Metal Cutting & Machine Tools. — Machine Tools & Machining

① Many components produced by primary manufacturing processes need machining to get their final shape, accurate size & good surface finish.

② The term machining is used to describe various processes which involve removal of material from the work piece.

Definition of Machining / Metal cutting:

Machining is an essential process of finishing by which jobs are produced to the desired dimensions and surface finish by gradually removing the excess material from the performed blank in the form of chips with the help of cutting tool(s) moved past the work surface(s).

Importance of Machining:

① The ever increasing importance of machining operations is gaining new dimensions in the present Industrial age.

② Competition towards the economical manufacture of machined parts.

③ Basic objectives of the economical and efficient manufacturing practices are,

→ Quick metal Removal or Metal Removal Rate.

→ High class surface finish.

→ Economy in tool cost

→ Less power consumption

→ Economy in cost of replacement and sharpen of tools.

→ Minimum lead time of machine tools.

What is Machine Tools ?

① A machine tool is a machine for shaping / machining metal / other rigid materials usually by cutting, boring, grinding or other forms of deformation.

② Machine tools employ some sort of tool that does the cutting / shaping.

Machining Processes:

Single point tool operation
- Turning operation
- Boring operation
- Shaping operation
- Planning operation

Multipoint tool operation
- Milling operation
- Drilling operation
- Tapping operation
- Reaming operation
- Hobing operation
- Broaching operation
- Sawing operation.

Abrasive Grinding
- Grinding operation
- Lapping operation
- Honing operation
- Super Finishing.

Classification of cutting tools:

Cutting tools used in metal cutting can be broadly classified by

① Single point cutting tools;
Those having only one cutting edge
Ex: Lathe tools, Shaper tools, Boring tools etc.

② Multipoint cutting tools:
Those having morethan one cutting edge
Ex: Milling cutter, Drilling, Broaches, Grinding wheels etc.

The cutting tools can be classified according to the motion as;

① Linear motion tools:
Ex: Lathe, Boring, Broaches, Planing, Shaping tools etc.

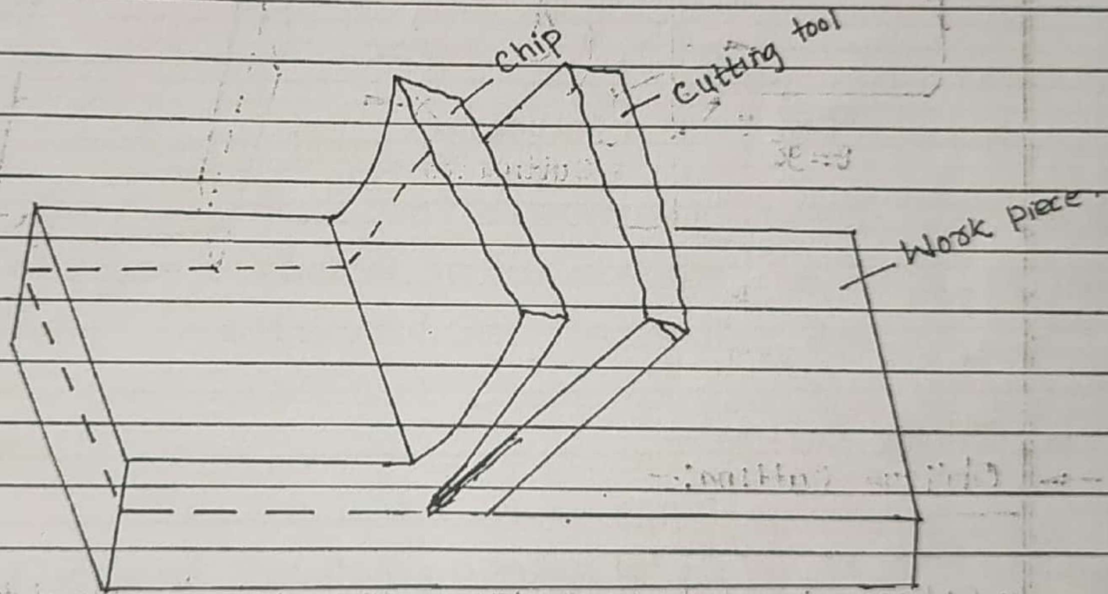
② Rotary motion tools;
Ex: Milling cutter, Grinding wheels etc.

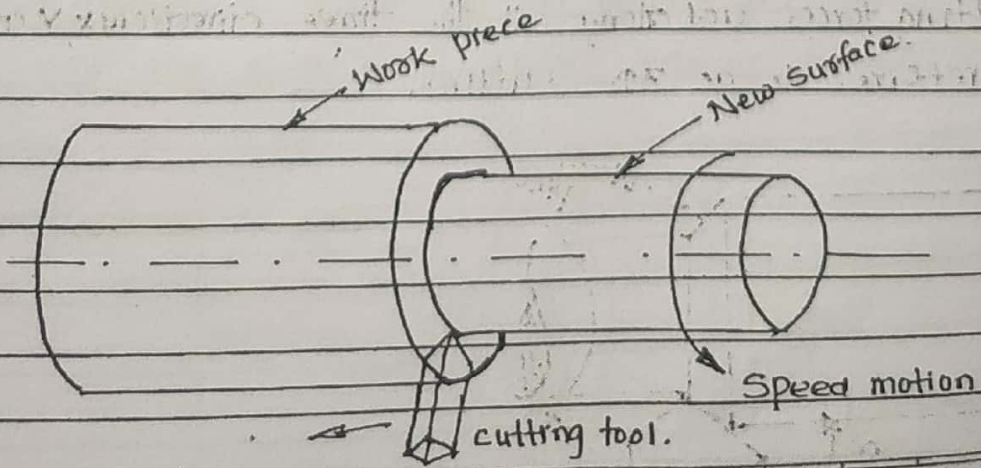
③ Linear and Roterry motion tools:
Ex: Drills, Honing tools, Boring heads etc.

How cutting takes place:

For providing cutting action a relative motion between the tool and ~~work piece~~ work piece is necessary. This relative motion can be provided by ~~This relative~~

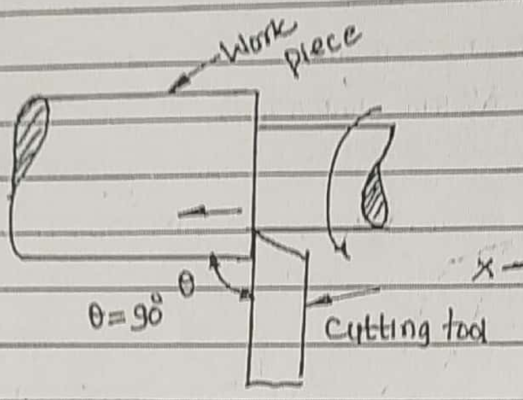
1. Either keeping the work piece stationary and moving the tool
   Ex: shaper, slotter, Broaching etc.
2. By keeping the tool stationary and moving the work piece.
   Ex: Planer machine.
3. By moving both in relation to one another.
   Ex: Grinding machine and Milling machine.

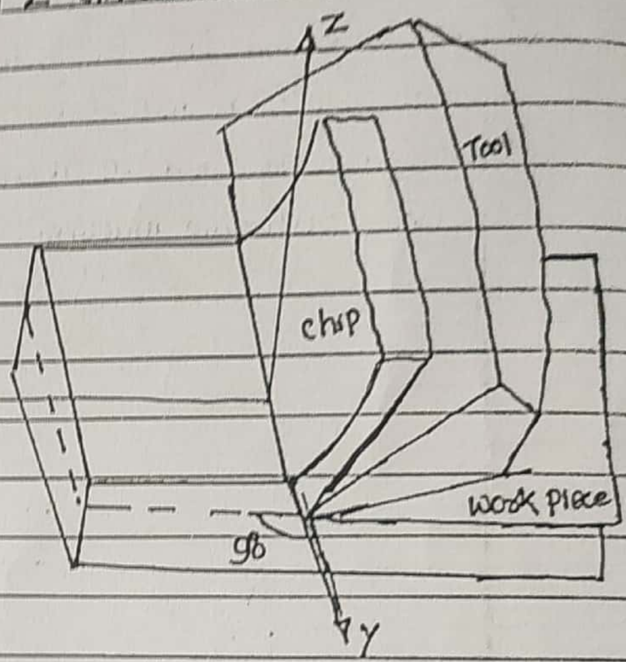




Orthogonal Cutting:–

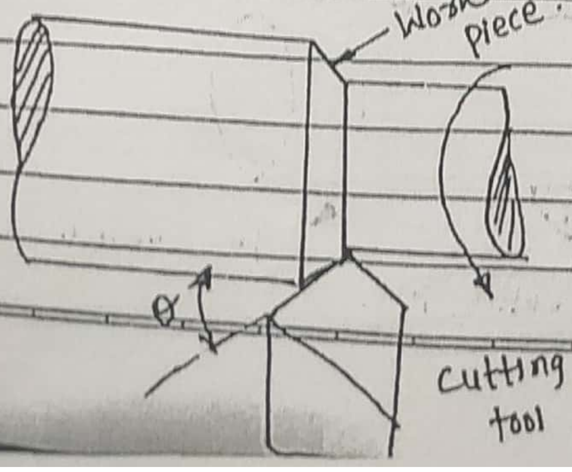
* Cutting edge of the tool is perpendicular to the direction of the velocity vector.
* The chip formed flows on the rake face of the tool with chip velocity perpendicular to the cutting edge.
* The cutting forces act along x and z directions only, hence referred to as 2D cutting.

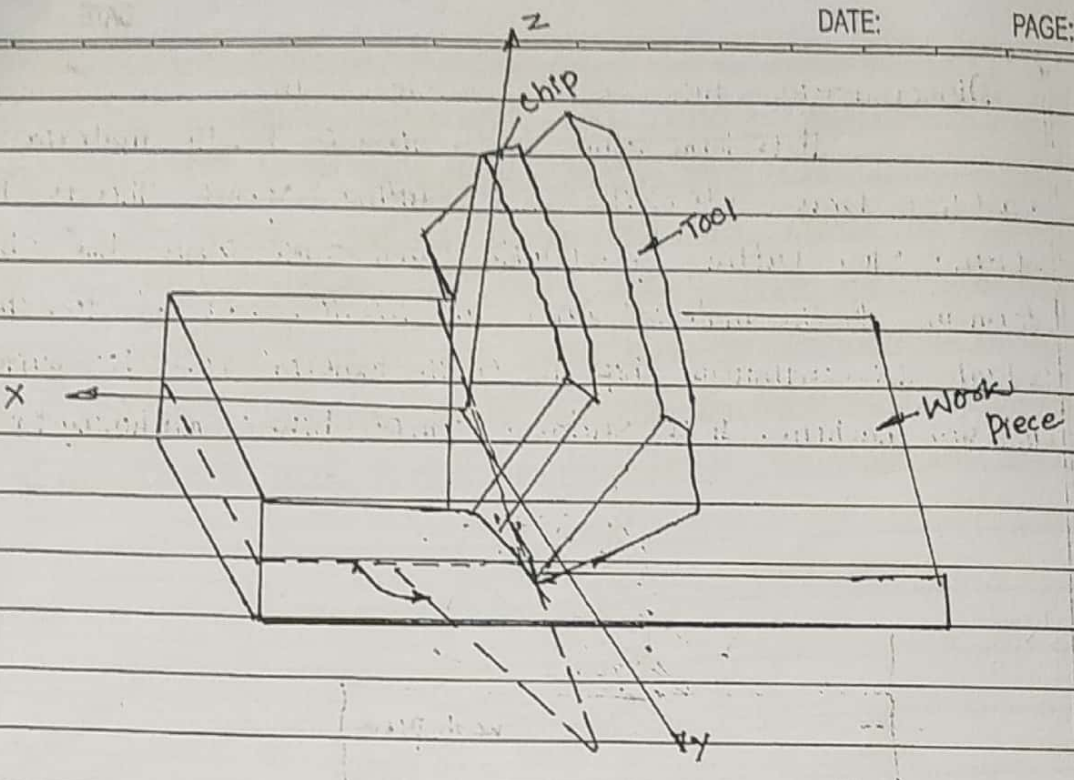




Oblique Cutting:–

* Cutting edge of the tool makes an angle with the normal to the cutting velocity vector
* The ~~f~~ chip formed flows on the rake face of the tool at an angle with the normal to the cutting edge in the plane of the face.
* The cutting forces act along all the three directions x, Y and z hence referred to as 3D cutting.



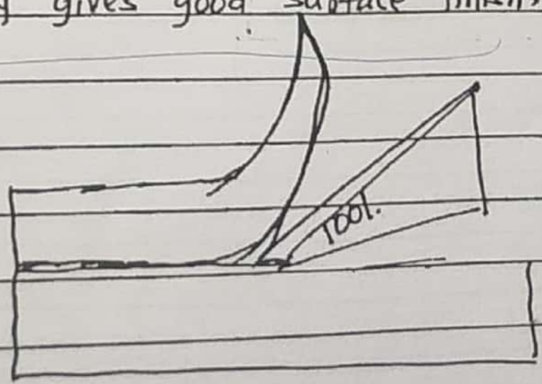


⊛ Types of Chips in Metal Cutting.

Chips formation is part of machining process. It is form during cut the work piece by some of mechanical means. The chips depends on the material of work piece and tool and cutting condition.

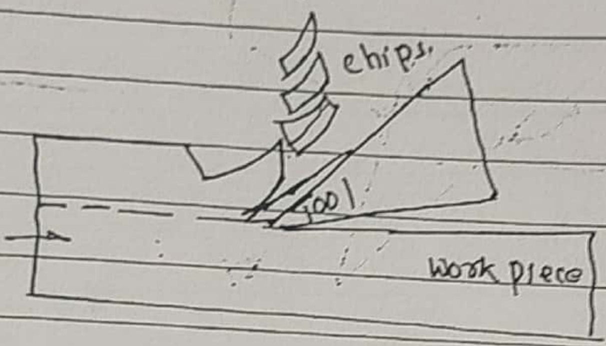
① Continuous chips:–

This chip is form during cutting of ductile material like aluminum, mild steel, copper etc. with a high cutting speed. The friction between tool and material is minimum during this process. This is form due to continuous plastic deformation of the material by application of tool. These chips have equal thickness throughout the length. It generally gives good surface finish.



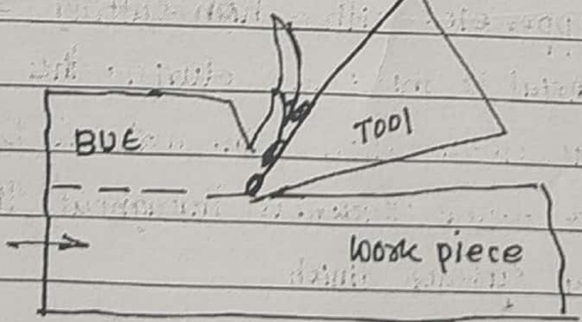
② Discontinuous Chips or Segmental Chips:

It is form when machining of brittle material like cast iron, brass etc, with slow cutting speed. This is formed during slow cutting speed with small rake angle. This chips form in ductile material when the friction between tool and work piece is high. Discontinuous chips in ductile material give poor surface finish and slow machine. It is suitable form of chips of machining brittle material.



③ Continuous chips with built up edge:—

This type of chip is same as the continuous chips except a built up edge is form at the face of tool. It is form during machining of ductile metal with excessive friction between tool and work piece. This chip is not smooth as continuous chips. The built up edge form due to high temperature between tool & work piece. This high temperature is due to high friction force between tool & work piece.

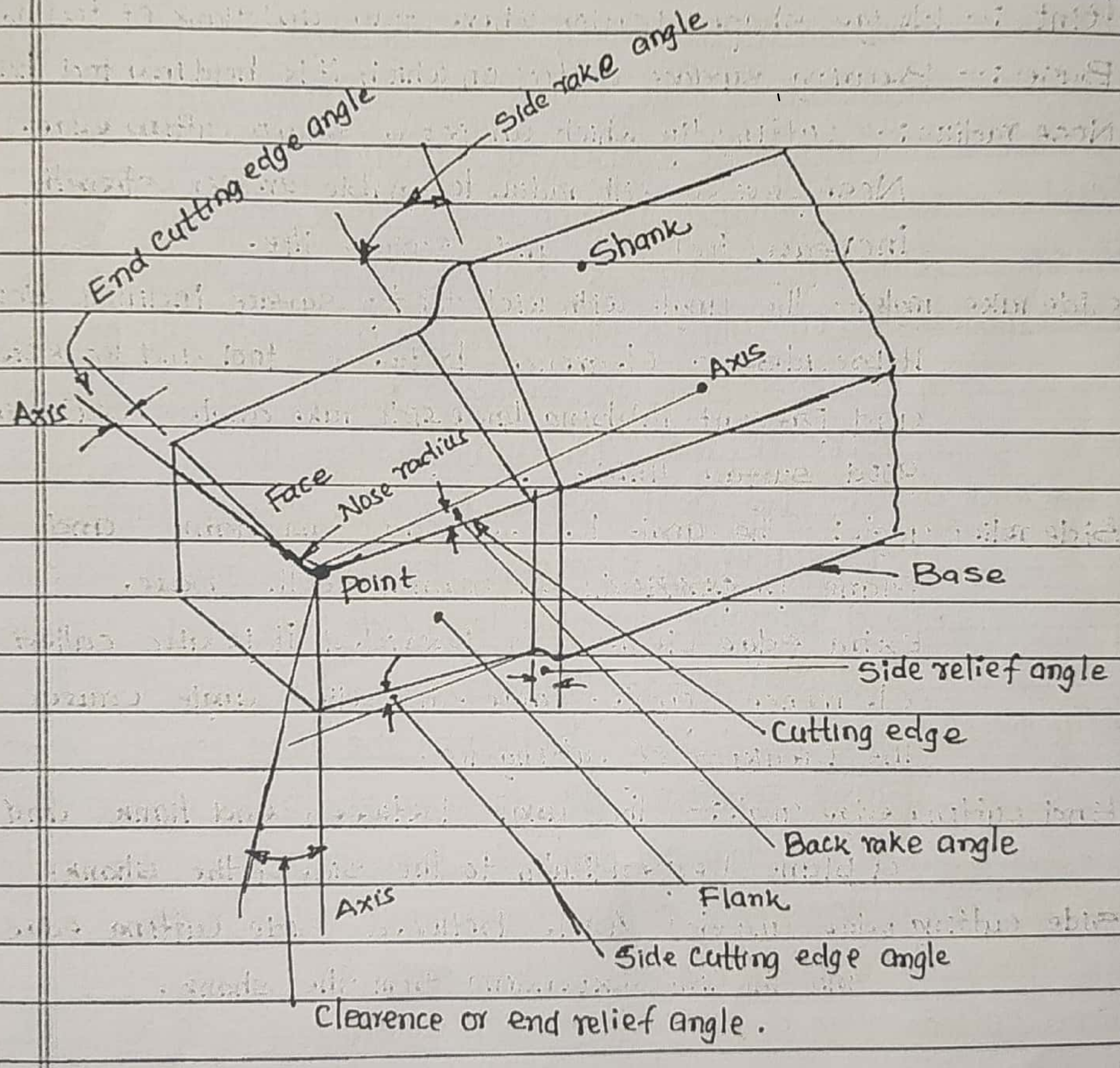


UNIT–1

Theory of Metal Cutting.

* Single point cutting tool: nomenclature:-

As it name indicates, a tool that has a single point for cutting purpose is called single point cutting tool. It is generally used in the lathe machine shaper machine etc. It is used to remove the material from the work piece.



Shank :- Main body of tool, It is part of tool which is gripped in the tool holder.

Face :- Top surface of tool between shank and point of tool. Chip flow along this surface.

Flank :- Portion of tool which faces the work. It is surface adjacent to and below the cutting edge when tool lies in a horizontal position.

Point :- Wedge shaped portion where face and flank of tool meet.

Base :- Bearing surface of tool on which it is held in a tool holder.

Nose radius :- Cutting tip which carries a sharp cutting edge. Nose provided with radius to enable greater strength, increase tool life and surface life.

Side rake angle :- The angle with wich the top surface inclined sideways. It providesa a clearence between tool and workpiece. and prevent rubbing large side rake angle results in good surface finish.

Side relief angle :- The angle between the end flank and plane ~~perpendicular~~ to normal to the base. Extra edge clearence is provided, it is also called clearence angle. Large end relief angle causes the breaking of cutting tool.

End cutting edge angle :- The angle between end flank and a plane perpendicular to the side of the shank.

Side cutting edge angle :- Angle between side cutting edge and the line extending from the shank.

* Merchants Circle diagram:-

Merchants diagram is a method for calculating the various forces involved in the cutting process. This will first be explained with vector diagrams. These in turn will be followed by few formulas.

* Following are the assumptions made in Merchants diagrams.

1. Cutting velocity always remains Constant.
2. Cutting edge of tool remains sharp throughout cutting and there is no Contact between work piece and tool flank.
3. There is no side ways flow of chip. i.e Orthogonal chip.
4. Only continuous chip is produced.
5. There is no built up edge
6. No consideration is made of the inertia force of the chip.
7. The behaviour of the chip is like that of a free body which is in the state of a stable equillibrium due to the action of two resultant forces which are equal, opposite and Collinear.

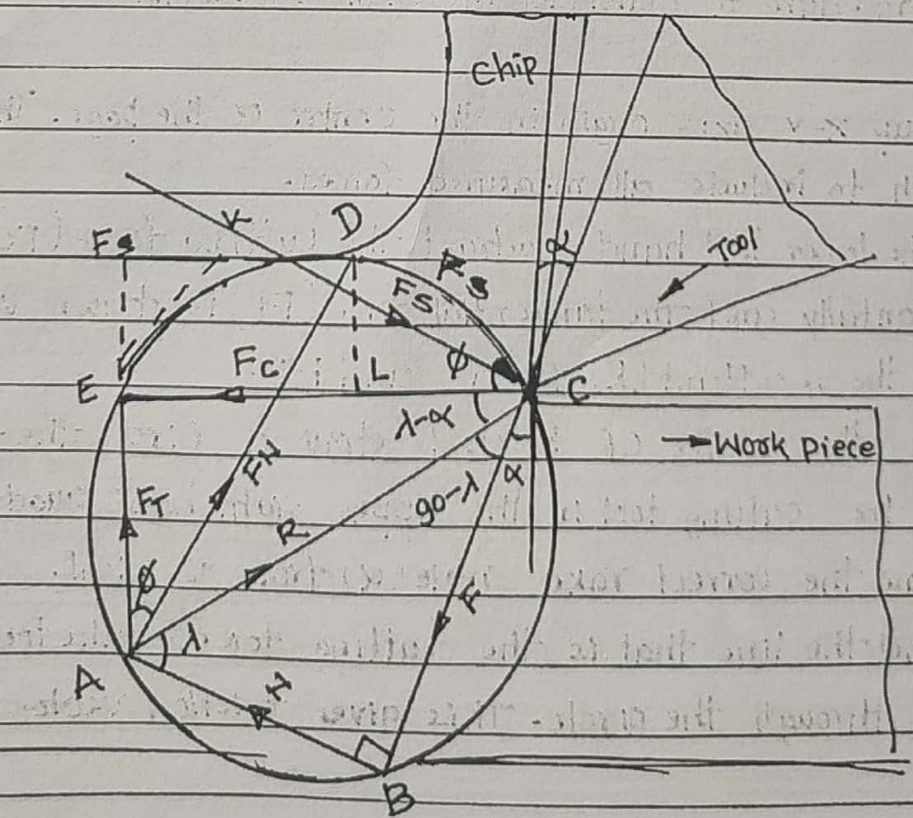
* Procedure to Construct Merchants diagram.

1. Set up x-y axis origin in the centre of the page. The scale should be enough to include all measured forces.
2. In the lower left hand quadrant the cutting force (F_c) is drawn horizontally and the tangential force (F_t) is drawn vertically.
3. Draw the resultant (R) for F_c and F_t.
4. Locate the centre of R and draw a circle the encloses vector $\vec{R}$
5. Draw the cutting tool in the upper right hand quadrant, taking care to draw the correct rake angle (α) from vertical.
6. Extend the line that is the cutting force of the tool (at the same rake angle) through the circle. This gives friction vector (F).

7. A line can now be drawn from the head of the friction vector (F) to the head of the resultant vector (R). This gives normal vector (N)
8. Draw shear plane perpendicular to tool axis and mark Shear force (Fs). Also measure shear force angle (Fs) and (Fc), (ϕ).
9. Finally add the compressive force (Fn) from the head of (Fs) to the head of (R).

ϕ = Shear angle λ = Friction angle α = Rake angle.
Friction vector F → Along the rake face
Normal vector N → perpendicular to rake face
Co-efficient of friction $\mu = \frac{F}{N}$, between chip and Tool.
$\mu = \tan\lambda$

This theory assumes that the cutting is orthogonal and that the shear angle is located where the energy required for deformation is minimum, where in the work done in cutting is minimum. This is known as the minimum energy criterion.



to

Resolving Forces:

1. Force by work on the chip → F_N → Compressive force on shear.
   F_S → Shear force on shear plane.

2. Force by tool on the chip → N → Normal force on rake face.
   F → Frictional force on rake face.

3. Force on tool → F_C → Tangential force, cutting forces ||el to cutting velocity.
   F_T → Thrust force.

4. ϕ = shear angle, λ = Friction angle α = Rake angle.

The resultant of F_C and F_T is R, $\vec{R} = \vec{F_T} + \vec{F_C}$ ΔAEC

F_N and F_S is R, $\vec{R} = \vec{F_S} + \vec{F_N}$ ΔADC

F and N is R, $\vec{R} = \vec{F} + \vec{N}$ ΔACB

Hence the tip of the all these force vectors must lie on an

* $EC = EL + EC$ $EC = F_C$

$= FD + LC$ From Δ^{le} AFD $\frac{FD}{AD} = \sin\phi$, $FD = \sin\phi$

Δ^{le} CLD $LC = F_S \cos\phi$

$\therefore F_C = F_N \sin\phi + F_S \cos\phi$ —— (1)

* $EA = FA - FE$ $EA = F_T$ Δ^{le} FAD $FA = F_N \sin\phi$

$= FA - DL$ Δ^{le} CLD $DL = F_S \sin\phi$

$\therefore F_T = F_N \cos\phi - F_S \sin\phi$ —— (2)

* $BC = BG + GC$ $\quad BC = F \quad \Delta^{le}\ EAH \quad AH = F_T \cos\alpha$

$= AH + GC \quad \Delta^{le}\ GEC \quad GC = F_C \cos(90-\alpha)$

$= F_C \sin\alpha$

$\therefore F = F_T \cos\alpha + F_C \sin\alpha$ ——— (3)

* $AB = HG = EG - EH \quad AB = N \quad \Delta^{le}\ EGC \quad EG = F_C \sin(90-\alpha)$

$= F_C \cos\alpha$

$\Delta^{le}\ EAH \quad EH = F_T \sin\alpha$

$\therefore N = N = F_C \cos\alpha - F_T \sin\alpha$ ——— (4)

* $CD = CK - DK \quad CD = F_S \quad \Delta^{le}\ CKE \quad CK = F_C \cos\phi$

$EP \quad DK = EP \quad \Delta^{le}\ EAP \quad EP = F_T \sin\phi$

$\therefore F_S = F_C \cos\phi - F_T \sin\phi$ ——— (5)

* $AD = AP + PD \quad AD = F_N \quad \Delta^{le}\ APE \quad AP = F_T \cos\phi$

$= AP + EK \quad PD = EK \quad \Delta^{le}\ ECK \quad EK = F_C \sin\phi$

$\therefore F_N = F_T \cos\phi + F_C \sin\phi$ ——— (6)

* $\Delta^{le}\ CAE \quad \frac{F_C}{R} = \cos(\lambda-\alpha)$

$F_C = R \cdot \cos(\lambda-\alpha)$ ——— (7)

and

$F_T = R \sin(\lambda-\alpha)$ ——— (8)

* Δ^{le} CAD $\frac{F_S}{R} = \cos(\phi+\alpha-\lambda)$

$$\therefore F_S = R \cdot \cos(\phi+\lambda-\alpha)$$

$$F_S = R\cos(\phi+\lambda-\alpha) \quad \text{——— (9)}$$

Using tool dynamometer F_C and F_T can be measured.

$\therefore$ F_S, F_N, F and N can be found by using the above equation.

Co-efficient of friction can be calculated from,

$$\tan\lambda = \mu = \frac{F}{N} = \frac{F_T \cos\alpha + F_C \sin\alpha}{F_C \cos\alpha - F_C \sin\alpha}$$

$$= \frac{F_C \tan\alpha + F_T}{F_C - F_T \tan\alpha} \quad \text{——— (10)}$$

From equation $\left(\frac{7}{9}\right)$ $\frac{F_C}{F_S} = \frac{R\cos(\lambda-\alpha)}{R\cos(\phi-\alpha+\lambda)}$

$$= \frac{\cos(\lambda-\alpha)}{\cos(\phi-\alpha+\lambda)} \quad \text{——— (11)}$$

b = uncut chip width τ = shear stress t_0 = uncut chip thickness

$$~~F_S S~~ \quad F_S \sin\phi = \tau \cdot t_0 \cdot b$$

$$\therefore F_S = \frac{\tau \cdot t_0 \cdot b}{\sin\phi} \quad \text{——— (12)}$$

$$* \quad F_C = \frac{\cos(\lambda-\alpha)}{\cos(\phi-\alpha+\lambda)} \cdot \frac{\tau \cdot t_0 \cdot b}{\sin\phi} \quad \text{——— (13)}$$

Similarly equation $\left(\frac{8}{7}\right)$ $\frac{F_T}{F_C} = \frac{R\sin(\lambda-\alpha)}{R\cos(\lambda-\alpha)}$

$$= \tan(\lambda-\alpha) \quad \text{——— (14)}$$

OR

$$F_T = F_C \cdot \tan(\lambda-\alpha)$$

$$\cancel{F_T = \frac{\cos(\lambda-\alpha)}{\cos(\phi-\alpha+\lambda)}}$$

$$F_T = \frac{\cos(\lambda-\alpha)}{\cos(\phi-\alpha+\lambda)} \cdot \frac{\tau \cdot t_0 \cdot b}{\sin\phi} \cdot \tan(\lambda-\alpha) \quad \text{——— (15)}$$

$$= \frac{\sin(\lambda-\alpha)}{\cos(\phi-\alpha+\lambda)} \cdot \frac{\tau \cdot t_0 \cdot b}{\sin\phi} \quad \text{——— (15A)}$$

Power consumption;

$$W = F_C \cdot V = \frac{\tau \cdot t_0 \cdot b}{\sin\phi} \cdot \frac{\cos(\lambda-\alpha)}{\cos(\phi-\alpha+\lambda)} \cdot V \quad \text{——— (16)}$$

During the cutting operation, Least energy is consumed when ϕ takes a certain value. i.e W is the least.

For a given value of V, b, t_0 and α, if we assume that τ and λ do not change and ϕ varies.

Then W is a function of ϕ only.

$$W(\phi) = \frac{\text{constant}}{\sin\phi \cdot \cos(\phi+\lambda-\alpha)} \quad \text{——— (17)}$$

$W(\phi)$ is minimum when the denominator is maximum.

$\therefore$ Differentiating the denominator w.r.t ϕ and equating it to zero for maxima. We get $\cos\phi \cdot \cos(\phi+\lambda-\alpha) - \sin\phi \cdot \sin(\phi+\lambda-\alpha)$

OR $\cos(2\phi+\lambda-\alpha) = 0$

OR $2\phi+\lambda-\alpha = \frac{\pi}{2}$ —— (18)

As α decreases it will cause ϕ to decrease with decrease in α and ϕ, t_c will increase.

Power required for machining increases as ϕ value decreases α value increases i.e F_C, F_N & F_T

- Force on rake face increases
- Tendency for BUE formation increases
- Chip tends to change from continuous to discontinuous one.

~~Eff~~ Effect of friction.

- By using cutting fluid μ and λ will decrease and thereby ϕ will increase.
- Increase in ϕ will decrease F_C, F_N and F_T.
  Therefore reduces tendency of BUE formation and strain.
- Reduces discontinuous chips.

DATE:

Ex 1) In an orthogonal cutting operation, a chip length of 80mm was obtained from an uncut chip length of 200mm while cutting with a tool of 20° rake angle using a depth of cut of 0.5 mm. Determine shear plane angle and chip thickness.

Chip length $l_c = 80$ mm, uncut chip length $L_0 = 200$mm, rake angle $\alpha = 20^\circ$, depth of cut $t_0 = 0.5$ mm, shear plane angle $\phi = ?$ chip thickness $t_c = ?$

We know chip thickness ratio,

$$r = \frac{t_0}{t_c} = \frac{L_c}{L_0} = \frac{80}{200} = 0.4$$

Shear plane angle is given by,

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

$$= \frac{0.4\cos 20^\circ}{1 - 0.4\sin 20^\circ} = \frac{0.4(0.9397)}{1 - 0.4(0.342)}$$

$$= \frac{0.3759}{0.8632}$$

$$\tan\phi = 0.4355$$

$$\therefore \phi = \tan^{-1}(0.4355)$$

$$\phi = 23^\circ 53'$$

Now chip thickness is given by

$$\frac{t_0}{t_c} = 0.4$$

$$t_c = \frac{t_0}{0.4}$$

$$= \frac{0.5}{0.4} = 1.25\text{ mm.}$$

Ex 2) In an orthogonal cutting the following observations were made. Pipe diameter 100mm, pipe thickness 0.2mm. Cutting speed 100 m/min, feed 0.25 mm/rev, cutting force 1000 N, back rake angle is -10°. calculate shear strain and shear energy.

$t_0 = 0.2$ mm $t_c = 0.3$ mm $\alpha = -10^\circ$ $F_c = 1000$ N $\gamma = ?$ $SE = ?$

Chip thickness ratio $r = \frac{t_0}{t_c} = \frac{0.2}{0.3} = 0.667$

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

$$= \frac{0.667\cos(-10)}{1 - 0.667\sin(-10)} = \frac{0.667(0.9848)}{1 - 0.667 \sin(-0.174)}$$

$$= \frac{0.6569}{0.8842} = 0.743$$

$$\phi = \tan^{-1}(0.743)$$

$$\therefore \theta = 36^\circ 61'$$

Ex 3) In orthogonal turning of M.S bar of 60mm diameter on a lathe of 0.8mm was used. A continuous chip of 1.4mm thickness was removed at a rotational speed of 80 rpm of work. Calculate the chip thickness ratio (r), chip reduction ratio (k) & The total length of chip removed in one minute.

$r = \frac{t_1}{t_2}$, t_1 = Feed rate mm/rev = 0.8mm, t_2 = given thickness of chip = 1.4 mm.

$$\therefore r = \frac{t_1}{t_2} = \frac{0.8}{1.8} = 0.57 \text{ mm}$$

$$K = \frac{1}{R} \Rightarrow \frac{1}{0.57} = 1.75$$

$r = \frac{L_2}{L_1} \Rightarrow$ $L_2 = r \times L_1 \Rightarrow 0.57 \times \pi \times D \times N = 0.57 \times \pi \times 60 \times 80 = 3912$ mm.

Ex 4) While doing orthogonal machining of a mild steel part, a depth of cut of 0.75 mm is used of 60 rpm. If the chip thickness is 1.5 mm and it is of continuous type then, determine:
① Chip thickness ratio
② The length of chip removed in one minute. If work diameter is 60 mm before the cut is taken.

$t = 0.75$ mm, $N = 60$ rpm $t_c = 1.5$ mm $D = 60$ mm.

① Chip thickness ratio r, $r = \frac{t}{t_c} = \frac{0.75}{1.5} = 0.5$

② Length of chip removed L_c;
Length of chip before cutting (Un cut chip length)
$L = \pi DN = \pi \times 60 \times 60 = 11309.7$ mm/min

$$r = \frac{t}{t_c} = \frac{L_c}{L}$$

$$L_c = r \times L$$
$$= 0.5 \times 11309.7 = 5654.8 \text{ mm}.$$

Ex 5) During the orthogonal cutting a bar of 90 mm dia is reduced to 87.6 mm. If the mean length of the cut chip is 88.2 mm and rake angle is 15°
Calculate ① Cutting ratio ② Shear angle.

$t = L_c = 88.2$ mm $\alpha = 15°$

① Cutting ratio r,
length of uncut chip $t_c = L = \frac{\pi(90+87.6)}{2} = 278.97$ mm.

∴ Cutting ratio $r = \frac{\text{Cut chip length (depth of cut)}}{\text{Un cut chip length.}}$

$$= \frac{t}{t_c} = \frac{L_c}{L} = \frac{88.2}{278.97} = 0.3162$$

② Shear angle : ϕ,

$$\phi = \tan^{-1}\left(\frac{r\cos\alpha}{1-r\sin\alpha}\right)$$

$$= \tan^{-1}\left(\frac{0.3162\times\cos 15^\circ}{1-0.3162\times\sin 15^\circ}\right)$$

$$= 18^\circ 4'$$

Ex 6) The following data relates to the orthogonal cutting of a component feed force 900 N, cutting force 1800 N, chip thickness = 0.26, tool rake angle 12°

Determine; ① Compression and shear force

② co-efficient of the chip on the tool face.

Given;

$F_f = 900N$, $F_t = 1800N$, $r = 0.26$, $\alpha = 12^\circ$

① Compression and shear force : F_c & F_s

$$\phi = \tan^{-1}\left(\frac{r\cos\alpha}{1-r\sin\alpha}\right)$$

$$= \tan^{-1}\left(\frac{0.26\cos 12^\circ}{1-0.26\sin 12^\circ}\right) = 15^\circ 05'$$

$$F_c = F_f\cos\phi + F_t\sin\phi$$

$$= 900\cos 15^\circ 05' + 1800\sin 15^\circ 05' = 1336.5\ N.$$

$$F_s = F_t\cos\phi - F_f\sin\phi$$

$$= 18\cos 15^\circ 5' - 900\sin 15^\circ 05' = 1504.5\ N.$$

② Co-efficient of friction μ

$$\mu = \frac{F_f + F_t\cdot\tan\alpha}{F_t - F_f\cdot\tan\alpha} = \frac{900+1800\times\tan 12^\circ}{1800-900\times\tan 12^\circ} = 0.797.$$

Ex 7) The data related to an orthogonal cutting process; Chip length obtained 96 mm, uncut chip length 240 mm, Rake angle 20° Depth of cut 0.6 mm. Horizontal & vertical components of cutting force 2400 N and 240 N respectively. Determine
① shear plane angle ② chip thickness ③ Friction angle.

$l_c = 96\,mm, \quad l = 240\,mm \quad \alpha = 20^\circ \quad t = 0.6\,mm$

① Shear plane angle ϕ;

$$\text{Chip thickness ratio } r = \frac{\text{Chip } \cancel{\text{uncut}} \text{ length } (l_c)}{\text{uncut Chip length } (l)} = \frac{96}{240} = 0.4$$

$$\phi = \tan^{-1}\left(\frac{r\cos\alpha}{1 - r\sin\alpha}\right)$$

$$= \tan^{-1}\left(\frac{0.4\cos 20^\circ}{1 - 0.4\sin 20^\circ}\right) = 23^\circ.5'$$

② Chip thickness t_c;

$$r = \frac{t \text{ (depth of cut)}}{t_c \text{ (chip thickness)}}$$

or

$$t_c = \frac{t}{r} = \frac{0.6}{0.4} = 1.5\,mm.$$

③ Friction angle β.

$$\mu = \tan\beta = \frac{F_f + F_t \tan\alpha}{F_t - F_f \tan\alpha}$$

$$= \frac{240 + 2400\tan 20^\circ}{2400 + 240\tan 20^\circ} = 0.4815$$

$$\therefore \beta = \tan^{-1}(0.4815) = 25^\circ 7'.$$

Ex 8) In orthogonal turning of a 50 mm diameter mild steel bar on a lathe, the following data were obtained. Rake angle 15°, cutting speed = 100 m/min feed = 0.2 mm/rev, cutting force = 180 kg, feed force = 60 kg. Calculate the shear plane angle (ϕ), co-efficient of friction (μ) cutting power, chip flow velocity (v_f) & shear force. If the chip thickness = 0.3 mm.

$r = \frac{t_1}{t_2}$, $t_1 = 0.2mm$ $t_2 = 0.3mm$ $\alpha = 15^\circ$

$= \frac{0.2}{0.3} = 0.667$

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

$= \frac{0.667\cos 15^\circ}{1-0.667\sin 15^\circ} = 0.7787$

$\phi = \tan^{-1} 0.7787 \Rightarrow 37^\circ 55'$.

$\mu = \tan = \frac{F}{N} = \frac{F_c\sin\alpha + F_t\cos\alpha}{F_c\cos\alpha - F_t\sin\alpha}$

$= \frac{180\sin 15^\circ + 60\times\cos 15^\circ}{180\cos 15^\circ - 60\times\sin 15^\circ} = \frac{180\times 0.2588 + 60\times 0.9659}{180\times 0.9659 - 60\times 0.2588}$

$= \frac{104.53}{158.33} = 0.66$.

Cutting Speed $= \frac{\text{cutting force} \times \text{cutting speed}}{4500} = \frac{180\times 100}{4500} = 4\,HP$.

Chip flow velocity (v_f) = cutting velocity (v_c) $\times r$ $= 100\times 0.667 = 66.7$ m/min.

Shear force (F_s) $= F_c\cos\phi - F_t\sin\phi$

$= 180\times 0.7893 - 60\times 0.6145$

$= 105.20$ kg.

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Ex 10)

Ex 9) Following data relate to an Orthogonal cutting process, Chip length obtained 96 mm, uncut chip length 240 mm Rake angle used 20° Depth of cut 0.6 mm, Horizontal & vertical components of cutting force 2400 N & 240 N. Determine
(1) Shear plane angle (2) Chip thickness (3) Friction angle (4) Resultant cutting force.

$L_c = 96\,mm$, $L = 240\,mm$, $\alpha = 20^\circ$ $t = 0.6\,mm$, $F_t = (F_H) = 2400\,N$,
$F_f = (F_V) \cancel{=} 2400\,N$

(1) Shear plane angle ϕ,

Chip thickness ratio, $r = \dfrac{\text{Chip length}(L_c)}{\text{Uncut chip length}(L)} = \dfrac{96}{240} = 0.4$

$$\phi = \tan^{-1}\left(\frac{r\cos\alpha}{1 - r\sin\alpha}\right)$$

$$= \tan^{-1}\left(\frac{0.4\cos 20^\circ}{1 - 0.4\sin 20^\circ}\right) = 23^\circ.5'$$

(2) Chip thickness t_c =

Now $r = \dfrac{t\,(\text{depth of cut})}{t_c\,(\text{Chip thickness})}$ or $t_c = \dfrac{t}{r} = \dfrac{0.6}{0.4} \Rightarrow 1.5\,mm$.

(3) Friction angle β,

$$\mu = \tan\beta = \frac{F_f + F_t\tan\alpha}{F_t - F_f\tan\alpha} = \frac{240 + 2400\tan 20^\circ}{2400 - 240\tan 20^\circ} = 0.4815$$

$$\therefore \beta = \tan^{-1}(0.4815) = 25^\circ.7'$$

(4) Resutant Cutting force R'

$$R = \sqrt{F_t^2 + F_f^2}$$
$$= \sqrt{2400^2 + 240^2} = 2412\,N.$$

Ex 10) In an orthogonal turning of aluminum nano composite of a 50mm dia with carbide tool the following data obtained: Rake angle 15°, cutting speed 100m/min feed = 0.2 mm/rev, cutting force = 180 kg, Feed force = 60 kg. Calculate shear angle, co-efficient of friction, shear force where chip thickness = 0.3 mm

Dia = 50mm, Rake angle = 15°, cutting speed = 100 m/min, feed = 0.2 mm/rev
cutting force = 180 kg, Feed force = 60 kg, Chip thickness $t_2 = 0.3$ mm
Calculate; shear angle ϕ = ? co-efficient of friction μ = ?, Shear force = F_s ?

① Shear angle;

let chip reduction co-efficient $r = \frac{t_1}{t_2} = \frac{0.2}{0.3} = 0.667$.

$$\tan\phi = \frac{r\cos\alpha}{1 - r\sin\alpha} = \frac{0.667 \cos 15^\circ}{1 - 0.667 \sin 15^\circ} = 0.7787$$

$\therefore$ Shear angle $\phi = 37^\circ 55'$.

② Co-efficient of friction μ;

$$\mu = \frac{F}{N} = \frac{F_c \sin\alpha + F_t \cos\alpha}{F_c \cos\alpha - F_t \sin\alpha}$$

$$= \frac{180 \times 0.2588 + 60 \times 0.9659}{180 \times 0.9659 - 60 \times 0.2588}$$

$$\therefore \mu = \frac{104.53}{158.33} = 0.6602$$

③ Shear force:

$$\text{Shear force} = F_c \cos\phi - F_t \sin\phi$$

$$= 180 \times 0.7893 - 60 \times 0.6145$$

$$= 142.074 - 36.87$$

$\therefore$ shear force = 105.20 kg.

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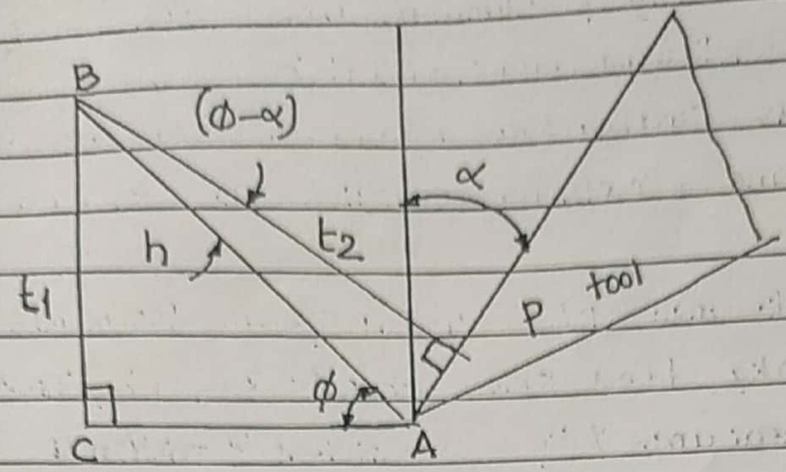
Shear angle ϕ or θ



At A, Let the angle between AB and Vertical is $x = 90-\phi$

$$\boxed{r = \frac{\sin\phi}{\cos(\phi-\alpha)}}$$

Chip thickness ratio $r = \frac{t_1}{t_2}$

$t_1 = h\sin\theta$, $\quad t_2 = h\cos(\theta-\alpha)$

$$r = \frac{t_1}{t_2} = \frac{h\sin\theta}{h\cos(\theta-\alpha)} = \frac{\sin\theta}{\cos\theta\cos\alpha+\sin\theta\sin\alpha}$$

$$\frac{r\cos\theta\cos\alpha}{\sin\theta} + \frac{r\sin\theta\sin\alpha}{\sin\theta} = 1$$

$$\frac{r\cos\alpha}{\tan\theta} + r\sin\alpha = 1$$

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

Tool Wear & Failure:

The usefulness of the tool cutting edges is lost through;
→ Wear
→ Breakage
→ Chipping
→ Deformation.

~~Wh~~ 'Wear,' which responsible for most tool failure, is very complex and involves chemical, physical and mechanical processess, often in combination.
'Tool Failur' implies that ~~to~~ the tool has reached a point beyond which it will not function satisfactory until it is reground.

Tool Wear;

Wear can be defined as the loss of weight or mass that accompanies the contact of sliding surfaces. Wear seldom involves in a single unique mechanism. The wear mechanism associated with gradual or progressive wear include;
i) Abrasion wear
ii) Adhesion wear
iii) Diffusion wear.

(1) Abrasion Wear:

(Abrasion wear occurs when hard constituents of one surface plough through the material of the other surface.)
This is basically a cutting process and, as a consequence, the amount of wear depends on the relative hardness of the contacting surfaces, as well as their elastic and plastic properties and mating geometries.
Many steels, cast irons, and nickel-based alloys contain hard carbides, oxides and nitrides that may contribute to abrasive wear.
The requirement for abrasive wear to occure in high-speed tools is that the constituents causing wear be harder than the martensitic matrix of the cutting tool.
As with high-speed steel tools, but to a lesser extent, forging scale and surface sand on castings cauce abrasive wear on carbide tools.

(ii) Adhesion wear:

This form of wear takes place when two surfaces are brought into intimate contact under normal loads and form welded junctions, which, when subjected to shearing loads, are subsequently destroyed. The temperature at which adhesion occurs is influenced by the characteristics of the tool and work materials, as well as by the force acting between the tool and workpiece; which in turn is established by the cutting condition. This type of wear is of primary importance at relatively low cutting speeds and since it is a time-dependent mechanism, it tends disappear at high cutting speeds.

(iii) Diffusion wear:-

The diffusion wear occurs by a 'solid-state diffusin mechanism' in which atoms in a metallic crystal lattice move from one lattice point to another in the direction of high atomic concentration to one of to low atomic concentration. The diffusion mechanism is dependent on the ambient temperature, and increases in temperature cause exponential increases in the rate of diffusion. In metal cutting the diffusion wear will occure if the mechanical process involved with adhesion raises the local localized interfacial-temperature sufficiently. In machining with high speed tools, there can be diffusion of carbon atoms from the tool into the stream of work material by. The wear of carbide cutting tools used in cutting steels is a well-known phenomenon in which diffusion plays an important role.

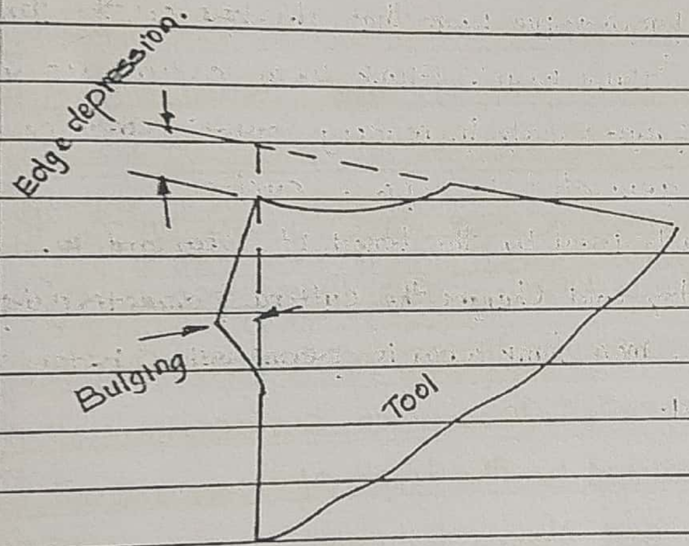
Tool Failure

The tool failure may occure due to the following factors;

1. Excessive temperature
2. Excessive stress
3. Flank wear
4. Crater wear

1. Excessive temperature:-

The high temperatures that occurs in tool chip workpiece contact zones may cause an initially sharp cutting tool to lose some of its strength and flow plastically under the pressures developed by the cutting force. The flow of the tool material along the flank surfaces causes the cutting tool to assume a configuration resembling that



This type of failure is not to limited to high speed steel cutting tools: for even though cemented carbide cutting tools are relatively brittle, they possess a certain amount of ductility under the high compressive loads and elevated temperatures present during cutting.

② Excessive stress:

When a cutting tool is acted upon by an excessive force its cutting edge may undergo immediate failure due to a lack of tool strength. Alternatively the mechanical failure of the cutting tool may result from a fatique-type failure. The chipping of a tool and the development of cracks along its cutting edge can be contributed to;

- Faulty tool design
- Material selection
- Re conditioning technique
- Machining condition.

③ Flank Wear:

The gradual or progressive wear that develops on the flank surface of a cutting tool is called 'flank wear'. Flank wear occurs as a result of friction between the progressively increasing contact area on the tool flank and the newly generated workpiece surface.

The wearland can be characterised by the length of wear land, w.

It modifies the tool geometry and changes the cutting parameters (depth of cut).

With a high clearence angle, more flank wear is permissible before the critical wear land is reached.

④ Crater Wear:-

The gradual or progressive wear that developes on the rake surface of a cutting tool is called 'craler wear'.

Crater wear occurs as a result of the friction developed as the chip flows over the rake surface of the cutting tool. It is largely a temperature-dependent phenomenon. The crater is on the rake face and is more or less ~~circular~~ circular. The crater does not always extend to the tool tip, but may end at a distance from the tool tip. It increases the cutting forces, modifies the tool geometry and softens the tool tip.

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Tool Life

Tool life is defined as the time interval between two successive regrinds. Tool life represents the useful life of the tool expressed generally in time units from a start of a cut to some end point defined by a failure criterion. A tool that no longer performs the desired function is said to have failed and hence reached the end of its useful life. At such an end point the tool is not necessarily unable to cut the workpiece but is merely unsatisfactory for the purpose required. The tool may be resharpened and used again.

Factors affecting tool life;

Tool life depends upon the following factors;

1. Tool material
2. Hardness of the material
3. Type of material being cut
4. Type of the surface on the metal (Rough or smooth)
5. Profile of the cutting tool.
6. Type of machining operation being performed
7. Microstructure of the material
8. Finish required on the workpiece
9. Cutting speed
10. Feed and depth of cut
11. Cutting temperature

* The tool life can be specified by any of the following measurable quantities;

→ Actual cutting time to failure
→ Length of work cut to failure
→ Volume of metal removed to failure
→ cutting speed for a given time to failure
→ Number of components produced

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Tool Failure Criteria:-

The following are some of the possible tool failure criteria that could be used for limiting tool life:

→ Based on tool wear;

1) Wear land size
2) Crater depth, width
3) A combination of the above two
4) Chipping or fine cracks developing at the cutting edge
5) volume or weight of material worn off the tool.
6) Total destruction of the tool.

→ Based on consequences of worn tool:

1) Limiting value of change in component size
2) Limiting value of surface finish
3) Fixed increase in cutting force or power required to perform a cut.

Taylor's Tool life Equation:-

Tool life of a cutting tool may be calculated by using the following relation.

$$VT^n = C$$

Where V = Cutting speed in m/min

T = Tool life in min

C = A constant

(Which is numerically equal to cutting speed that gives the tool life of one min.

n = Anothe constant (depend upon finish, work piece materials, ~~that gives the tool life~~ tool material)

Ex 1) A cutting tool, cutting at 22 m/min, gave a life of 1 hour between regrinds when operating on roughening cuts with mild steel. What will be its probable life when engaged on light finishing cut?
Take $n = \frac{1}{8}$ for roughening and $\frac{1}{10}$ for finishing cuts in the Taylor's eqn $VT^n = C$

Cutting speed $V = 22$ m/min. $T_r = 1$ hour $\Rightarrow 60$ min, $n = \frac{1}{8}$ and $\frac{1}{10}$ for roughening and finishing.

Taylor's equation $VT^n = C$

For finishing cut $22 (T_f)^{1/10} = C$ —— ①
For roughening cut $22 (T_r)^{\frac{1}{8}} = C$ —— ②

From equation ① and ② we get

$$(T_r)^{\frac{1}{8}} = (T_f)^{\frac{1}{10}}$$

$$(60)^{\frac{1}{8}} = (T_f)^{\frac{1}{10}}$$

$$(T_f) = (60)^{\frac{10}{8}}$$
$$= 167 \text{ min.}$$

Ex 2) Calculate the cutting speed for a tool to have a tool life of 160 min. The same tool had a life of 9 min when cutting at 250 m/min.

Given $V_1 = 250$ m/min $T_1 = 9$ min $T_2 = 160$ min $n = 0.22$
Cutting speed V_2
Taylors tool life equation : $VT^n = C$
$\therefore \quad V_1 T_1^n = V_2 T_2^n$

$$V_2 = \left(\frac{T_1}{T_2}\right)^n \times V_1$$
$$= \left(\frac{9}{160}\right)^{0.22} \times 250 = 132.73 \text{ m/min.}$$

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* Cutting Tool Materials:

→ Characteristics of an Ideal Cutting-Tool Material:

① Hot hardness:- The material must remain harder than work material at elevated temperature.

② Toughness:- - The material must have sufficient strength and ductility to withstand shocks and vibrations and to prevent breakage.

③ :- Wear resistance:- The material must withstand excessive wear even-though the relative hardness of the tool-work materials changes.

④ The co-efficient of friction at the chip tool interface must remain low for minimum wear and reasonable surface finish.

⑤ The cost and easeness of fabrication should be within reasonable limits.

* Types of Cutting Tool Materials:

→ While selecting proper tool material the type of service to which the tool will be subjected should be given primary consideration. No one material is superior in all respects, but rather each has certain characteristics which limits its field of application.

→ The principle carbon tool materials are;

① Carbon steels
② Medium alloy steels
③ High speed steels
④ Stellits
⑤ Cemented Carbide
⑥ Ceramics
⑦ Diamonds
⑧ Abrasives

① High speed steels:-

High speed steels is the general purpose metal for low and medium cutting speed steels operate at cutting speeds 2 to 3 times higher than for carbon steels and retain their hardness upto about 900°c. It is used as a popular operations of drilling, tapping, hobbing, milling. There are three general types of high-speed steels, tungsten, molybdenum and cobalt. Tungsten in HSS provides hot hardness and form stability. Molybdenum maintains tool Sharpness (keenness) of the cutting edge. Addition of cobalt improves hot hardness and makes the cutting tool more wear resistant.

→ HSS (T-series) 18-4-1 This steels contains 18% tungsten, 4% chromium and 1% vanadium, is considered to be one of the best of all purpose tool steels.

→ Molybdenum HSS (M-series) 6-4-4: This steel containing 6% Molybdenum 6% Tungsten, 4% chromium, 2% vanadium have excellent toughness and cutting ability.

→ Cobalt HSS. Cobalt is added from 2 to 15% in to increase hot hardness and wear resistance. 20% Tungsten, 4% chromium, 2% vanadium and 12% Cobalt.

② Coated Carbide tools:-

For coated carbide tools, a thin chemically stable, shock resistance refractory coating of TiC, Al_2O_3 and TiN are applied on the tungsten carbide inserts, using chemical vapour deposition method (CVD). In this coating first layer is of TiC, second layer is of Al_2O_3 and the top thin layer is of TiN. This process makes the insert two to three times stronger for wear resistance. The variations of hardness of a few of the tool material with temperatures.

③ **Ceramics :-**

The latest development in the metal-cutting tools uses aluminium oxides generally referred to as ceramics. Ceramics tools are made by composing aluminium oxide powder in a mould at about 280 kg/cm² or more. The part is then sintered at 2200°c. This is known as cold pressing. Hot pressed ceramics are more expensive owing to higher mould cost. Ceramic tool materials are made in the form of tips that are to be clamped on metal shanks. Other materials used to produce ceramic tools include silicon carbide, boron nitride, titanium carbide and titanium boride.

* **Cutting Fluids :-**

Cutting fluids, sometimes referred to as lubricants or coolents are liquids and gases applied to the tool and workpiece to assist in the cutting operations.

* **Purpose of cutting Fluids:**

Cutting fluids are used for the following Purpose:

① To cool the tool
② To cool the workpiece
③ To lubricate and reduce friction
④ To improve surface finish
⑤ To protect the finished surface from corrosion
⑥ To cause chips breakup into small parts
⑦ To wash the chips away from the tool

① To cool the tool:-

Cooling the tool is necessary to prevent metallurgical damage and to assist in decreasing friction at the tool-chip interface and at the tool-workpiece interface. Decreasing friction means less power required to machine, and more important, increased tool life and good surface finish. The cooling action of the fluid is by direct carrying away of the heat developed by the plastic deformation of the shear plane and that due to friction. Hence a high specific heat and high heat conductivity together with a high film-coefficient for heat transfer is necessary for a good coolent. For cooling ability, water is very effective, but it is objectionable for corrosiveness and lack of friction reducing wear.

② To cool the workpiece:-

The role of the cutting fluid in cooling the workpiece is to prevent its excessive thermal distortion.

③ To lubricate and reduce friction:-

a) The energy or power consumption in removing metal is reduced.
b) ~~Abrasion~~ Abrasion or wear on the cutting tool is reduced thereby increasing the life of the tool.
c) By virtue of lubrication, less heat is generated and the tool, therefore operates at lower temperatures with the tendency to extend tool life.
d) Chips are helped out of the flutes of drills, taps, dies, saws etc.

④ To protect the finished surface from corrosion:-

To protect the finished surface from corrosion, especially in cutting fluids made up of a high percentage of water, corrosion inhibitors are effective in the form of sodium nitrate.

⑤ To cause chips break up into small parts:-

Rather than remain as long as ribbons which are hot and sharp and difficult to remove from the workpiece.

⑥ To wash the chips away from the tool:- This is perticularly desirable to prevent fouling of the cutting tool with the workpiece.

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* Desired properties of cutting Fluids:

A cutting fluid should have following properties.

1. High heat absorption for readily absorbing heat developed.
2. Good lubricating qualities to produce low-coefficient of friction.
3. High flash point so as to eliminate the hazard of fire.
4. Stability so as to not to oxide in the air
5. Neutral so as not to react chemically
6. odorless so as not to produce any bad small even when heated.
7. Harmless to the skin of the operators.
8. Harmless to the bearings.
9. Non-corrosive to the work or the machine.
10. Transparency so that the cutting action of the tool may be observed.
11. Low viscosity to permit free flow of the liquid
12. Low priced to minimize production cost.

* Types of cutting fluids:-

The type of cutting fluid to be used depends upon the work material and the characteristic of the machining process. For some machining processes, a cutting fluid which is predominantly a lubricant is desirable. With other machining processes, a cutting fluid which is predominantly a coolent should be used. Cutting fluids are Water, soluble oils, straight oils, mixed oils, Chemical additive oils Chemical compounds and solid lubricants.

1. Water
2. soluble oils
3. straight oils
4. Mixed Oils
5. Chemical-additive oil
6. Chemical compounds
7. Solid lubricants.

(1) Water :- Water, either plain or containing an alkali, salt or water-soluble additive but little or no oil or soap are sometimes used only as a coolant. But water alone is, in most cases objectionable for its corrosiveness.

(2) Soluble oils :- Soluble oils are emulsions composed of around 80% or more water, soap and mineral oil. The soap acts as an emulsifying agent which break the oil into minute particles to dispose them throughout water. The water increases the cooling effect, and the oil provides the best lubricating properties and ensures freedom from rust.

(3) Straight oils :- The straight oils may be (1) straight mineral (petroleum) oils, kerosene, low-viscosity petroleum fractions, such as mineral oil.
(2) Straight fixed or fatty oils consisting animal, vegetable; they have both cooling and lubricating properties and are used in light machining operations.

(4) Mixed oils :- This is a combination of straight and straight fatty oils. This blend makes an excellent lubricant and coolant for automatic-screw-machine work and other light machining operations where accuracy and good finish are of prime importance.

(5) Chemical-additive oil :- Straight oil or mixed oil when mixed up with sulphur or chlorine is known as chemical additive oil. Sulphur and chlorine are used to increase both the lubricating and cooling qualities of the various oils with which they are combined.

(6) Chemical compounds :- These compounds consist mainly of a ~~ro~~ rust inhibitor such as sodium nitrate, mixed with a high percentage of water. Chemical compounds have grown in favour as coolants, particularly in grinding an on machined surfaces where formation of rust is to be avoided.

(7) Solid lubricants :- Stick waxes and bar soaps are sometimes used as a convenient means of applying lubrication to the cutting tool.

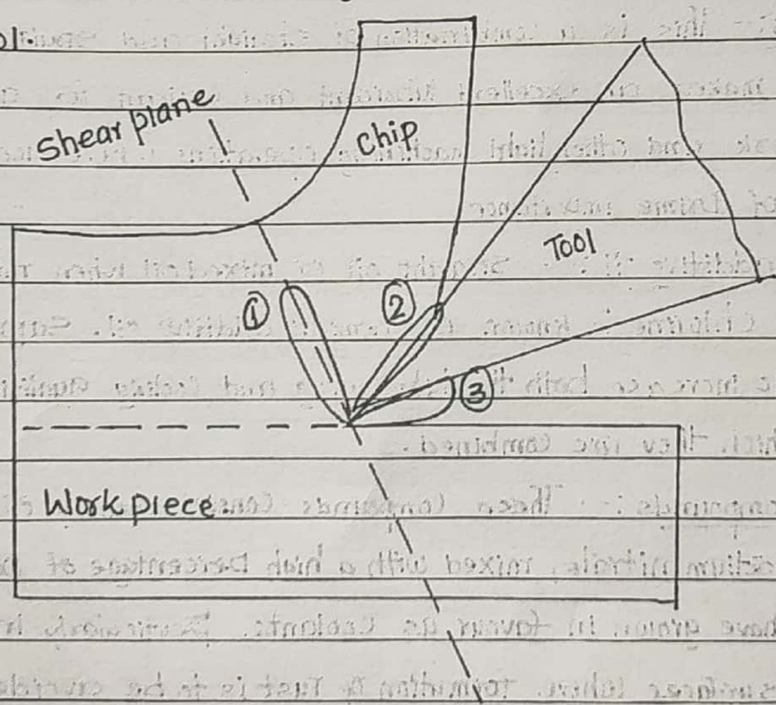
* Selection of Cutting fluids:-

The selection of cutting fluids depends upon the following factors;

1. Type of operation
2. The rate of metal removal
3. Material of the workpiece
4. Material of the tool
5. Surface finish requirement
6. Cost of cutting fluid.

* Heat generation in Metal cutting:-

During metal cutting, the heat energy dissipated gets converted into heat. Consequently high temperatures are generated in the region of the tool cutting edge, and these temperatures having a controlling infuence on the rate of wear of the cutting tool and on the friction between the chip and tool.



During the metal cutting, heat is generated in the three regions.

1. Around shear plane (Primary shear zone):-

It is the region in which actual ~~plane~~ plastic deformation of the metal occurs during machining. Due to this deformation heat is generated. A portion of this heat is carried away by the chip, due to which its temperature is raised. The rest of the heat is retained by the workpiece.

② Tool-chip Interface; Secondary deformation zone:

As the chip slides upwards along the face of the tool friction occurs between their surfaces, due to which heat is generated. A part of this heat is carried by the chip, which further raises the temperature of the chip and the rest ~~transfered~~ transferred to the tool and coolant.

③ Tool-Workpiece Interface:-

The portion of the tool flank which rubs against the work surface is another source of heat generation due to friction. This heat is also shared by the tool, workpiece and the coolant used.

* Factors affecting heat generation:

① Workpiece and Tool material:-

Materials with higher thermal conductivity produce lower temperature than tools with lower conductivity.

② Tool Geometry:-

While rake angle has only a slight infuence on the temperature. It increases considerably with increase in approach angle.

③ Cutting condition:-

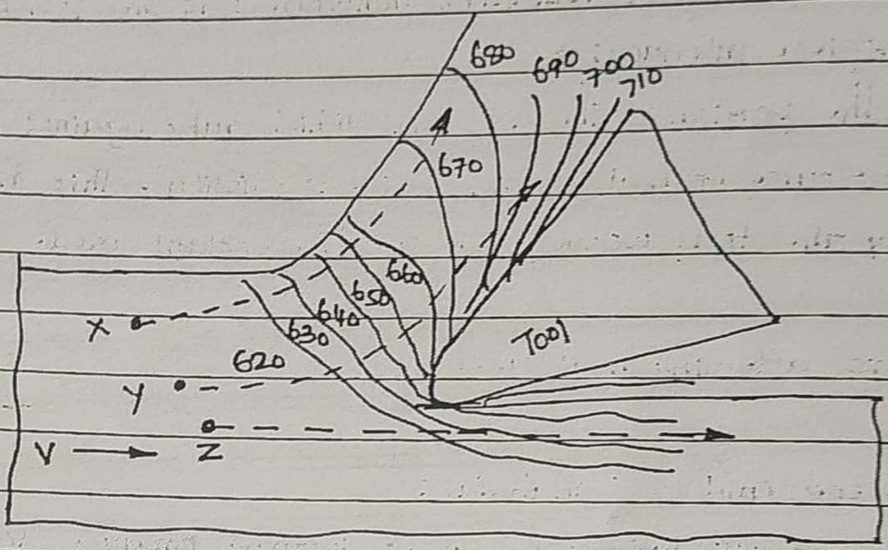
Cutting speed has predaminant effect on the cutting temperature.

④ Cutting Fluid:-

At high speed cutting speed has negligible effect on tool-chip Interface temperature. This fluid is carried away by the outward flowing chip more rapidly than it cannot be forced between the tool & the chip.

* Heat distribution in tool and Work:-

Heat distribution in work piece and chip during Orthogonal cutting (Obtained from an infrared photograph, for free-cutting mild steel where the cutting speed is 0.38 m/s, the width of cut is 6.35 mm, the working normal rake is 30°, and the workpiece temperature is 611 °c).



The maximum temperature in the cutting zone occurs not at the tool tip but at some distance further up the rake face.

→ Material at a point such as X, gets heated as it passes through the shear zone and finally leaves as a chip.

→ For points such as Y, heating continuous beyond the shear plane in to the frictional heat region. These points, however, loose shear zone heat to the chip while moving up but again frictional heat.

→ Points such as Z remain in the work piece and their temperature rises merely due to conduction of heat into the work piece.

* Measurement of tool tip temperature:

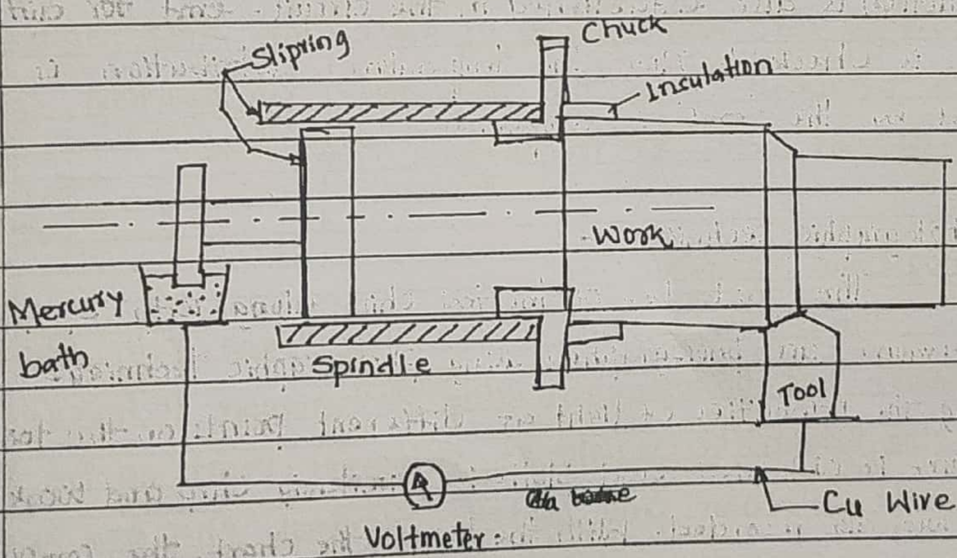
Since heat is generated during cutting, it influences the quality of the work ~~piece~~ piece and alters the tool performance. The amount of heat generated depends on the work material, tool material, cutting parameters, type of operation, machine used etc. Hence it is very essential to determine the magnitude of temperature as affected by the cutting parameters.
Determination of temperature and its distribution in the cutting tool is very important for the elimination of tool wear and enhance tool life.

* Methods used for Measurement of tool tip temperature:—

1. Using photosensitive paints:—

Certain paints are sensitive to the change of temperature when they are heated. The paint changes its colour on application of heat. This property is used for the determination of temperature. The paint is applied on to the tool and during cutting operation the change in colour is recorded. The colour is then correlated with the temperature. This is an approximate method as it depends on observing the change in the colour.

2. Tool-work as Thermocouple:—



Principle:— In a conducting circuit an 'emf' is produced between hot contact of tool and work piece and their cold ends.

Setup:—
Work is held in a chuck separated by an insulation.

A slip is fixed to the spindle with an insulation. The other end of the spindle is dipped in a mercury bath. Circuit is established between the tool-Hg bath and work through a copper wire. A voltemeter is When the cutting is being carried out the temperature of the tool rises and the emf also changes. The values of emf is noted. Now the calibration is carried out by dipping the tool tip in molten lead and the emf is recorded when the lead is cooled. The temperature of the lead is measured with a thermometer. A graph of temperature of lead V/s emf is plotted. This gives the calibration chart. Now read the temperature from the chart for the emf obtained in the earlier experiment. The temperature in the tool can be read out.

③ ~~Embedded thermocouple~~

③ Embedded thermocouple:-

A thermocouple is mounted on the rake face (a small hole is drilled and TC inserted) very near to the tip of the tool and connected to a circuit to measure 'emf' developed. A cold junction is also established in the circuit. emf for different temperature is checked. Now the temperature distribution is determined by the 'emf' Vs temperature chart.

④ Infrared photographic technique:-

The side face of the tool chip along with strips of known temperature are photographed using photographic technique. By comparing the intensities of light at different points on the tool, the temperature is obtained and plotted. Similarly chip and workpiece temperature were also recorded. With the help of the chart, the complete details of temperature can be found. The temperature distribution is also plotted on the tool.

5 ④ Control of Heat in Metal cutting operation:-

Certain liquids and gases are applied to the tool and work piece for carrying away heat during cutting operation. They are used to minimize tool wear, improve surface finish & control heat.

UNIT-2

PRODUCTION LATHE

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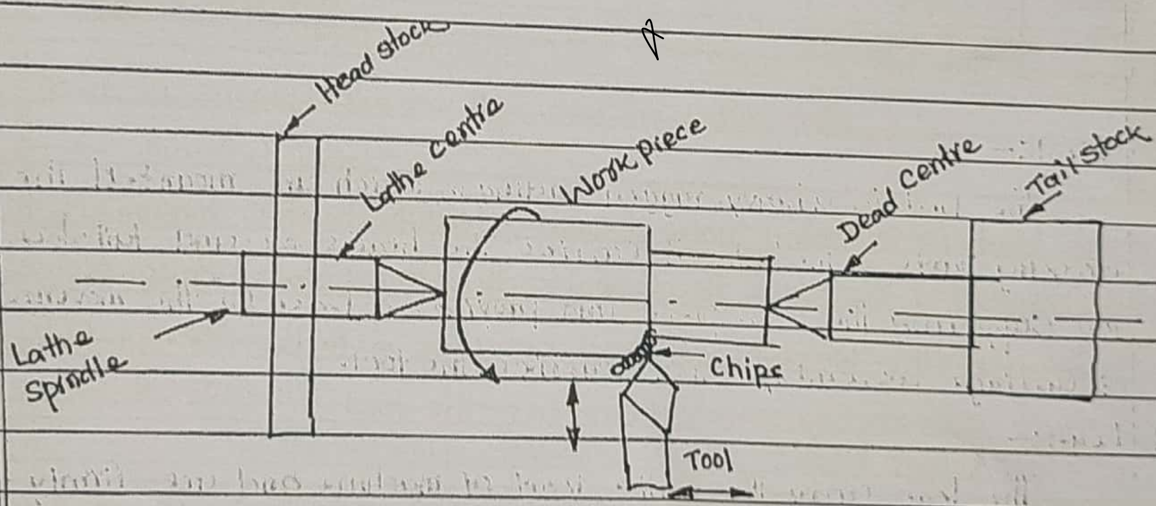
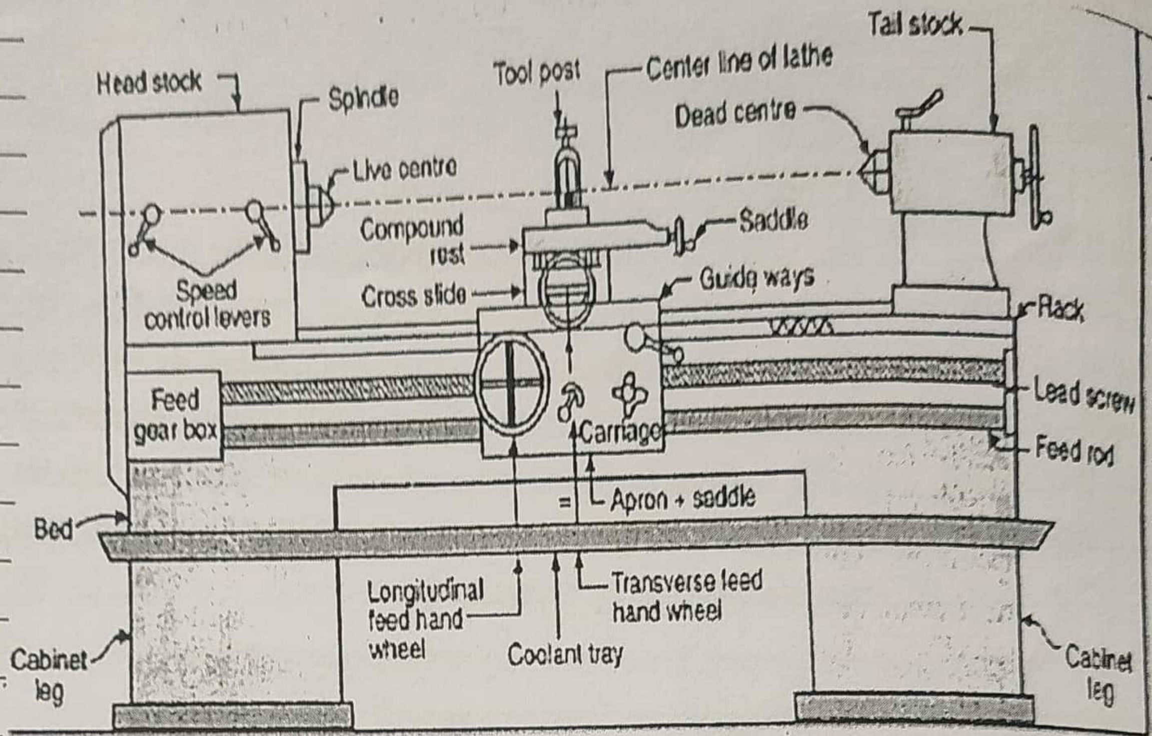
Lathe is one of the oldest machine tool. It machines the given workpiece in to required product by employing turning effect. In a lathe the workpiece revolves along with the chuck to which the motor is connected by various gears and shafts.

Working principle:—

The lathe is a machine tool which holds the workpiece between two rigid and strong supports called centers or in a chuck or face plate which revolves. The cutting tool is rigidly held and supported in a tool post which is fed against the revolving work. The normal cutting operations are performed with the cutting tool fed either parallel or at right angles to the axis of the work. The cutting tool may also be fed at an angle relative to the axis of work for machining tapers and angles.



Construction:-



① **Bed:-**

The bed is a heavy, rugged casting in which are mounted the working parts of the lathe. It carries the headstock and tailstock for supporting the workpiece and provides a base for the movement of carriage assembly which carries the tool.

② **Legs:-**

The legs carry the entire load of machine and are firmly secured to floor by foundation bolts.

③ **Headstock:-**

The headstock is clamped on the left side of the bed and it serve as housing for the driving pulleys, back gears, head stock spindle, live centre and the feed reverse gear. The headstock spindle is a hallow cylindrical shaft that provides a drive from the motor to work holding devices.

④ **Gear Box:-**

The quick-change gear box is placed below the headstock and contains a number of different sized gears.

(5) Carria Carri

(5) Carriage :-

The carriage is located between the headstock and tailstock and serves the purpose of supporting, guiding and feeding the tool against the job during operation.

The main parts of carriage are;

→ The saddle:-

The saddle is an H-shaped casting mounted on the top of lathe ways. It provides support to cross-slide, compound rest & Tool post.

→ The cross slide:-

The cross slide mounted on the top of saddle, and it provides a mounted or automatic cross movement for the cutting tool.

→ The compound rest:-

The compound rest is fitted on the top of cross slide and is used to support the tool post and the cutting tool.

→ The tool post:-

The tool post is mounted on the compound rest, and it rigidly clamps the cutting tool or tool holder at the proper height relative to the work centre line.

→ The apron:-

The apron is fastened to the saddle and it houses the gears, clutches and levers required to move the carriage or cross slide. The engagement of split nut lever and the automatic feed lever at the same time is prevented the carriage along the lathe bed.

(6) Tail stock:-

The tailstock is movable casting located opposite the headstock on the ways of the bed. The tail stock can slide along the bed to accomodate different lengths of workpiece between the centers. A tail stock ~~c~~ ~~stride~~ ~~clamp~~ clamp is provided to lock the tailstock at any desired position. The tail stock spindle has an internal taper to hold the dead centre and the tapered shank tools such as reamers and drills.

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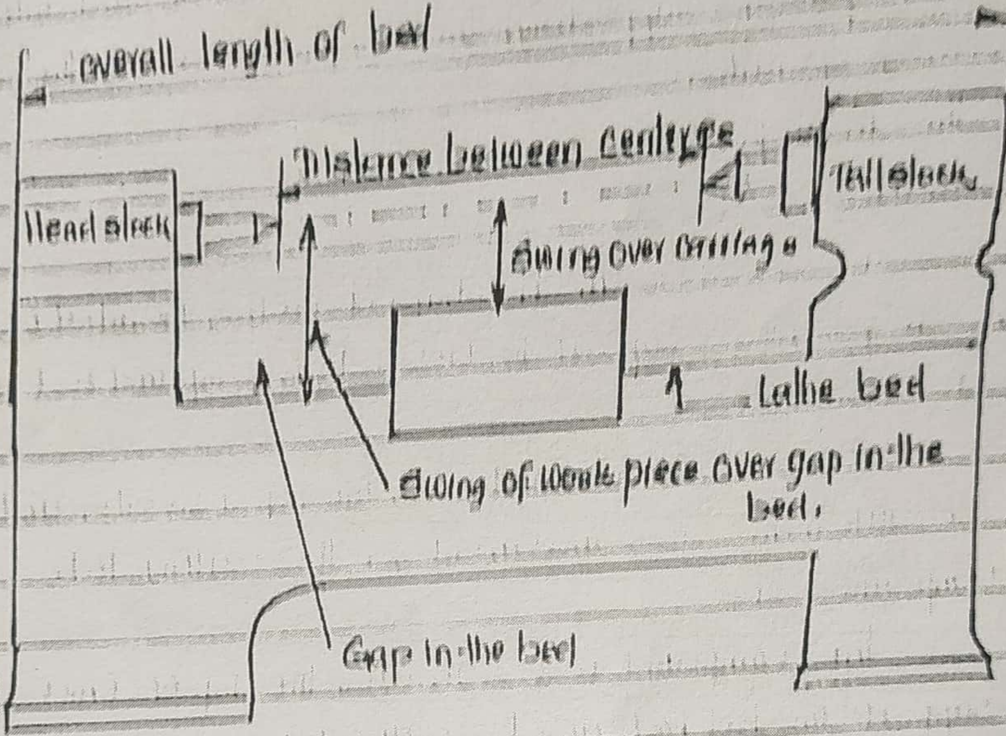
Lathe specifications

Lathe specification/

Size of a lathe is specified in any one of the following ways



① The height of the centers measured over the lathe bed

② Swing or maximum diameter that can be rotated over the bed ways.

③ Swing or diameter over carriage. This is the largest diameter of work that will revolve over the lathe saddle.

④ Maximum job length in mm that may be held between the centers. (Head stock and Tail stock centres).

⑤ Bed length in metres which may includes the headstock length also.

Classification of Lathes:-

① Speed Lathe:-

In this lathe spindle can rotate at a very high speed with the help of a variable speed motor built inside the head stock of the lathe. It is used mainly for wood working, Centering, metal spinning & Polishing etc.

② Engine or Centre lathe:-

It is the most common types of lather and is widely used in workshop. The speed of the spindle can be widely varied as disered which is not possible in a speed lathe. The cutting tool may be feed both in Cross and longitudinal directions with reference to the lathe axis with the help of a carriage.

③ Bench lathe:

It is usually mounted on a bench. It is very similar to speed or Centre lathe the only difference being it is smaller in size which enables it handle small work.

④ Tool room lathe:-

It is similar to an engine lathe, designed for obtaining occuracy. It is used for manufacturing precisions components, dies, tools, Jigs etc. and hence it is called as tool room lathe.

⑤ Turret and Capstan lathe:

These lathes have provision to hold a number of tools and can be used for performing wider range of operations. These are perticularly suitable for mass production of identical parts in minimum time.

⑥ Automatic lathes:-

These lathes are designed that the tools are automatically fed to the work and withdrawn after all operations, to finish the work are complete. They require little attention of the operator, since the entire operation is automatic. These are used for mass Production of identical parts.

⑦ Special purpose lathe:-

These lathes are primarily designed for carrying out a perticular operation with utmost efficiency.

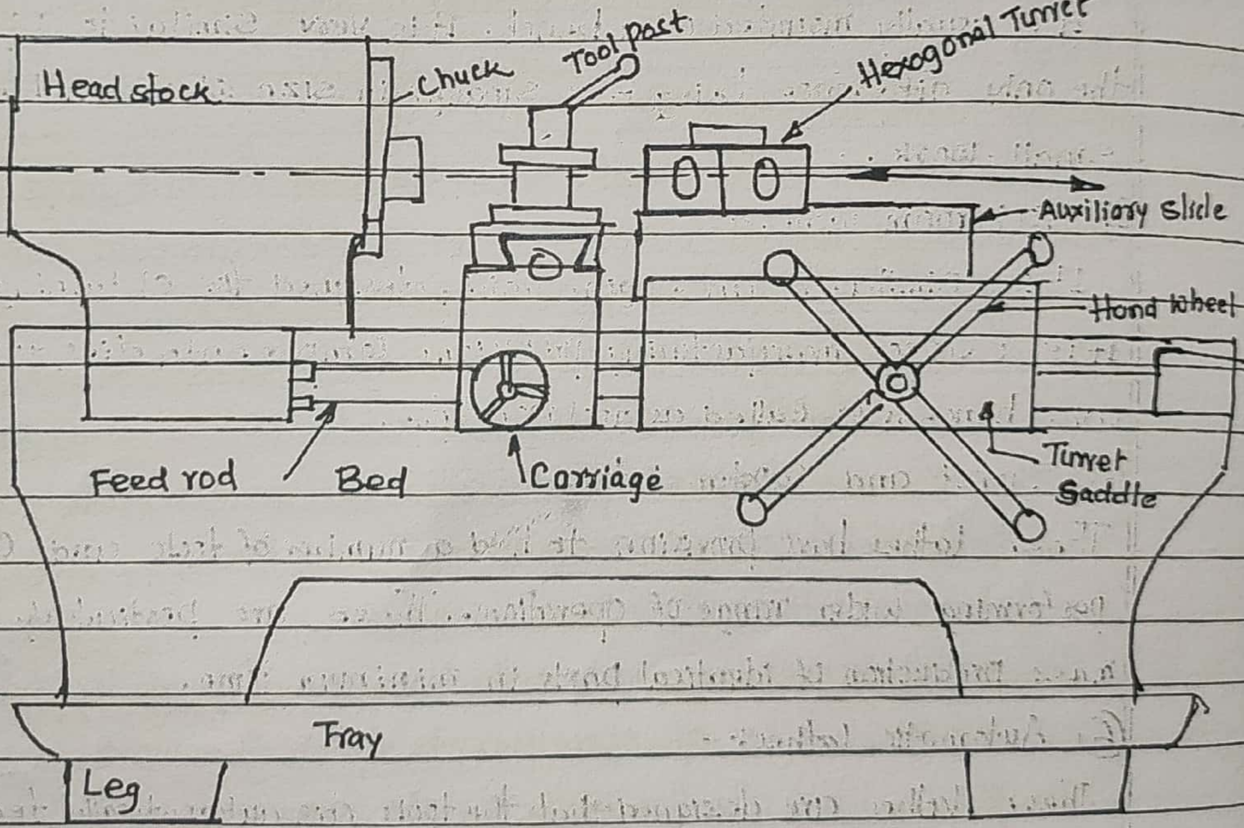
Scanned with CamScanner

Capstan & Turret Lathe:-

Constructional Features:-

Some major auxiliary motions and handling operations like bar feeding, speed change, tool change etc. are done quickly and consistently with lesser human involvement. The operators need lesser skill and putting lesser effort and attention. Suitable for batch or small production. Costlier than Centres lathe of same capacity.

Capstan Lathe and Turret lathe



Capstan & Turret lathe:-

→ They have essentially the same parts of an engine lathe except the turret and complex mechanism of feeding/indexing.

→ They consists of bed, a geared head stock and saddle, on the saddle four station tool post is mounted and carries four different tools.

→ In place of tail stock a hexagonal turret is mounted on the slide. The slide rests on the bed.

→ The turret is six faced and carry six different tools. The turret can be made to rotate about vertical axis and can be slide the saddle or on the bed and the tools mounted on it can be fed on to the work.

→ The longitudinal feed and cross feed of the saddle and cross slide are controlled by adjustable stops.

→ With the helps of these stops, different tool can be set at different stations and can move at predetermined distances to perform a series of operations in sequence.

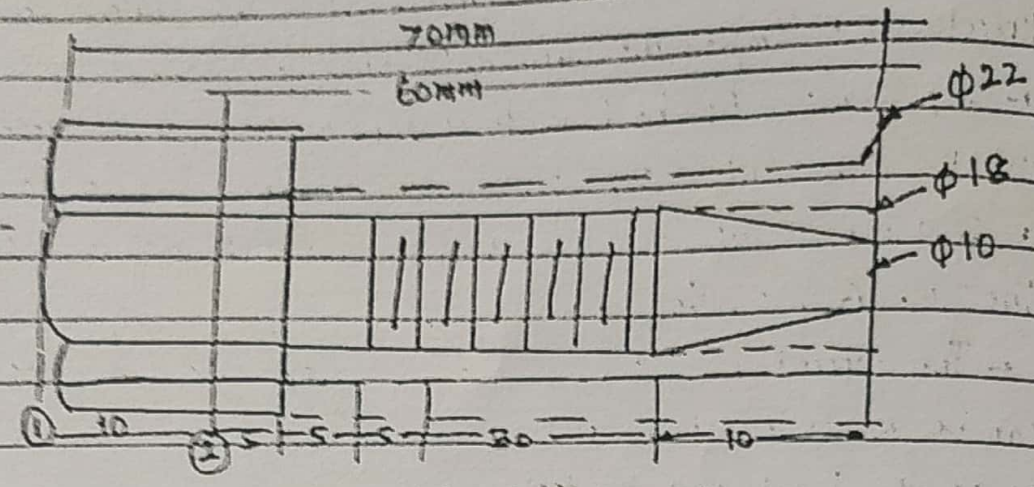
Tool Layout:-

→ Heavy turret being mounted on the saddle which directly slides with larger stroke length on the main bed.

→ One additional guide rod or pilot bar is provided on the head stock of the turret lathe, to ensure rigid axial travel of the turret head.

→ External screw threads are cut in capstan lathe if required using a self opening die being mounted in one face of the turret. Where as in turret lathes external threads are generally cut, if required by a single point or multi point chasing tool being mounted on the front slide & moved by a short leadscrew & a swing type half nut.

Tool Layout :-



Operation	Portion operation	Tool portion	Tools	Remarks.
①	Hold the bar in collet	1st turn	Bar stop	70mm bar set
②	Turn bar to the 22 dia for 60mm	2nd turret	Roller steady bar turning	
③	Turn the bar to 18 dia for 50mm length	3rd Turret	"	
④	Taper turning to get 10 dia at the end & 18 maintained at the other end	4th Turret	form tool	
⑤	Groove Cutting	Four way turret	Parting tool	
⑥	Thread cutting	5th Turret	Die head	
⑦	Chamfering	Four way turret	Chamfering tool	
⑧	Parting off	Four way turret	Parting tool	

~~Tool Working devices~~:-

Tool & Work holding devices:-

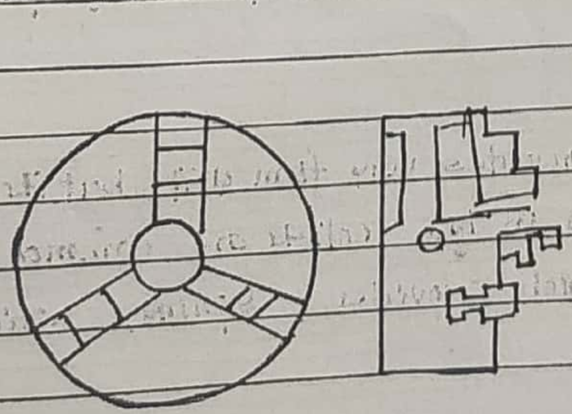
The devices employed for handling and supporting the work and Tool on the lathe are called its accessories.

① **Chucks:-** The chucks provide a very efficient and true device of holding work on the lathe during the operation.
Some of the commonly used chucks are

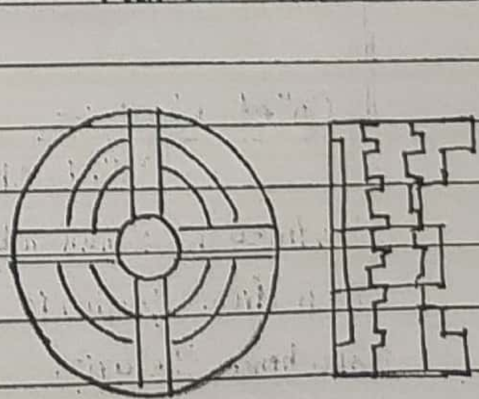
→ Three Jaw universal chucks
→ Four Jaw independant chuck
→ Combination chuck (Three Jaw & Four Jaw)
→ Magnetic chuck
→ Air or hydraulic chucks
→ Collet chuck.

Chucks are most commonly used work holding device and one of the most important devices for holding and rotating a workpiece in a lathe. Work piece of short length, large diameter or irregular shapes. large diameter work piece etc can be held quickly and rigidly. It is attached to the lathe spindle by means of bolts with back plate screwed on to the spindle nose.

Three Jaw chuck



Four Jaw Chuck



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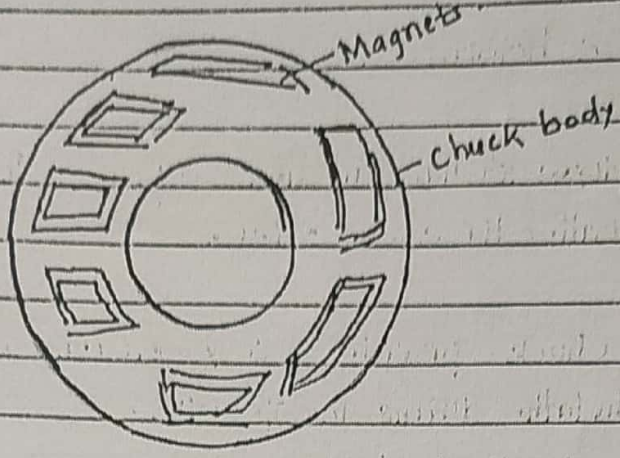
Magnetic Chuck:-



It implies the use of electric current for developing a strong electromagnetic which holds the job e centrally in the chuck. Although many designs of these chucks are prevalent, still the rotary Type is in common use. The principle involved in the working of these chucks is that magnetic flux is produced either by electromagnets or by permanent magnets in the latter case, due to which the work is held. When the operating lever brings the magnets to 'ON' position the flux created inside the chuck passes through the work and hence holds it.

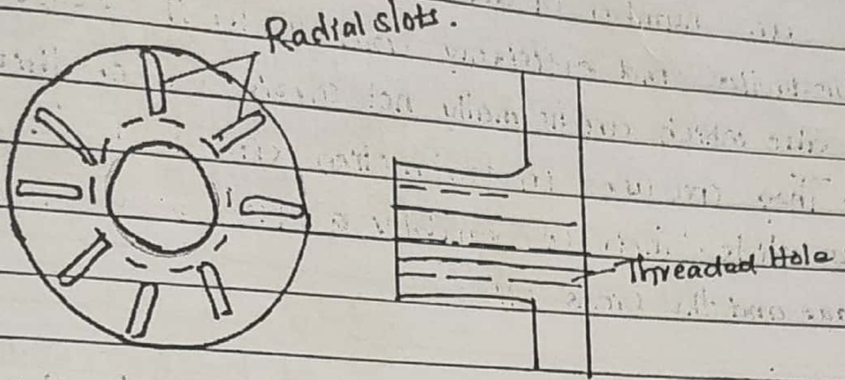
Air or Hydraulic Chuck:-

Air or hydraulic pressure is used for pressing the Jaws against the job. The pressure is provided by a cylinder & piston mechanism, fitted at the rear of the head stock, and is controlled by a valve by the operator. These chucks are very quick acting & provide a very firm grip.

Collet chuck:-

Collet chuck which provides very firm grip, but its use is confined to small jobs only. Draw-in type collets are common use. Their front portion is splitted which provides a springy action and hence the grip.

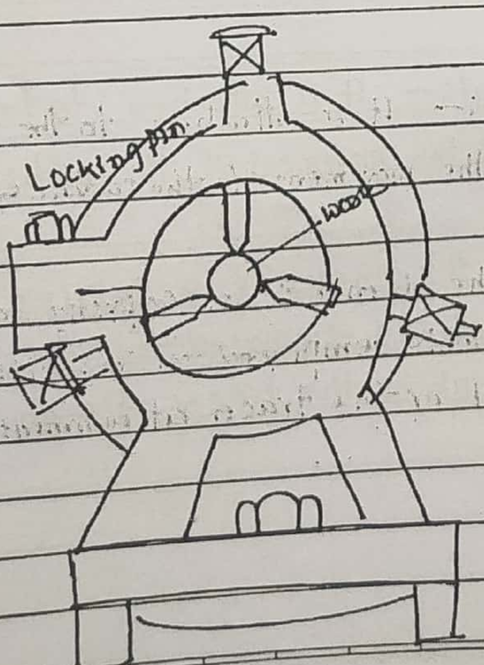
Face plate :-



Holes and slots are provided on both faces so that it may be clamped on a face plate and can hold the work piece on the other face by slots & clamps. Angle plates are used in conjuction with a face plate when holding surface of the work piece should be kept horizontal.

Rest :-

A rest is mechanical device which supports a long slender work piece used at some intermediate point to prevent bending of work due to its own weight and vibration due to cutting forces. A rest should be used when length of 10-12 times the diameter is there.



Lathe attachments:-

There are number of attachments which are used on Centre lathe to increase production and efficiency and widen its scope of use for such works also which are normally not carried out on this machine.

1) stops:- They are used in conjunction with both the carriage as well as cross-slide. Their use enables a quick & accurate positioning of the carriage and the cross-slide.

2) Grinding attachments:- It consists of bracket, which is mounted on the cross-slide, a grinding wheel and separate motor. Thus the grinding wheel is driven separately by this motor. The job is held as usual in a chuck or between centre and the rotating grinding wheel is fed against the job. Attachment for internal and external grinding are also available.

3) Milling attachments:- This attachment consists of vertical pillar to which is attached an individual motor & device to mount the cutter on it. Base of the pillar is fastened rigidly to the saddle in front of the lathe & the unit carrying the motor & the cutter can moved vertically up and down by means of a screw & hand wheel provided at the top of the pillar.

4) Taper turning attachment:- It is attached to the rear side of the lathe and is operated through the movement of the saddle & the cross-slide.

5) Copying attachment:- In the absence of a copying lathe the common Centre lathe can be easily employed for repetition work. For this the copying attachment or the tracer attachment is reqd to be fitted to it.

(8) **Relieving attachment:-** Relieving is usually done on most of the multi point tools such as milling cutters, taps & reamers etc. with the help of the relieving attachment this operation can be performed on a centre lathe. This attachments consists of an auxiliary slide mounted on the cross-slide in place of the compound rest.

Lathe operations:-

1. Turning operation
2. Facing "
3. Chamfering "
4. Taper turning "
5. Knurling "
6. Drilling "
7. Thread cutting "
8. Grooving "

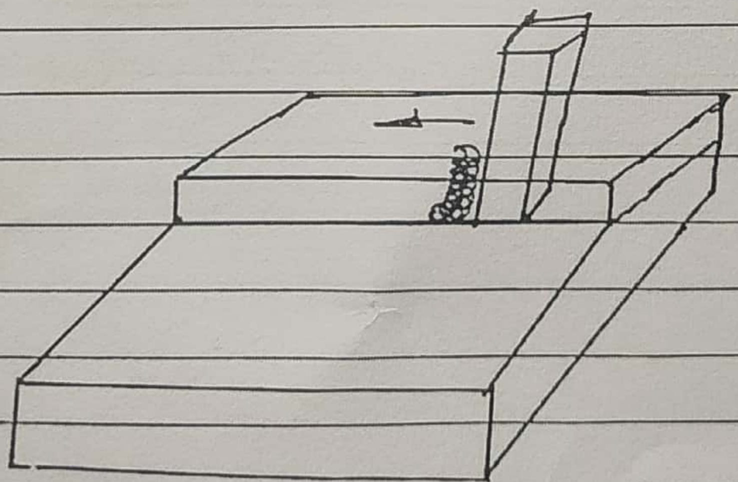
Refer Dr. K. Radhakrishna Book

Shaping Machine:-

A Shaper is a versatile machine which is primarily intended for producing flat surfaces. These surfaces may be horizontal, vertical or inclined. This machine involves the use of a single point tool held in a properly designed tool box mounted on a reciprocating ram. The main significance of this machine lies in its greater flexibility on account of ease in work holding, quick adjustment & use of tools of relatively simple design.

Working principle of a Shaper:-

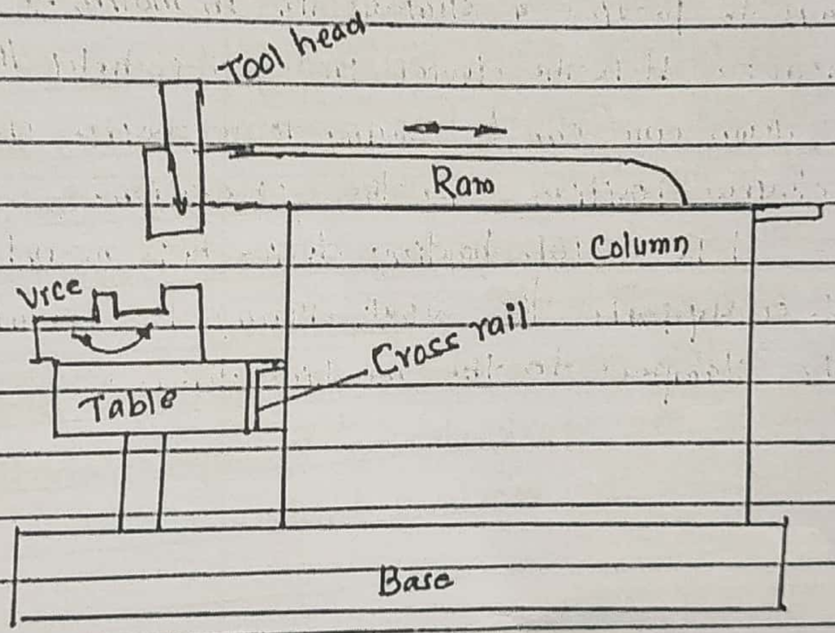
In case of shaper, the job is rigidly held in a suitable device like a vice / clamped directly on the machine table. The tool is held in the tool post mounted on the ram of the machine. This ram reciprocates to and fro and in doing so makes the tool to cut the material in the forward stroke. No cutting of material takes place during the return stroke of the ram. Hence it is termed as 'idle' stroke.



Classification of Shaping machine:-

1) Standard shaper.
2) Draw-cut shaper
3) Horizontal shaper
4) Universal shaper
5) vertical shaper
6) Geared shaper.
7) Crank shaper
8) Hydraulic shaper.

Principal parts of shaping Machine.



1) Base:- It is heavy & robust cast iron body which is act as a support for all the other parts of the machine which are mounted over it.

2) Column:- It is a box type cast iron body, mounted on the base and act as housing for the operating mechanism of the machine & the electricals. It also act as support for other parts of the machine such as cross rail & ram.

Cross-rail — It is heavy cast iron construction attached to the column at its front of the vertical guideways. It carries two mechanisms, one for elevating table & other for cross traverse of the table.

Table:- It is made up of cast iron and has a box type construction. It holds and supports work during the operation & slides along the cross-rail to provide feed to the work. T-slots are provided on its top and sides ~~for~~ securing the work to it.

~~5)~~ Ram:- It is also iron casting, semi circular in shape & provided with a ribbed construction inside for rigidity and strength. It carries the ~~tool~~ tool head & travels in dovetail guideways to provide a straight line in motion to the tool.

Tool head:- It is the device in which is held the tool. It can slide up and down and can be swung to a desired angle to set the tool at a desired position for the operation.

Vice:- It is a job holding device & is mounted on the table. It holds & supports the work during the operation. The job directly clamped to the machine table.

Shaper operations:-

Using a shaper intermittent cutting operation can be carried

It can be used for machining horizontal surface, vertical surface, angular surface, to cut external keyway, to cut internal

Table 9.2. Differences between a turret lathe and a capstan lathe

S. No.	Aspects	Turret lathe	Capstan lathe
1.	*Turret position*	Turret (head) is mounted *directly on the saddle.*	Turret is mounted on an auxiliary slide, which *moves on the guideways provided on the saddle.*
2.	*Feeding of tools*	For feeding the tools entire saddle is moved.	The saddle is fixed at a convenient distance from the work and the tools are fed by moving the slide.
3.	*Extent of rigidity*	Very high rigidity because all the cutting forces are transferred to the lathe bed.	Because of the overhung of the slide or ram, the tool support unit is subjected to bending and deflection, resulting in vibrations.
4.	*Capability to handle jobs*	Can handle *heavier jobs* (as a consequence of No. 3) involving heavy cutting forces and severe cutting conditions.	Since this type of lathe cannot withstand heavy cutting loads, therefore its use is confined to *relatively lighter and smaller jobs and precision work.*
5.	*Maximum bar size that can be handled*	Upto 200 mm diameter.	Upto 60 mm diameter.
6.	*Tool travel*	*Almost full length of the bed* (since the turret saddle directly rides over the bed way).	*Limited tool travel* (since the tool feeding is done by the traverse of the slide).
7.	*Rate of tool feeding*	Relatively slower and as such provides more fatigue to the operator's hands.	The tool traverse is faster and offers less fatigue to the operator's hands.
8.	*Type of carriage*	Reach-over type or side hung type.	Usually equipped with the reach-over type only since it is employed for relatively smaller jobs and therefore, does not require a large swing over bed; moreover this type of carriage provides better rigidity.
9.	*Other provisions*	• Heavier designs are usually provided with pneumatic or hydraulic chucks to ensure a firmer grip over heavy jobs • Provision for cross feeding of the hexagonal turret (in some designs) to enable cross feeding of turret head tools.	These lathes do not have such provisions.

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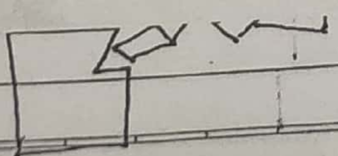


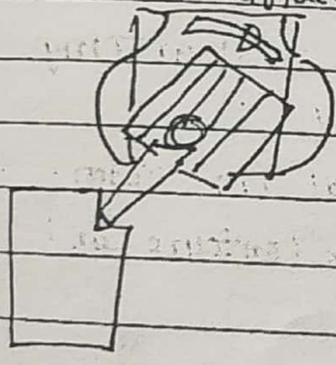
micrometer provided on the ram. Tool is made reciprocate & the hand wheel is rotated to cut the metal. Angular machining is obtained, Shaper operations:—

Using a shaper intermittent cutting operation can be carried out? It can be used for machining horizontal surface, vertical surface angular surface, to cut external key way, to cut internal key way, irregular surface to cut grooves on the surface to, to cut grooves on the circumference.

① Horizontal surface machining:—

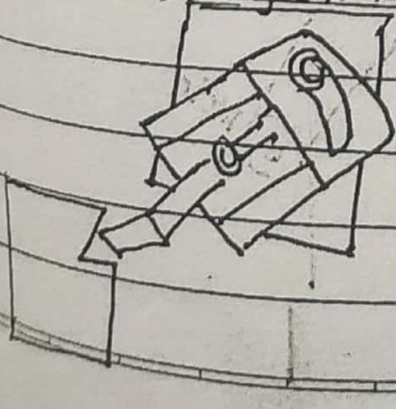
The tool is set in the tool holder the depth of cut is adjusted by turning the handle w.r.t dial micrometer. The crossfeed screws is engaged and the machine is operated. The tool traverse from one end ~~to~~ of the work to the other end removing the metal. A flat horizontal surface is created.

② Vertical surface machining.



Here the tool is set as usual. The apron is tilted such that there is no interference of the tool holder and the workpiece. The stroke length of the tool is ~~adjus~~ adjusted. By operating the hand wheel on the tool head holder the tool is allowed to take cut during forward direction. Depth of cut is given progressively so that the tool progresses slowly during every forward stroke.

③ Machining angular surfaces:—



Here the tool head of the shaper is tilted as well as apron. The desired angle is set by adjusting tool head wrt the angular micrometer provided on the ram. Tool is made reciprocate & the hand wheel is rotated to cut the metal. Angular machining is obtained,

Slotting Machine:-

Basically the slotting machine is a vertical axis shaper. The chief difference between shaper and slotter is the direction of the cutting action. the tool moves vertically rather than in horizontal direction.

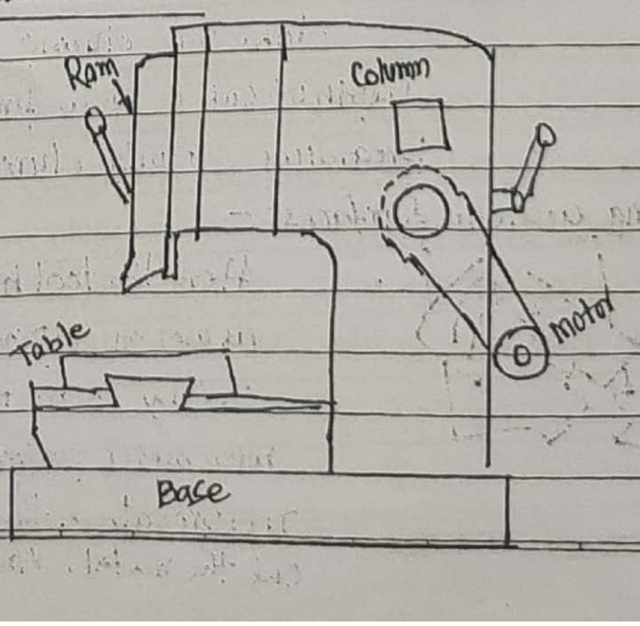
The slotter has a vertical ram and a hand or power operated rotary table. On some machines the ram may be inclined as much as 10° to either side of the vertical position when cutting inclined surface.

The stroke of ram is smaller in slotting machines than in shapers to account for the type of work that is handled in them.

Use of slotter:-

1. Internal machining of blind holes
2. Work requiring machining on internal sections such as splines, keyways, various slots & grooves and teeth.
3. Machining of die, punches, straight & curved slots.
4. Cutting of teeth on ~~rachet~~ ratchet or gear rings which require primarily rotary feed.
5. By combining cross, ~~longid~~ longitudinal and rotary feed movements of the table, even complex contours can be machined.

Constructional feautures:-



Base:- It is also known as bed and is a heavy cast iron construction. It act as a support for the column, the driving mechanism ram, table and all other fittings.

Column:- It is also made up of cast iron. It act as housing for the complete driving mechanism. Its front face has guideways for the reciprocatory ram.

Table:- On slotting machines, usually a circular table is provided. However in some heavy duty slotters, such as a puncher slotter, either a rectangular or circular table can be mounted. On the top of the table T-slots are provided to clamp the work or facilitate the use of fixtures etc.
The table can be moved is horizontal plane by two perpendicular cross-slide.

Ram:- It moves in vertical direction between the vertical guideways provided infront of the column. The ram supports the tool head to which the tool is attached. The cutting action takes place during the downward movement of the ram.

Types of slotters:-

1) Punche slotter:
2) General production slotter
3) Precision tool room slotters
4) Key slotter.

Slotter operations.

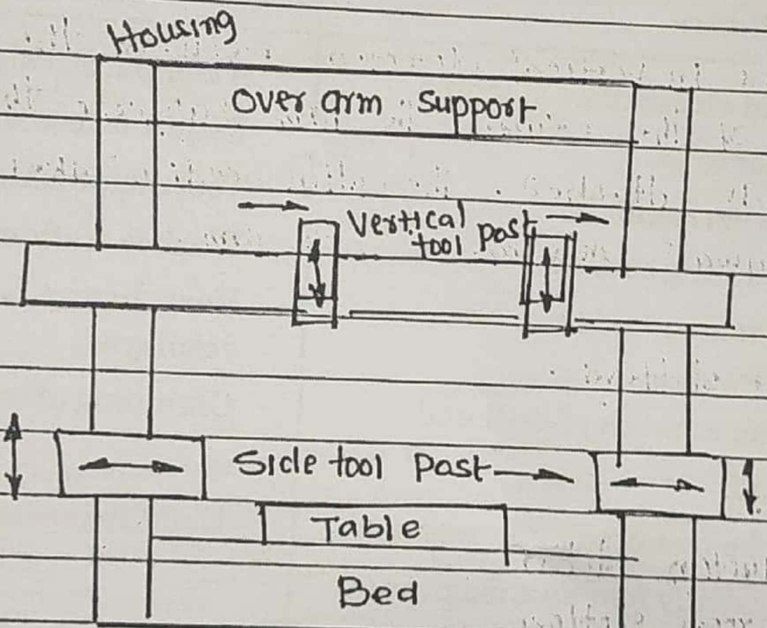
1) Cutting of internal grooves or key ways
2) Cutting of internal gears
3) Cutting of recesses.

Planing Machine

A planer is reciprocating type machine tool, similar to a shaper. In a planer the work piece mounted on the table generally reciprocates and the tool is mounted on the cross-rail provides the necessary cross feed. Cutting of the metal takes place due to relative motion between the work piece and the tool. Feed is provided by the lateral movement of the tool.

A planer is the largest of the reciprocating machines. larger work pieces can be handeled and heavier cuts can be given. A planer is primarily used for machining plane and flat surfaces by using single point cutting tool.

Constructional Features:-



Bed:-

Table:-

Column / Housing

Cross-rail:- It is mounted on the precision machined ways of the two housing. It may be raised or lowered on the housings to accomodate work of different heights on the table & allow for the adjustment of the tools.

Tool heads:-

9.7.3. Comparison between Planer and Shaper

Comparison between a planer and a shaper is given in the Table 9.3 below :

Table 9.3. Comparison between Planer and Shaper

S.No.	Planer	Shaper
1.	Heavier, more rigid and costlier machine.	A comparatively lighter and cheaper m
2.	Requires more floor area.	Requires less floor area.
3.	Work reciprocates horizontally.	Tool reciprocates horizontally.
4.	Tool is stationary during cutting.	Work is stationary during cutting.
5.	Heavier cuts and coarse feeds can be employed.	Very heavy cuts and coarse feeds employed.
6.	Work setting requires much of skill and takes a longer time.	Clamping of work is simple and easy.
7.	Several tools can be mounted and employed simultaneously, usually four as a maximum, facilitating a faster rate of production.	Usually one tool is used on a shaper.
8.	Used for machining large size workpieces.	Used for machining small size comparatively.

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* Driving Mechanism of Shaper:
  1. Crank & Slotted Link.
  2. Whitworth quick return
  3. Hydraulic drive.
* Slotter drive mechanism:

Refer Dr. K. Radhakrishna Book

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UNIT-3.

DRILLING MACHINES:-

Drilling is a process of making hole or enlarging a hole in an object by forcing a rotating tool called 'Drill'. The drill is generally called as 'twist drill' since it has a sharp twisted eges formed around a cylindrical tool provided with a helical grooves along its length to allow the cut material to escape through it. The sharp edges of the conical surface around at the lower end of the rotating twist drill cut the material by ~~peeling~~ peeling it circularly layer by layer when forced against a work piece.

A power operated machine tool which holds the drill in its spindle rotating at high speed and when manually actuated to move linearly simeltaneously against work piece produces a hole is called drilling machine.

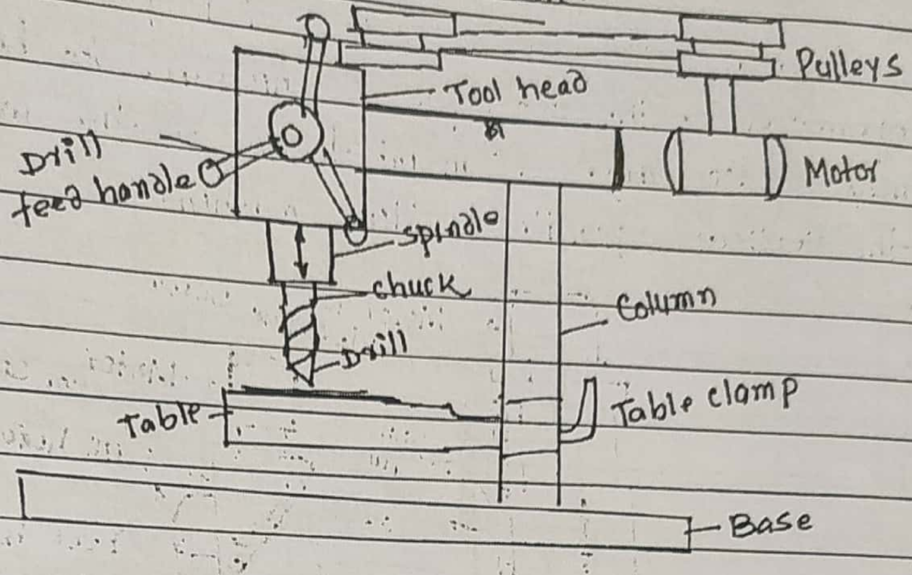
Drilling machine is one of the simplest, moderate and accurate machine tool used in production shop & tool room. It consists of a spindle which imparts rotary motion to the drilling tool, or mechanism for feeding the tool into the work, a table on which the work rests and a frame.

Types of drilling machines:

Drilling machines are manufactured in various sizes & varieties to suit the differently types of work.

1) Portable drilling machine
2) Sensitive or bench drilling machine
3) Upright drilling machine
4) Radial drilling machine
5) Gang drilling machine
6) Multiple spindle drilling machine
7) Automatic drilling machine.

Sensitive or Bench drilling machine:—

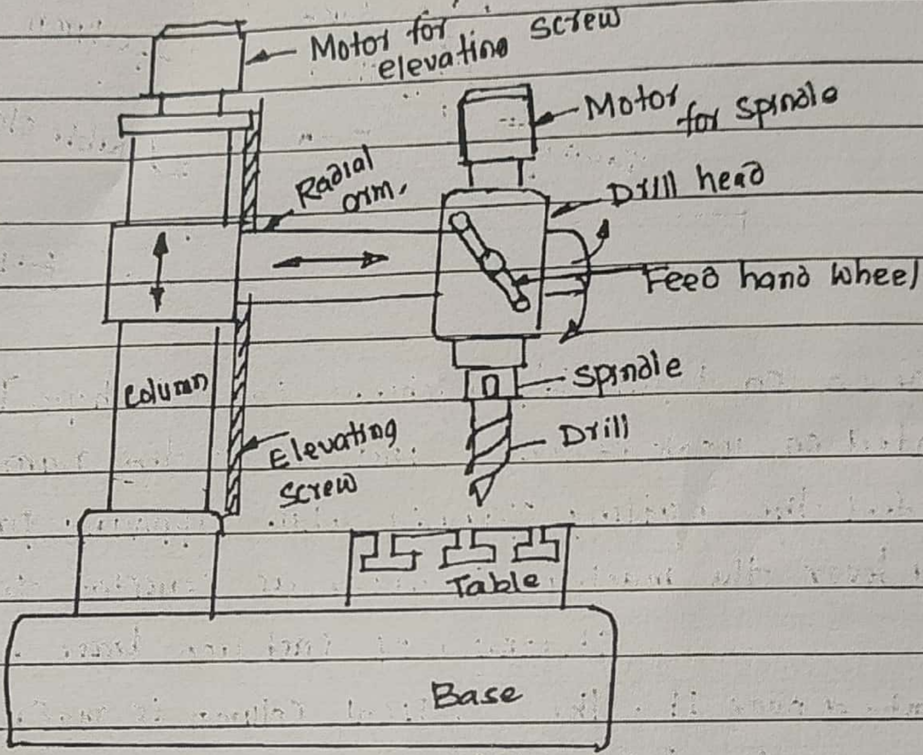


These ar light duty machines in workshops. They are normally mounted on work benches and hence the name. As the operator can feel the cutting operation while applying pressure using the feed lever, the machine is known as sensitive drilling machine.

It consist of cast iron base with a vertical column mounted over it. The vertical column is made of hallow steel pipe on which the table slides up and down. The table can be fixed to the required position by means of a table clamp. The lable can also be swung radially at any desired position. The ~~teof~~ top of the column houses the drive consisting of endless belt running over the V-pulleys. Based on the spindle required V-belt can be shifted to different grooves of the pulleys. To drill small diameter holes, a twist drill is fitted in the drill chuck, which in turn fits into the spindle of the machine. This designed is used to drill hole from 1.5 mm to 15 mm diameter. The controls are light and delicate speeds from 800 to 900 rpm.

Radial drilling machine.

Radial drilling machine is used to perform the drilling operations on the work pieces which are too heavy and also may be too large to mount them on the work table of the vertical spindle drilling machine.



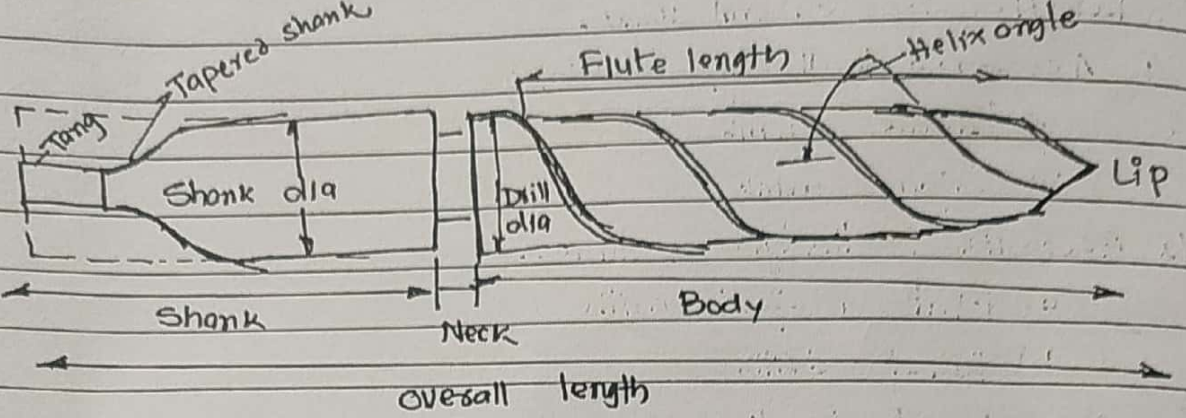
It consists of heavy base and vertical column with along horizontal radial arm extending from and can be radially rapidly raised, lowered and swung in horizontal plane about the main column to any desired location. The drilling head can be to and fro along the arm and can be swivelled only in the universal radial drilling machines to drill holes at an angle. The combinations of motions of the radial arm and drilling head offer a great deal of flexibility in moving the drill to any position. The main advantage of radial drilling machine is that the drilling can be carried out on heavy work pieces in any position without moving them.

Classification of Drills:-

The tool used for drilling is drill. The commonly used drills may be classified in several ways.

1. According to the type of shank
   a) Parallel shank
   b) Taper shank
2. According to the type of flutes.
   a) Flat or spade drills
   b) Twist drills
3. According to length
   a) Short series drills
   b) Stub series drills
   c) long series drills
4. According to the applications
   a) Core drills
   b) Drill for long hole drilling
   c) Centre drills
   d) Masonry drills
5. According to the tool material
   a) High speed drills
   b) carbide tipped drills.

Twist Drill Nomenclatures:



The elements of a twist drill. The twist drills consists of mainly two parts body and shank. Bothe are saparated by a neck. Two long and diametorically opposite helical groover called flutes run throughout the length of the drill.

1) Body:-

The body is the portion of the drill which extends from its extreme points upto the neck or shank of the drill. It consists of body clearence, chiesel edge, face, flank, flutes, heel, land point, lip and web.

* Body clearence:- It is the portion of the body surface with reduced diameter which provides diametral clearance.
* Face:- It is the portion of the flute adjacent to the lip on which chip flows as it is cut from the w/p.
* Flank:- It is the conical surface of the drill point which extends behind the lip to the following flute.
* Flutes:- These are helical groover cut on the cylindrical surface of the drill & provide the lip.
* Heel:- It is the edge formed by the intersection of flute surface and the body clearence.
* Land:- It is the cylindrically ground narrow strip on the leading edges of drill flutes.

* Point:- It is the cone shaped sharpened end of the drill that produces lips, faces, flanks & chiecol edges of the drill.
* Lips:- The lips also known as cutting edges, are the edges formed by the Intersection of the flanks and faces.
* Web:- It is the thickness of the drill between the flutes which extends from Point towards the shank.

Shank:- The shank is cylindrical portion of the drill which is used to hold and drive the drill. It extend from the neck and it may be either straight or tapered.

Tang:- It is flattened end of the tapered shanks which fits into socket. It ensures positive drive of the drill from the drill spindle.

Drilling operations:

In addition to drilling, the following operations are carried out on a drilling machine.

1. Reaming operation
2. Boring "
3. counter-boring "
4. counter-sinking "
5. Spot-facing "
6. Tapping "
7.

Refer Dr. K. Radhakrishna Book

Milling Machines:

Milling machine is a machine tool in which metal is removed by means of a revolving cutter with many teeth, each tooth having a cutting edge which removes metal from a work piece. In milling machine the work is supported by various methods on the work table.