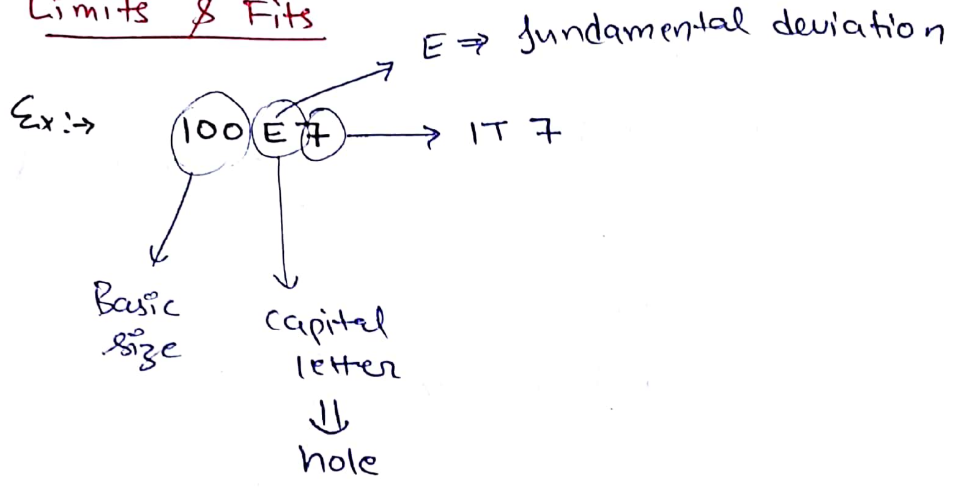
$$B = 0$$

$$\sigma_n = A + \frac{B}{x^2} = -P = \text{constant}$$

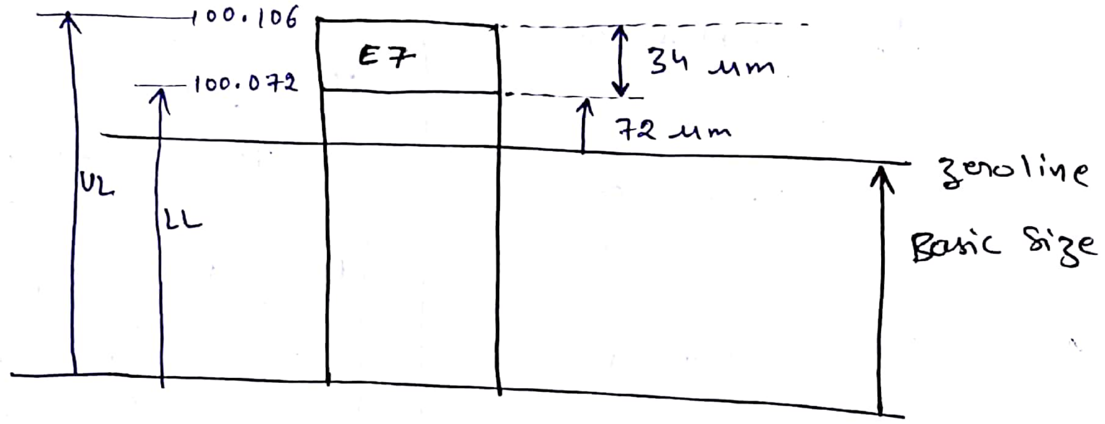
$$\sigma_r = A - \frac{B}{x^2} = -P = \text{const.}$$

P-45
S-58

Limits & Fits



Step-1



Step-2

$$\boxed{D = \sqrt{D_1 D_2}}$$

$D = \sqrt{80 \times 120} = 97.98$ mm

Step-3 Standard tolerance unit or fundamental tolerance unit

$$\boxed{i = 0.45\sqrt[3]{D} + 0.001D}$$

$i = .45\,(97.98)^{1/3} + 0.001 \times 97.98 = 2.1725$ µm

Step-4 find tolerance

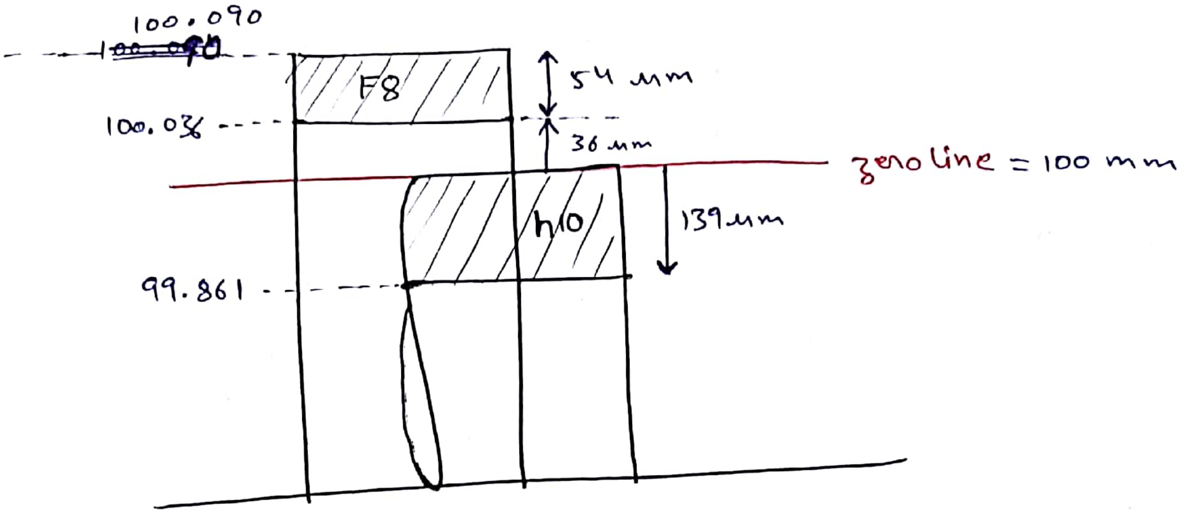
According to IT 7 ⇒ Tolerance $= 16i = 34.76$ µm

Step 5 find fundamental deviation

for shaft e ⇒ $FD = -11\,D^{0.41}$

for hole E ⇒ $+11\,D^{.41} = 72.07$ µm

P-46
S-70



$D = \sqrt{80 \times 120} = 97.98$ mm

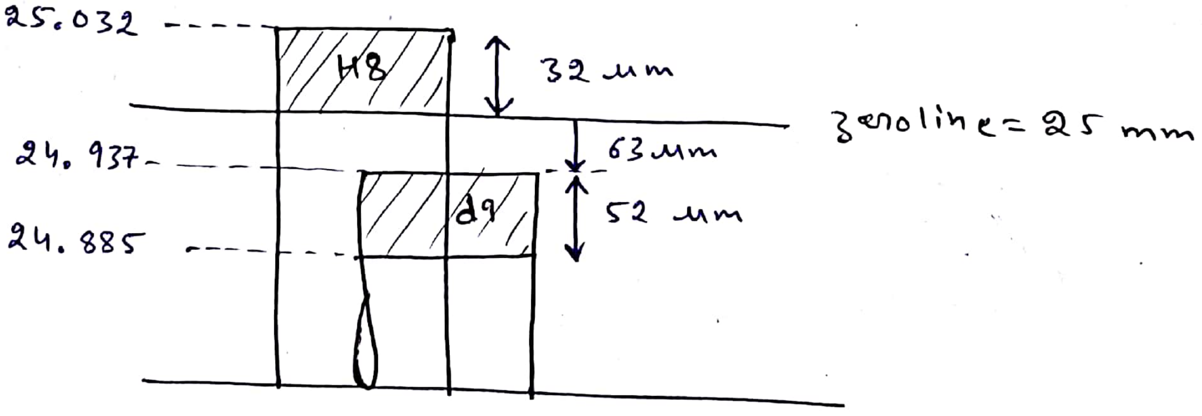
$i = 0.45 (D)^{1/3} + 0.001 D = 2.17$ μm

hole Tolerance $= 25 i = 25 \times 2.17 = 54$ μm

shaft Tolerance $= 64 i = 64 \times 2.17 = 139$ μm

FD hole $= 5.5 \times D^{.41} = 36$ μm

S-71



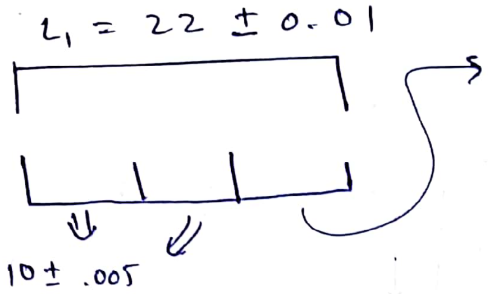
$D = \sqrt{18 \times 30} = 23.2379$ mm

$i = 0.45 (D)^{1/3} + .001 D = 1.3$ μm

T ⇒ IT8 ⇒ $25 i =$ 32.68 μm

t ⇒ IT9 ⇒ $40 i =$ 52.29 μm

FD shaft $= 16 \times D^{.44} = 63.86$ μm

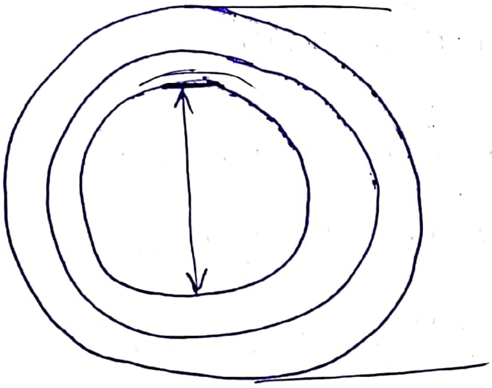


$$X_{max} = 22.01 - 9.995 - 9.995 = 2.02$$

$$X_{mini} = 21.99 - 10.005 - 10.005 = 1.98$$

$72.35 + x - 72.175 = 0.125$ $\Rightarrow x = 2 \pm 0.02$

$\Rightarrow x = -0.05$



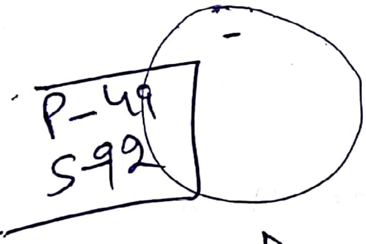
~~$d_{mini} + 2t_{min} = D_{imi}$~~

~~$30.01 + 2 \times .02 =$~~

~~$D_{mini} = \boxed{30.03}$~~

~~$d_{max} + 2t_{max} = D_{max}$~~

~~$30.05 + 2 \times 0.015 = \boxed{30.08}$~~
~~0.03~~



$D_{min} - 2t_{max} = d_{mini}$

$D_{max} - 2t_{mini} = d_{max}$

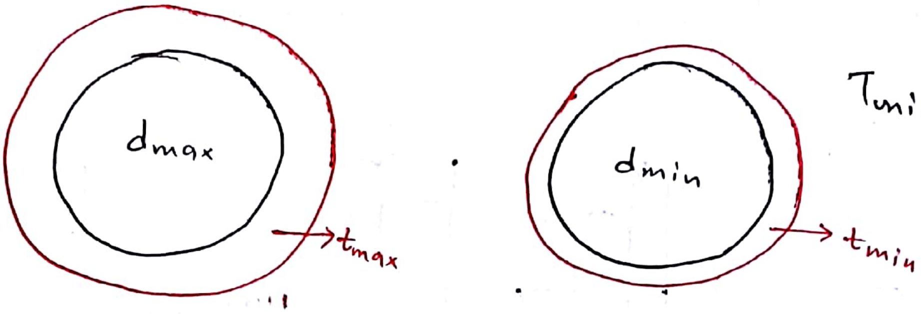
$D_{mini} = d_{mini} + 2t_{max} = 30.01 + 2 \times 0.015 = 30.04$

$D_{max} = d_{max} + 2t_{min} = 30.05 + 2 \times 0.01 = 30.07$

Electroplating

$T_{max} = d_{max} + 2t_{max}$

SHAFT



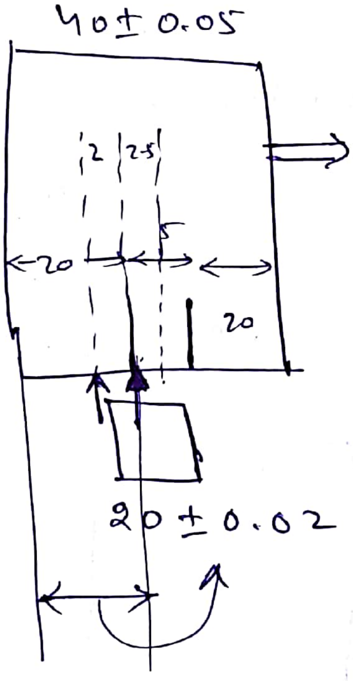
$T_{min} = d_{min} + 2t_{min}$

P-49
S-93

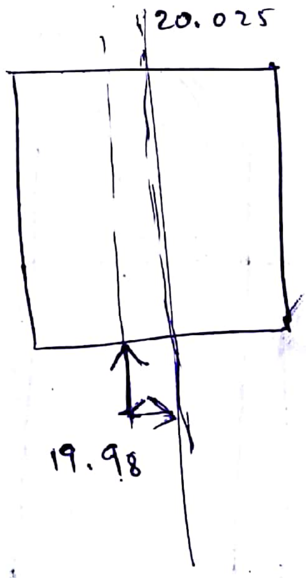
mini = 25.01 + .056 = ~~24.46 mm~~ 25.066 mm

largest = 25.02 + 0.064 = 25.084 mm

S-94



⟹ max offset = ~~45~~
= 0.045 mm

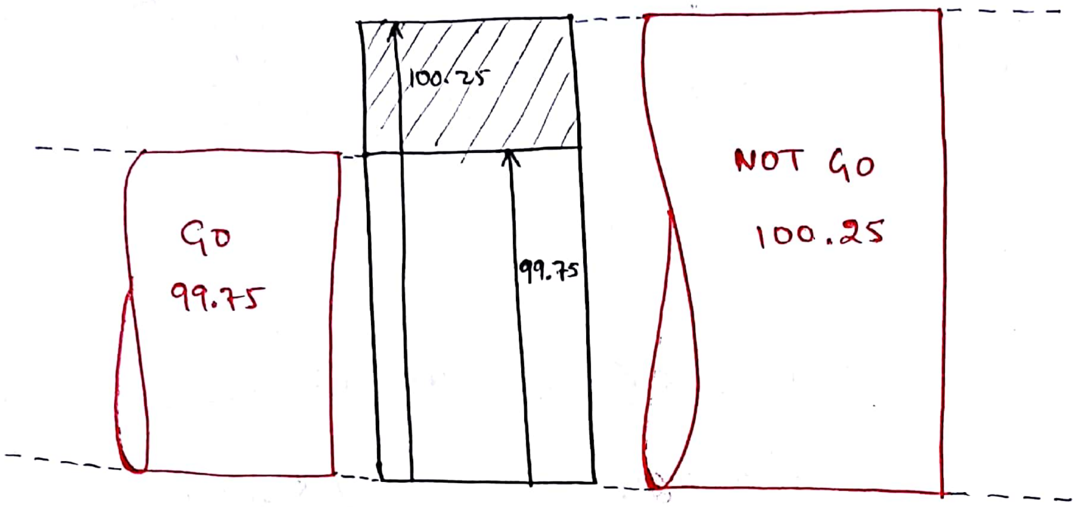


offset = 20.025 − 19.98
= 0.045

P-45
S-95

Limit Gauges

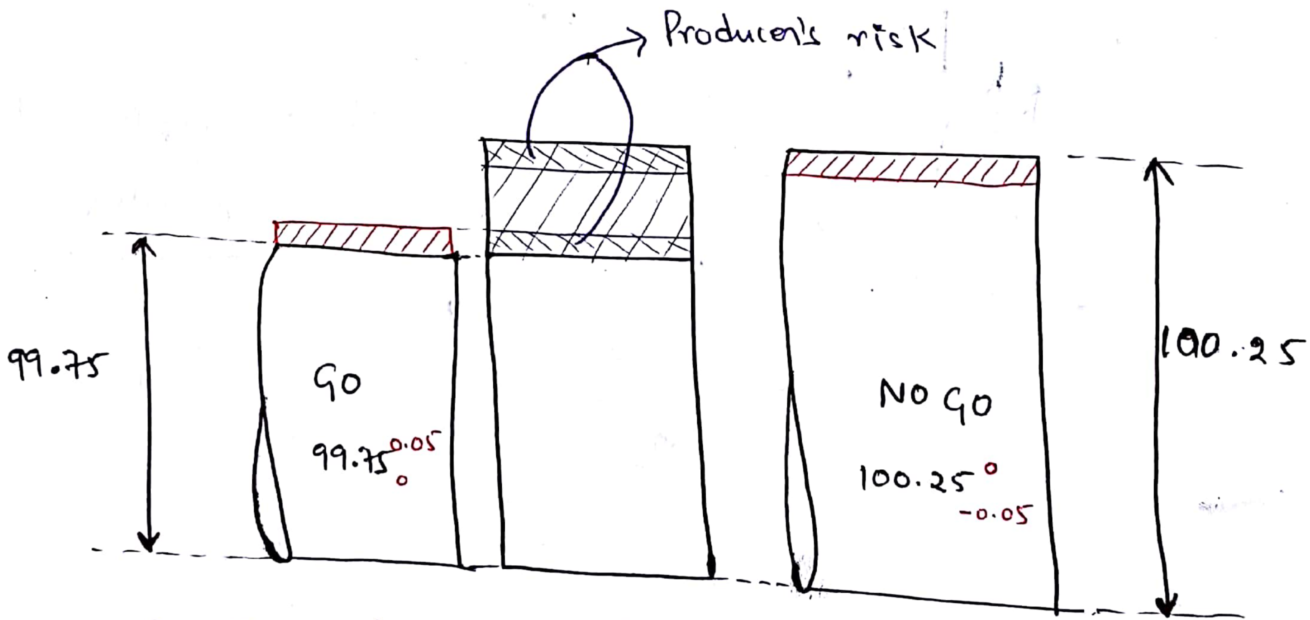
Ques: Design a plug gauge to inspect holes 100 ± 0.25 mm



Rule of 10

Gauge tolerance will be 10 % of work tolerance = 10% of 0.5 mm
= 0.05 mm

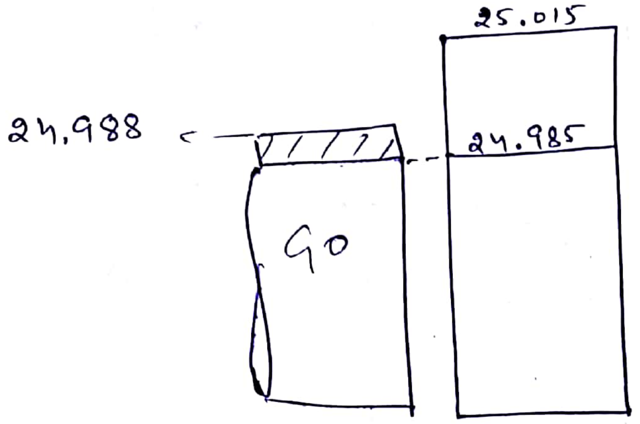
Unilateral tolerance



BS = 99.75 mm
UL of Go = 99.80 mm
LL of Go = 99.75 mm

BS of NO GO = 100.25 mm
UL of NO GO = 100.25 mm
LL of NO GO = 100.20 mm

S-102

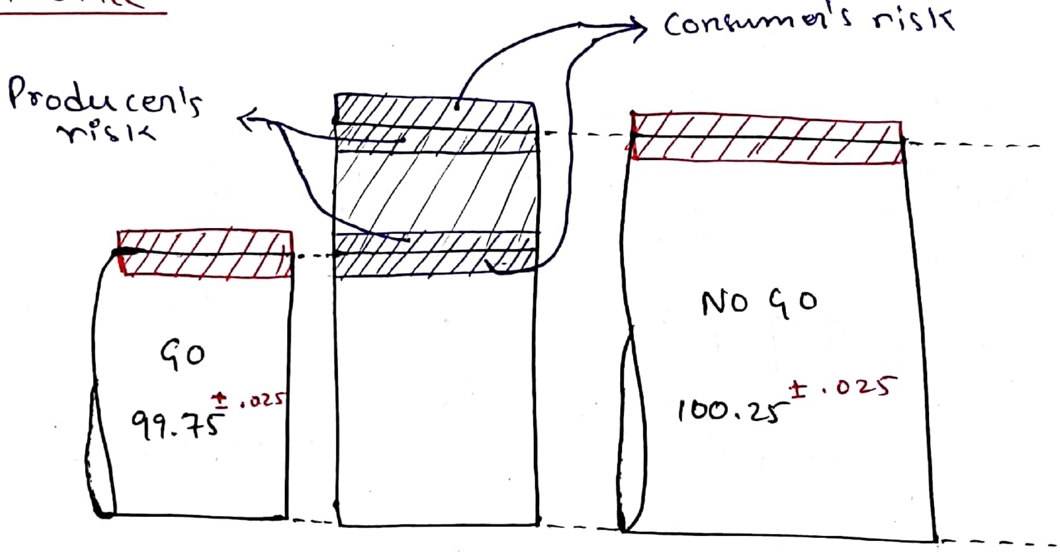


tolerance = 0.1 × 0.03

= 0.003

$$\boxed{24.985^{0.003}_{0.00}}$$

Bilateral tolerance

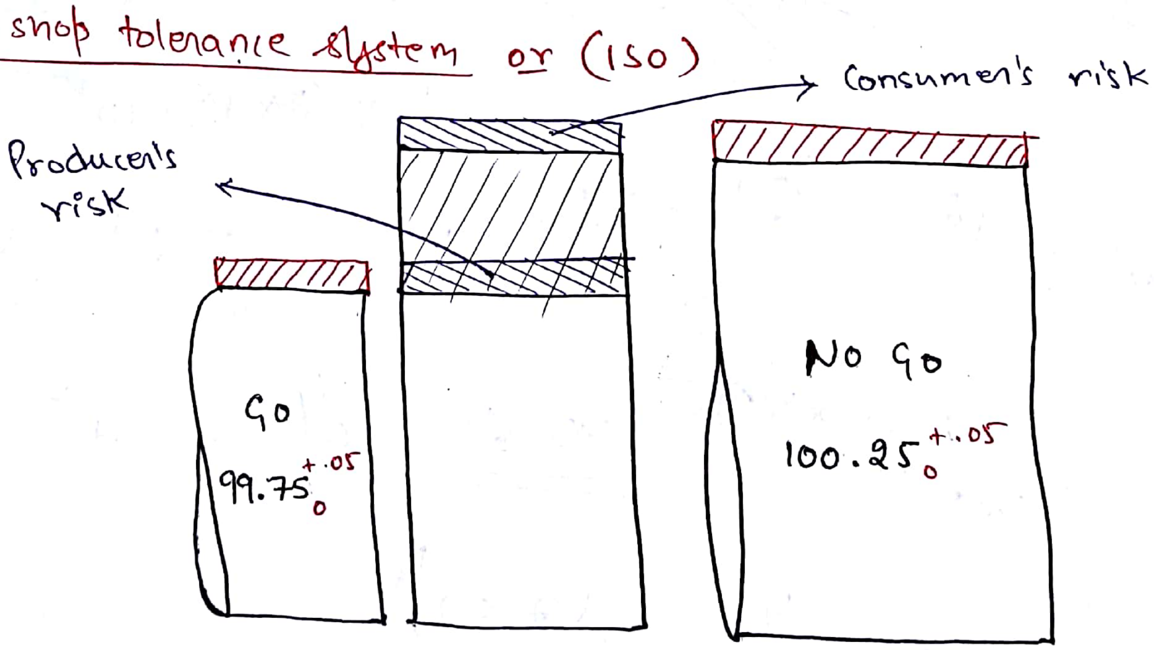


gauge tolerance = 10% of work tolerance

= 0.1 × 0.5 = 0.05 mm

⇒ ± 0.025 mm

workshop tolerance system or (ISO)



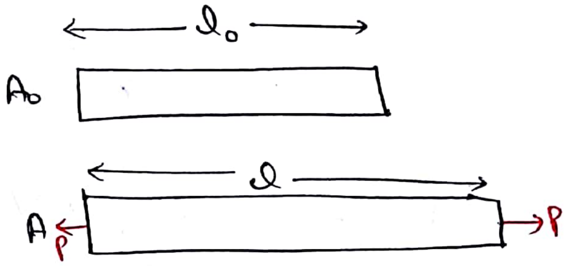
gauge tolerance = 10% of work tolerance

= 0.05

Rolling

- In rolling $\boxed{F \times V = \text{Power}}$ $\Rightarrow$ not applicable bcz direction of force and direction of velocity are not same.

True stress & True strain



$$\text{Stress} = \frac{P}{A_0}$$

$$\text{True stress} = \sigma_T = \frac{P}{A}$$

$$\text{Strain} = \varepsilon = \frac{\Delta l}{l_0}$$

$$\text{True Strain} = \varepsilon_T = \frac{\Delta l}{\text{Instentenous length}} = \int_{l_0}^{l} \frac{dx}{x} = \ln\left(\frac{l}{l_0}\right)$$

$$A_0 l_0 = A l$$

$$\Rightarrow \frac{l}{l_0} = \frac{A_0}{A} = \frac{l_0 + \Delta l}{l_0} = 1 + \frac{\Delta l}{l_0} = 1 + \varepsilon$$

$$\Rightarrow \boxed{\varepsilon_T = \ln(1+\varepsilon)} = \ln\left(\frac{A_0}{A}\right) = 2 \ln\left(\frac{d_0}{d}\right)$$

$$\boxed{\sigma_T = \sigma(1+\varepsilon)}$$

- In case of compression, σ & ε ko negative mey put krna hoga, formula wahi hai.

Ques:

$$\varepsilon_T = \ln(1+\varepsilon) = 0.099\,\%$$

$$\varepsilon_T = \ln(4)$$

$$\frac{A_f}{A_0} l_f = \frac{\cancel{A_0}}{\cancel{A_0}} l_0$$

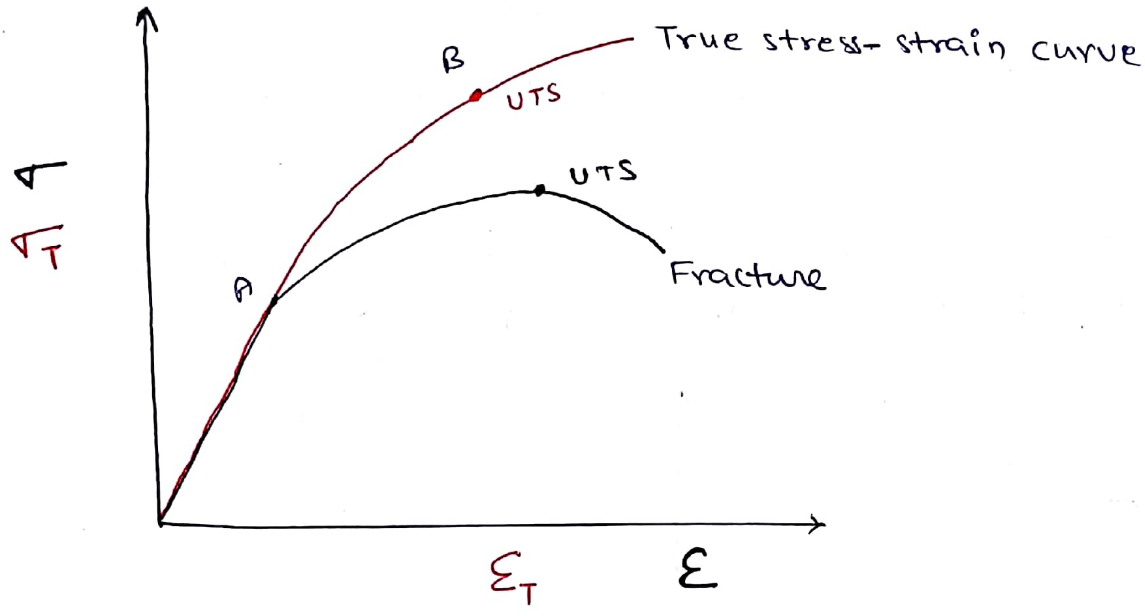
Ques:

$$\varepsilon_T = \ln\left(\frac{A}{A_0}\right) = \ln(.65)^7 = 3.015$$

Ans:

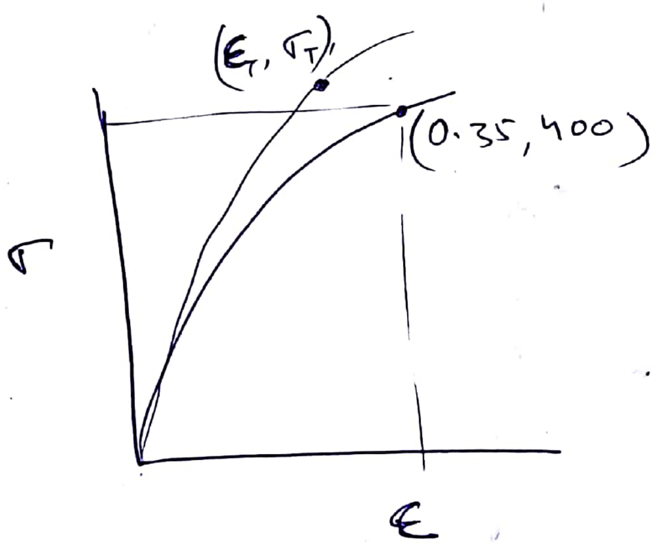
$$\varepsilon_T = \frac{dl}{l} = \frac{2\cancel{l_0}t}{\cancel{l_0}(1+t^2)} = \frac{2\times1}{1+1} = 1$$

Strain hardening & flow stress



metal forming ⇒ A to B

S-222
Ques:
P-93



$\sigma_T = \sigma(1+.35)$

$= 400\times1.35$

$= 540$ MPa

$\varepsilon_T = 0.3$

$\sigma_T = K\,\varepsilon_T^{\,n}$

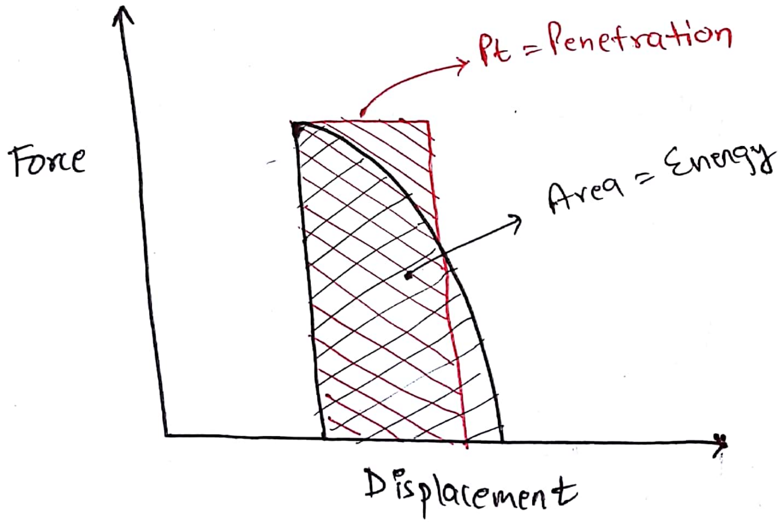
at Ultimate tensile stress ⇒ $n = \varepsilon = 0.3$

$540 = K\times(.3)^{.3} \Rightarrow K = 774.93$

$\simeq 775$

$\sigma_T = 775\,\varepsilon^{.3}$

Force V/s Displacement curve for Punching/blanking



$$\text{Power} = E \times \begin{bmatrix}\text{no. of punching} \\ \text{or} \\ \text{blanking per sec.}\end{bmatrix}$$

$$E = F_{max} \times Pt \times (t)$$

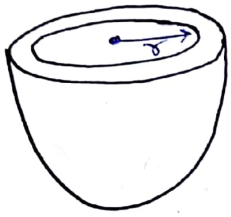
Pt = % Penetration

t = thickness of plate

E = energy.

Drawing

Ex: Hemispherical Katori



$$2\cancel{\pi} r^2 t = \frac{\cancel{\pi}}{4} D^2$$

$$D^2 = 8r^2 t \Rightarrow D = \sqrt{8r^2 t}$$

* * *

Servo motor [more pricise than stepper motor]

- Servo motors are special electromechanical devices that produce pricise degrees of rotation
- A Servo motor is a D.C. or A.C. or brushless D.C. motor combined with a position sensing device.
- Servo motors are also called control motors as they are involved in controlling a mechanical system.
- A reference input is sent to the servo amplifier, which controls the speed of servomotor.
- In many servo systems, both velocity and position are monitored.
- Servo motors provide accurate speed, torque and have ability of direction control.

Basic length unit (BLU)

agar hum motor ko ek pulse bhejenge to table jitna move karega is called BLU

$$BLU = \frac{\text{Pitch}}{\text{no. of steps in stepper motor}}$$