ROHINI

COLLEGE OF ENGINEERING & TECHNOLOGY

Unit - 1

Theory of metal cutting

Cutting Tools
- → Single Point Tool (Lathe, Slotting, Shaper tool)
- → Multi point tool (Milling Cutters, Broaching tool)

Factors that have a predominant influence on metal cutting:-

① Cutting tool Geometry → Rake angle, → Clearance angle.

② work & cutting Tool material

③ Cutting speed ④ feed

⑤ Depth of Cut ⑥ Cutting fluids used.

Rake angle & Clearance angle:-

* "Rake angle" is the angle b/w the Rake face of the cutting tool & the line ∥" to the base of the tool (or) It is the angle b/w the Rake face and the line normal to the machining direction.

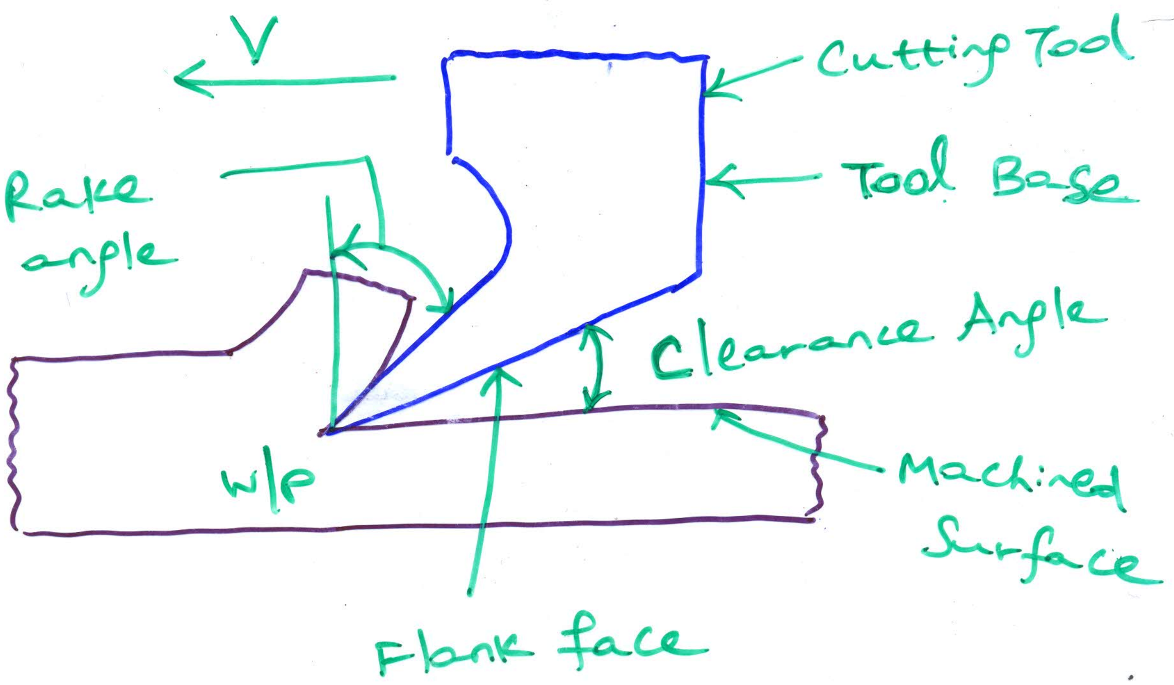
Significance of the Rake angle:-

① It specifies the ease with which a metal is cut.

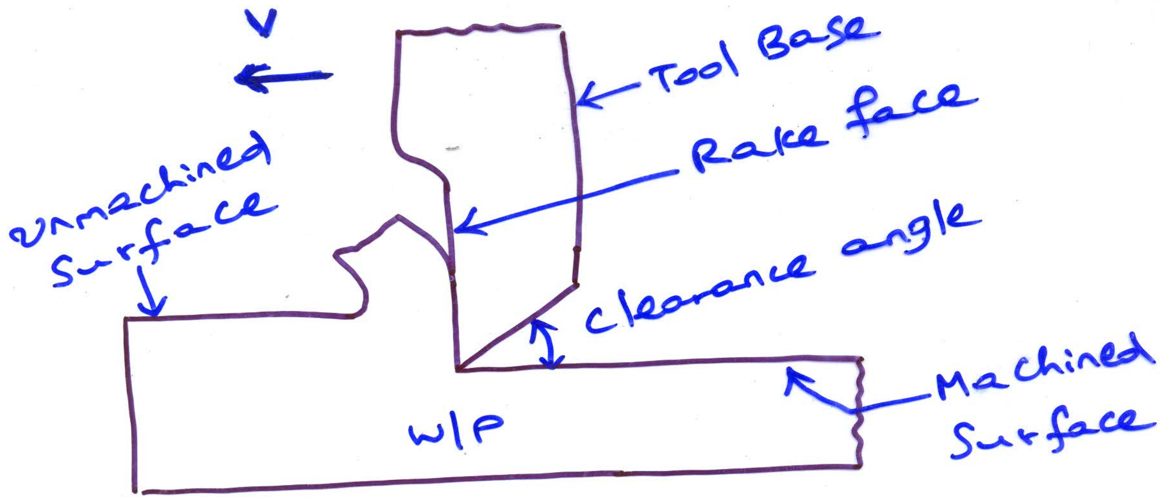
② Higher the rake angle, better is the cutting and less are the cutting forces.

Note:-

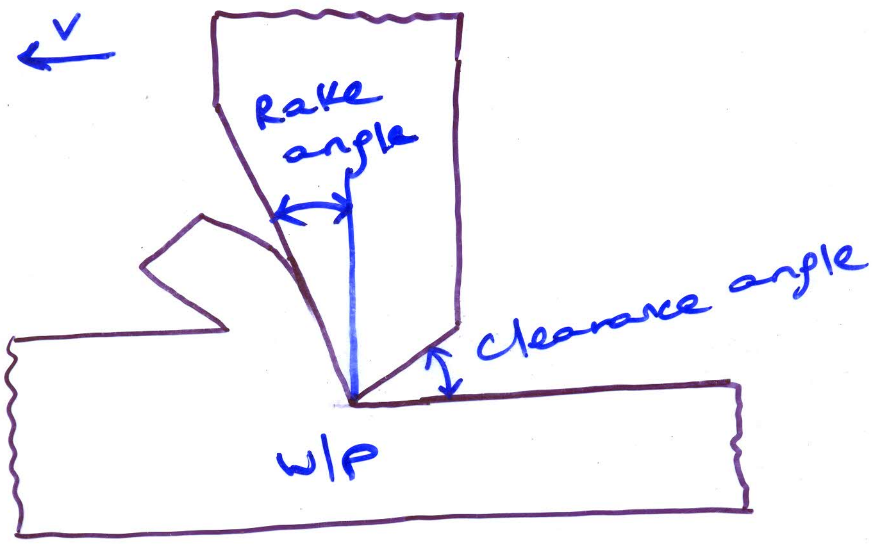
* The maximum limit for the rake angle is 15°
* Zero & negative rake angle is used for giving extra strength to the tool tip. These tools are used for m/cing highly hard material such as Carbides (or) Diamond.



(a) Positive Rake angle



(b) Zero (or) Neutral Rake angle



(c) Negative Rake angle

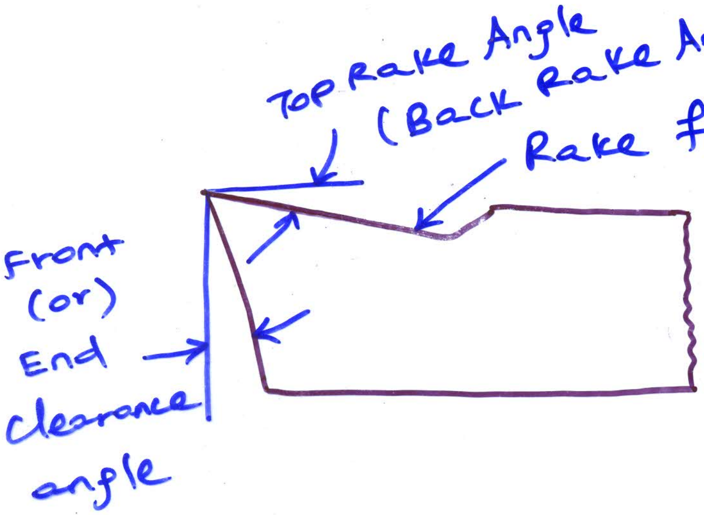
"Clearance Angle" is the angle b/w the machined surface and the flank face of the tool.

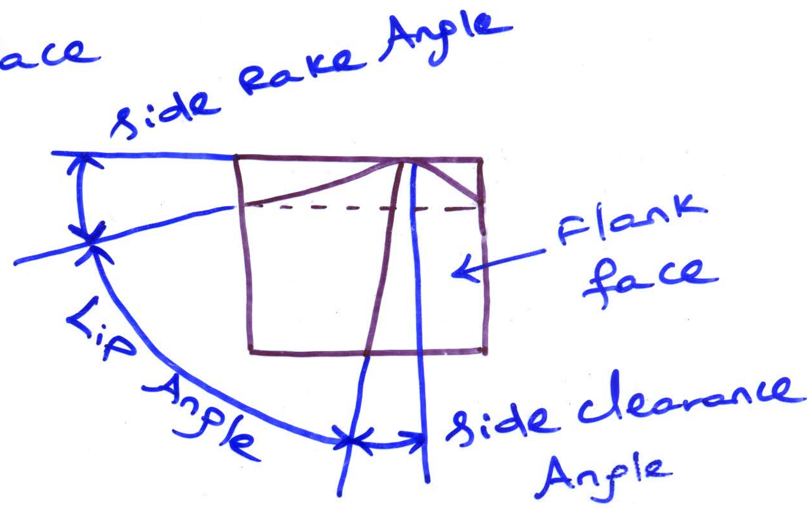
Significance of Clearance Angle:—

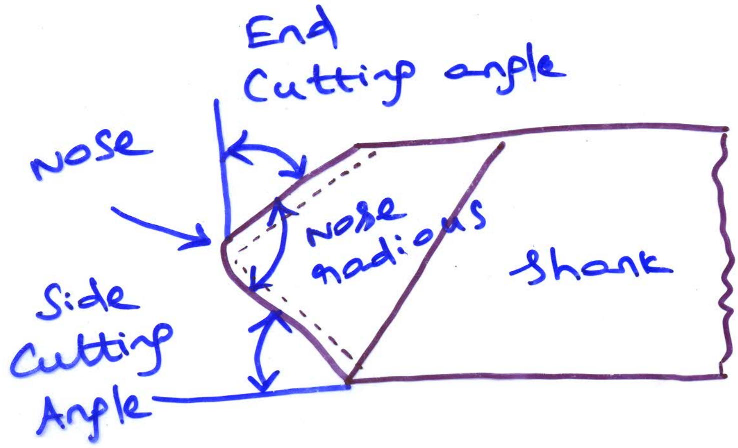
① It is provided on the tool to avoid the rubbing of the tool on the w/p when the machining takes place. Hence it prevents the spoiling of the machined surface

② It is used to increase the cutting forces.

Single Point Cutting Tool Nomenclature:—







① Shank:-

Portion of the tool bit which is not ground to form the cutting edges & is rectangular in cross-section.

② Rake face:-

Surface against which the chip slides

③ Flank face:-

Surface which faces the w/p.

④ Nose:-

The point of intersection of Side & End cutting edges. Nose radious increases the tool life & surface finish.

⑤ Cutting edge:-

It is the junction of the Rake face & the flank face.

a) Side cutting edge

b) End Cutting edge.

⑥ Various angles in the cutting Tool:-

① Rake Angle → Top Rake Angle
→ Side Rake Angle

② Clearance Angle (or) Relief Angle

a) End (or) Front Relief angle

b) Side clearance angle

③ Cutting edge Angle

a) Side Cutting edge Angle

b) End Cutting edge Angle

④ Nose radious (or) Nose angle.

Top Rake angle:-

* Also called as "Back Rake angle".
* It is the angle b/w the Rake face of the tool & the line ∥ to the base of the tool. This is measured along the length of the tool.

Side Rake angle:-

It is also the angle b/w the Rake face & the base of the tool. But it is measured along the width of the tool.

End (or) Front Relief angle:-

It is the angle b/w the front flank face & the line ⊥ to the base of the

Unit-1

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   - → Rake angle
   - → Clearance angle
2. work & cutting Tool material
3. Cutting speed
4. feed
5. Depth of Cut
6. Cutting fluids used.

Rake angle & Clearance angle:-

* "Rake angle" is the angle b/w the Rake face of the cutting tool & the line ∥ to the base of the tool (or) It is the angle b/w the Rake face and the line normal to the machining direction.

tool. The purpose of providing this angle is to avoid the rubbing of the tool on the w/p when the tool is fed along the length of the Job.

Side Relief (or) Clearance angle:-

It is the angle b/w the Side flank face and the line $\perp^r$ to the base of the tool. The purpose of providing this angle is to avoid the rubbing of the tool on the w/p when the tool is fed crosswise to the w/p.

Side & End cutting edge angle:-

* Side cutting edge angle is the angle b/w the side cutting edge and the longitudinal axis of the cutting Tool whereas the end cutting edge angle is the angle b/w the End cutting edge and the line $\perp^r$ to the longitudinal axis.

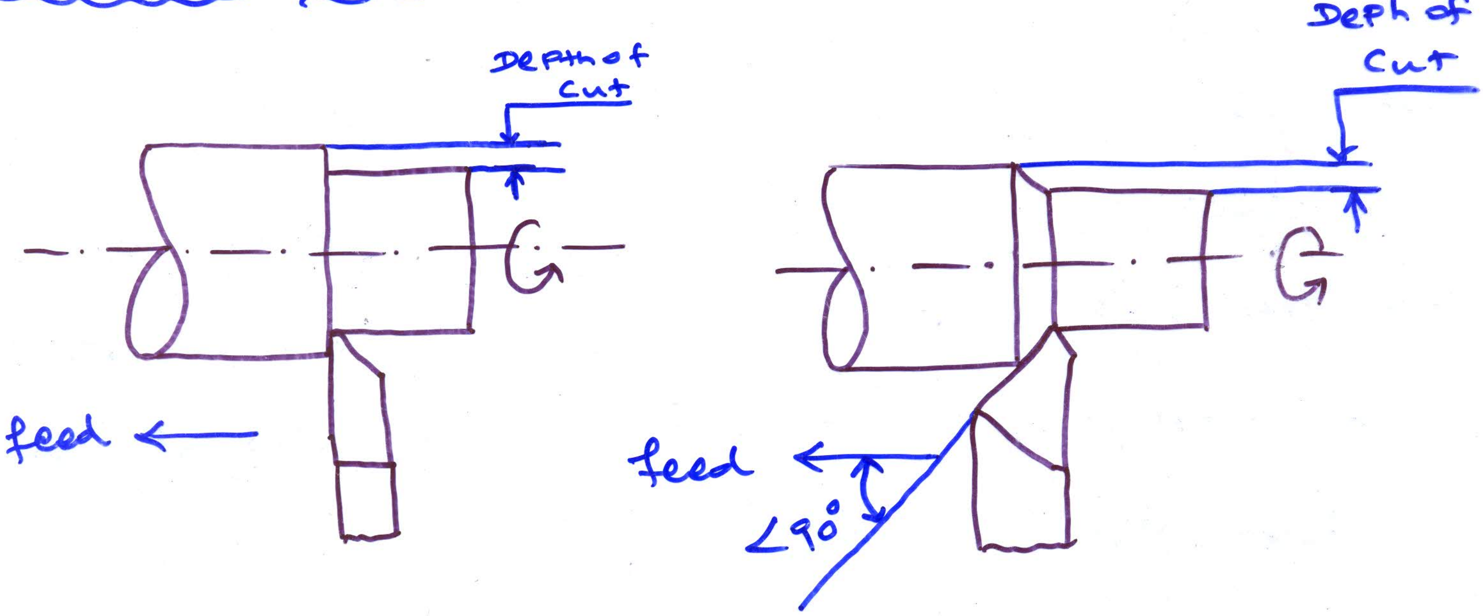
* These angles will allow only a Smaller portion of the cutting edge to contact with the w/p and thus prevents the Vibration and chatter. Normally this angle Varies from 5° to 15°.

Nose angle (or) nose Radious:—

* It is the angle b/w the side cutting edge and End cutting edge

* It is used to increase the tool life and surface finish of the w/p.

Orthogonal & oblique cutting:—



The metal cutting processes are mainly classified into 2 types

(i) Orthogonal cutting [2-D cutting]

(ii) Oblique cutting process [3-D cutting]

* If the cutting edge is at 90° to the

it is known as "oblique cutting".

line of action (or) path of the

tool,

* If the cutting edge of the tool is at an acute angle [less than 90°] to the line which is normal to the cutting velocity vector it is known as "oblique cutting".

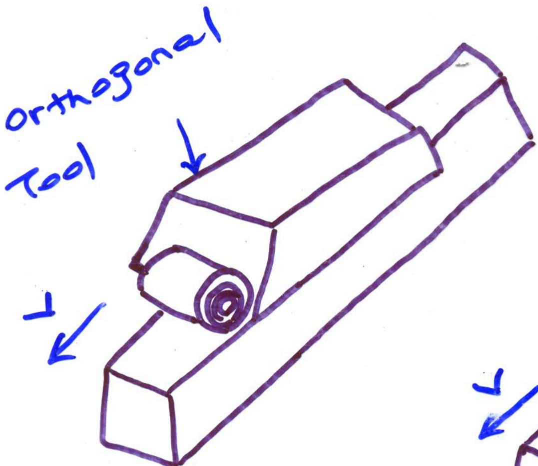
Points to be noted:—

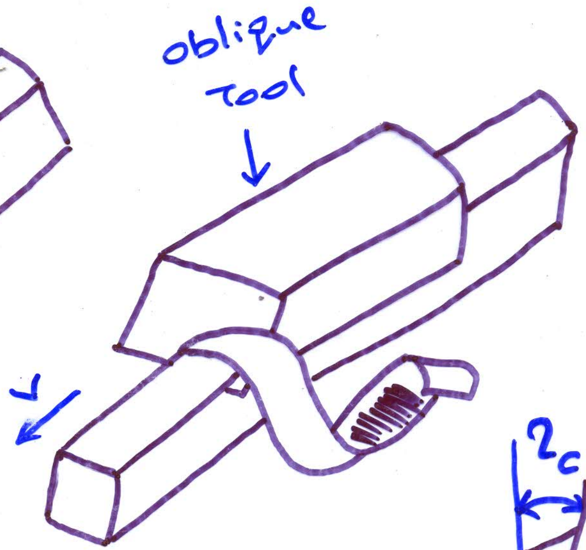
* For the same depth of cut & feed,

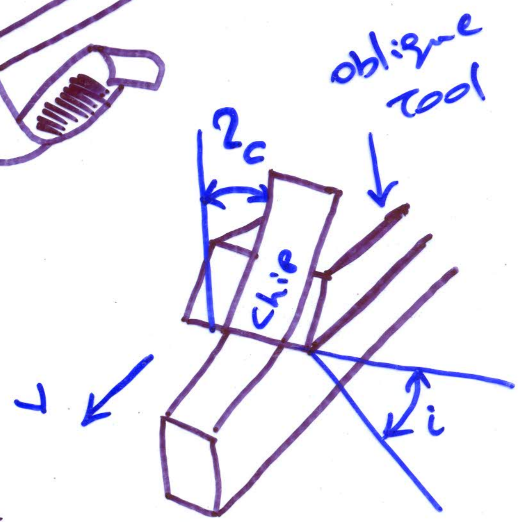
a) the force which cuts (or) shears the metal acts on a larger Area in case of oblique tool and the oblique tool will have a longer life as the heat developed per unit Area due to friction along w/p–tool interface is small.

b) The oblique tool will remove more metal compared to orthogonal tool.

Chip flow in orthogonal & oblique cutting:—







η_c → **Chip flow Angle**

- Angle b/w the direction of chip flow and the line normal to the cutting edge

i → **Inclination Angle**

- Angle b/w the cutting edge and the line normal to the cutting velocity vector.

* In oblique cuttings, the cutting edge is inclined at an angle "i" and the chip flows in a sideways in the form of long curl.

* In orthogonal cuttings the inclination angle "i" is zero and the chips flow like "tight, flat spiral" and hence η_c is also zero. (ie) Here $i=0$ & $\eta_c=0$

Example for orthogonal & oblique cutting:-

Orthogonal cutting - Sawing, Broaching, Slotting, parting-off oprns.

oblique cutting - turning opreation in Lathes, Milling, drilling opreations etc,

Comparison b/w orthogonal & oblique cutting:-

S.no	Orthogonal cutting	oblique cutting.
1.	Cutting edge of the tool is $\perp^{r}$ to the line of action (or) path of the tool.	Cutting edge of the tool is at an acute angle to line which is normal to the cutting velocity vector.
2.	the chip flows like a tight flat spiral.	The chip flows like long curl.
3.	Only one cutting edge contacts with the w/p during oprn.	Frequently, more than one edge are in action during the opreation

S.No	Orthogonal cutting	oblique cutting.
4.	Only 2 components of forces are there during opreation [feed & cutting force]	3 components of forces are there during opreation [feed, cutting & thrust force]
5.	For the same depth of cut, the frictional force/unit Area is high as less area contacts with the w/p during the oprn and hence tool life is comparatively less	For the same depth of cut, the frictional force/unit Area is comparatively low as more area contacts with the w/p during the oprn and hence the tool life is comparatively more
6.	examples:- Sawing, Broaching, slotting and Lathe Parting-off oprns, Shaping opreations.	examples:- Lathe turning oprn, Milling, drilling etc.,

Chip formation:-

Various types of chips are formed during metal cutting. The type of chip formed during metal cutting depends on the machining condition & material to be cut.

Factors affecting the formation of chip:-

(i) Mechanical properties of the material to be cut & the cutting tool.

(ii) Depth of cut, cutting speed, feed rate.

(iii) Geometry of the Tool.

(iv) Type of cutting fluid.

(v) M/cing temperature in the cutting region.

(vi) Co-eff of friction b/w w/p & Tool.

Types of chips:-

1. Continuous chips (or) Ribbon type chip.
2. The discontinuous chip (or) Segmented chip.
3. The continuous chip with Buid-up edge (BUE)

① Continuous Chip (or) Ribbon type Chip:-

* During cutting ductile material, a continuous ribbon like chips is produced.

* These chips are in the form of long curl and have same thickness throughout its length.

Advantages:-

Good surface finish, less power consumption, more tool life

DisAdvantages:-

a) Chip disposal is not easy

b) The surface finish of finished goods gets affected.

Favourable conditions:-

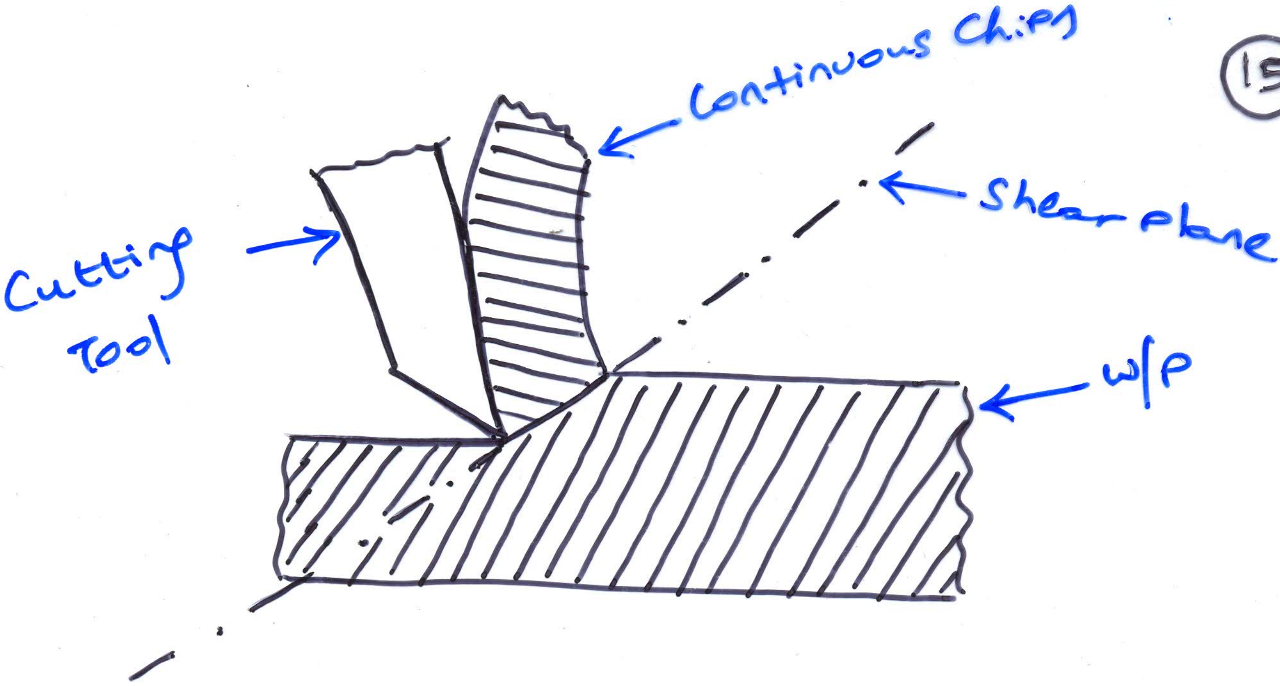
① Ductile material such as low carbon steel, aluminium, copper etc.,

② Smaller depth of cut

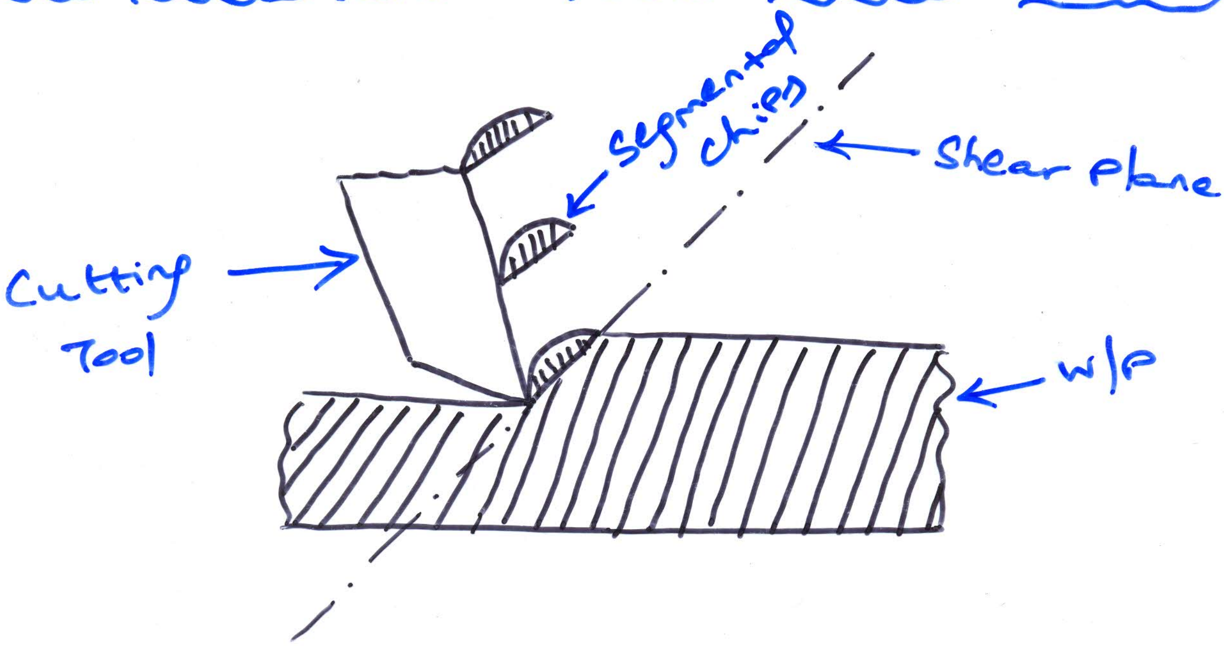
③ High cutting speed ④ Large rake angle.

⑤ Proper cutting fluid.

⑥ Low friction b/w tool & chips.



2 Discontinuous Chips (or) Segmental Chips:-



* This type of Chips are produced while machining brittle materials such as bronze, brass & cast Iron.

* Here, Chips are produced in the form of small segmental separate pieces.

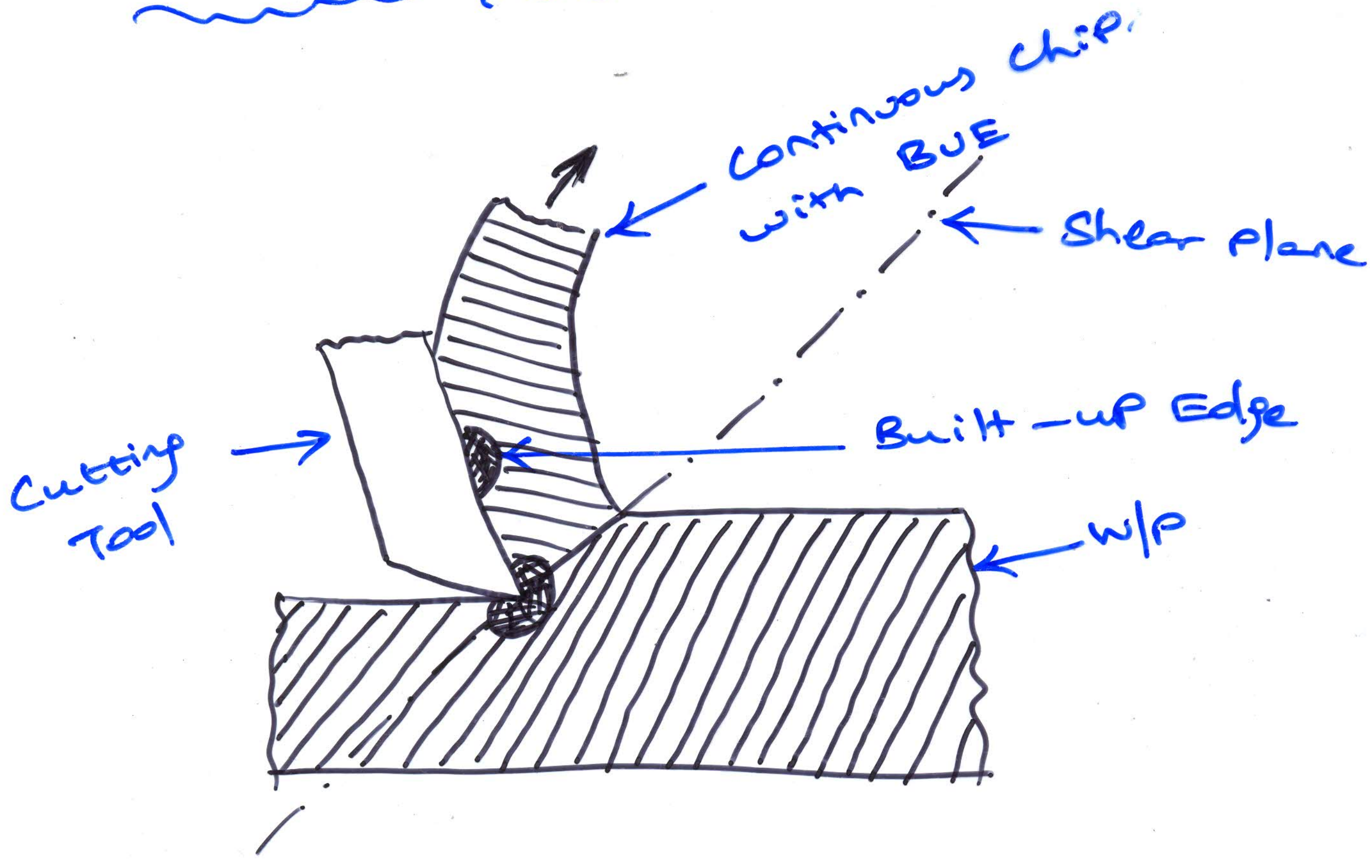
* The discontinuous chips can also be produced in cutting of ductile metals at very low feed, high cutting speed, larger depth of cut & high friction.

* If the discontinuous chips are produced from the brittle material, then the surface finish is fair, power consumption is low & tool life is reasonable. However if it is produced from ductile metals, then finish is poor & the tool wear is excessive.

Conditions promoting the formation of discontinuous chips:—

1. Machining the brittle materials
2. For ductile metals
    a) Greater depth of cut
    b) High cutting speed
    c) low feed
    d) Smaller rake angle
    e) High friction b/w w/p & Tool.

(3) Continuous Chips with Built-up Edge (BUE):-



Here, the chips are continuous with Built-up edge.

Built-up edge:-

During the cutting process of ductile metals, the interface temperature and pressure are quite high and hence there is a high friction b/w the tool & chip interface. It causes the chip to weld itself to the cutting edge of the tool and it will act as a false cutting edge of the tool. This extra welded metal on the cutting edge is called as "the Built-up Edge (BUE)".

The BUE is a highly strain hardened brittle material. So when the chip flows over the tool face, it will easily break & some part of it will be carried away with the chip and the remaining part of it will adhere to the workpiece leading to a poor surface finish.

(17-1)

Disadvantages of BUE:-

① Poor surface finish.

② The rake angle of the tool is altered & hence the cutting force of the tool will get affected.

Advantages of BUE :-

① The Rake face of the tool is protected from wears due to the moving chips over the tool face. It may result in increasing the tool life

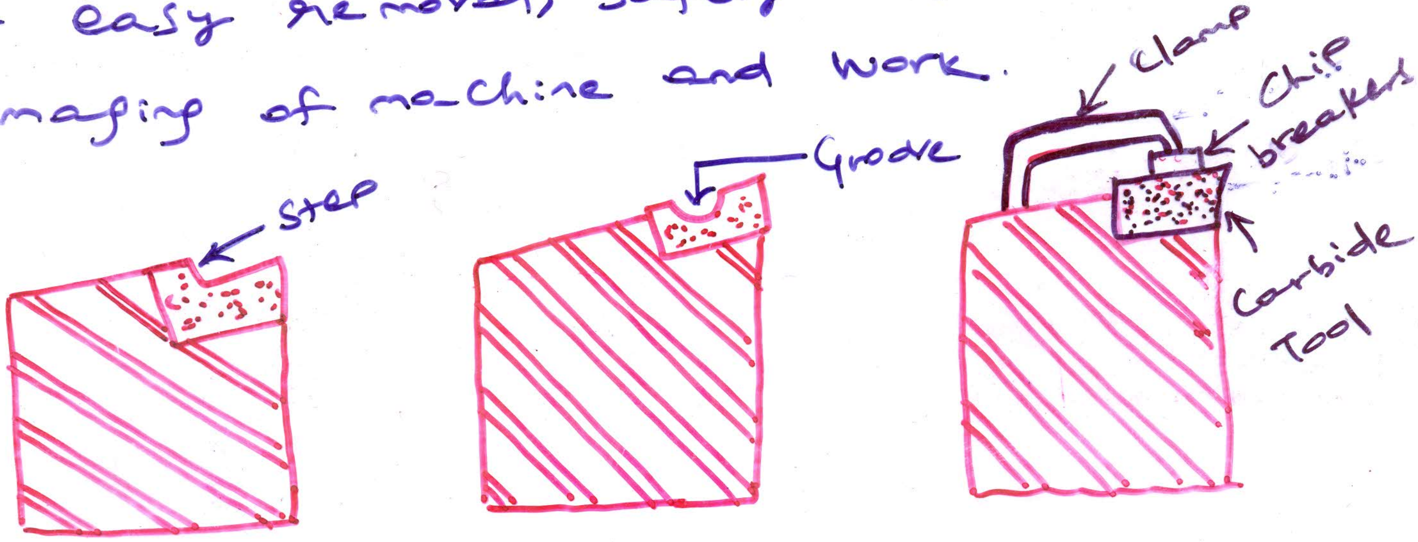
Conditions Promoting the formation of Built-up Edge (BUE):—

(17-2)

1. Low cutting speed
2. Excessive feed
3. Larger depth of cut.
4. Lack of Lubricant
5. Smaller Rake angle
6. High friction b/w the tool & w/p.

CHIP BREAKERS:-

During machining of ductile material, long and continuous chip that are formed at high cutting speed will affect the machining. It will spoil tool, work and machine. It will be difficult to remove this types of chip and also it is dangerous to safety. Chip breakers are used to break the chips into small pieces for easy removal, safety and to prevent damaging of machine and work.



Step type   Groove type   Clamp type

This is very important in automatic machines which are running at very high speeds. The chip breaker is provided on the cutting edge as shown in the figure.

The different type of chip breaker used on a cutting tool are.

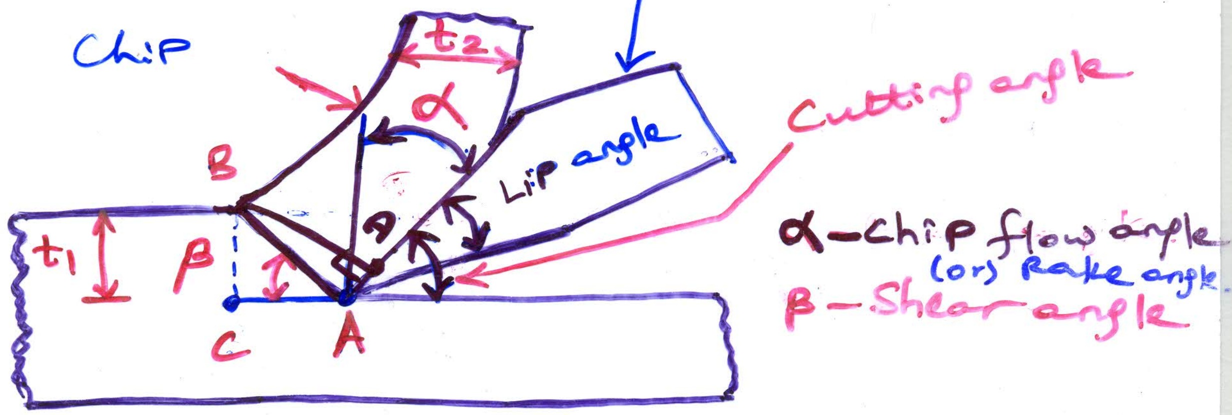
① Step type ② Groove type ③ Clamp type.

In step type, a step is ground on the tool face behind the cutting edge. (19)

In groove type, a groove on the tool face behind the cutting edge will break the chip.

In clamp type, a thin chip breaker is clamped (or) screwed on the face of the tool.

Mechanism of Metal cutting (or) Mechanism of chip formation :—



* During machining, the cutting tool exerts a shear force on the workpiece.

* The material of the w/p is stressed beyond its yield point under this shear force.

* This causes the material to deform plastically and finally get sheared off.

* The plastic flow takes place in a localized region called shear plane (or) shear zone which extends from the cutting point to

the uncut surface

* The sheared material begins to flow along the cutting tool face in the form of small pieces called chips.

* when the chip flows over the tool face, high heat is produced b/w the chip & Tool face. This temperature rise in the tool tends to soften the cutting edge and leads to failure of the cutting edge

Geometry of chip formation:-

* Generally, the chip thickness is longer than the thickness of material to be removed. Also, the metal prior to cut is longer than the length of the chip. Hence volume of metal prior to and after the cut is same

Let,

t_1 = chip thickness prior to cut

t_2 = chip thickness after cut.

* The ratio of chip thickess before cutting to chip thickness after cutting is called as 'chip thickness ratio (r)'.

(ie) Chip thickness ratio, $r = \frac{t_1}{t_2}$

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Its value is always less than one. A ratio of 1:2 yield a good result.

* The reciprocal of the chip thickness ratio is called "Chip reduction coefficient" (K).

(ie) $K = 1/r$

* Volume of metal to be removed } = Volume of Chip

$t_1 \times l_1 \times b_1 = t_2 \times l_2 \times b_2$

$t_1 \times l_1 = t_2 \times l_2 \quad (\because b_1 = b_2)$

$\therefore \frac{t_1}{t_2} = \frac{l_2}{l_1} = r =$ Chip thickness ratio

Shear angle (β):—

From $\triangle$ ABC,

$\sin\beta = \frac{t_1}{AB} \Rightarrow AB = \frac{t_1}{\sin\beta}$ ——— (1)

From ΔABD;

$$\sin[90-\beta+\alpha] = \frac{BD}{AB} = \frac{t_2}{AB}$$

$$\therefore \quad AB = \frac{t_2}{\sin(90-\beta+\alpha)} \quad \text{———} \quad (2)$$

Comparing (1) & (2)

$$\frac{t_1}{\sin\beta} = \frac{t_2}{\sin(90-\beta+\alpha)}$$

$$\frac{t_1}{t_2} = \frac{\sin\beta}{\sin(90-\beta+\alpha)}$$

$r = \dfrac{\sin\beta}{\cos(\beta-\alpha)}$
$\therefore r = \dfrac{\sin\beta}{\cos\beta\cos\alpha + \sin\beta\sin\alpha}$

$$\frac{r[\cos\beta\cos\alpha + \sin\beta\sin\alpha]}{\sin\beta} = 1$$

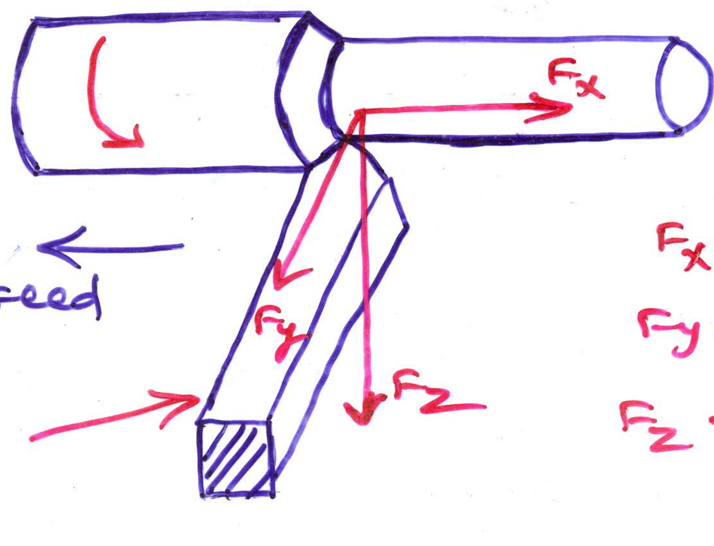
$$\frac{r\cos\alpha}{\tan\beta} + r\sin\alpha = 1$$

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

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

$$\therefore \text{Shear angle, } \beta = \tan^{-1}\left[\frac{r\cos\alpha}{1 - r\sin\alpha}\right]$$

Cutting forces in Metal cutting :-



$F_x \rightarrow$ feed force

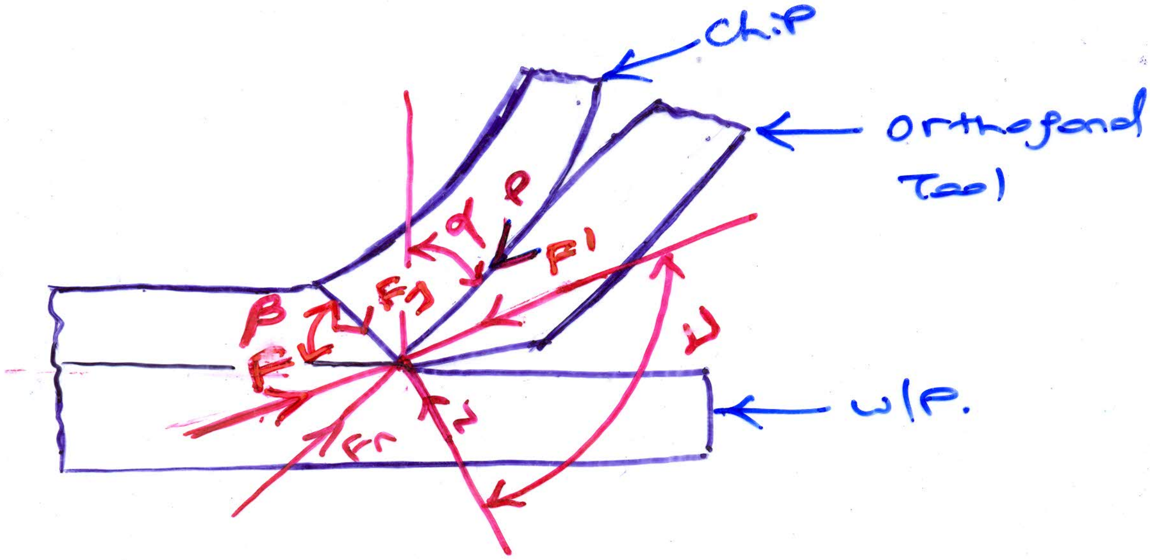
$F_y \rightarrow$ Thrust force

$F_z \rightarrow$ Cutting force

In orthogonal cutting, only two forces are there (ie) F_x – feed force & F_z – Cutting force

* Feed force (F_x) acts in a direction opposite to the feed.
* Thrust force (F_y) acts in a direction $\perp^r$ to the generated surface.
* F_z acts in a direction of cutting velocity.

The various forces acting on the tool and workpiece other than the cutting forces in orthogonal cutting?—



F, F' = Resultant forces for Fn, Fs & P, N respectively

α, β, ν = Rake angle, Shear angle, friction angle respectively.

Fs = Shear Resisting force

Fn = Back-up force on the chip by the workpiece.

P = Frictional force along the rake face

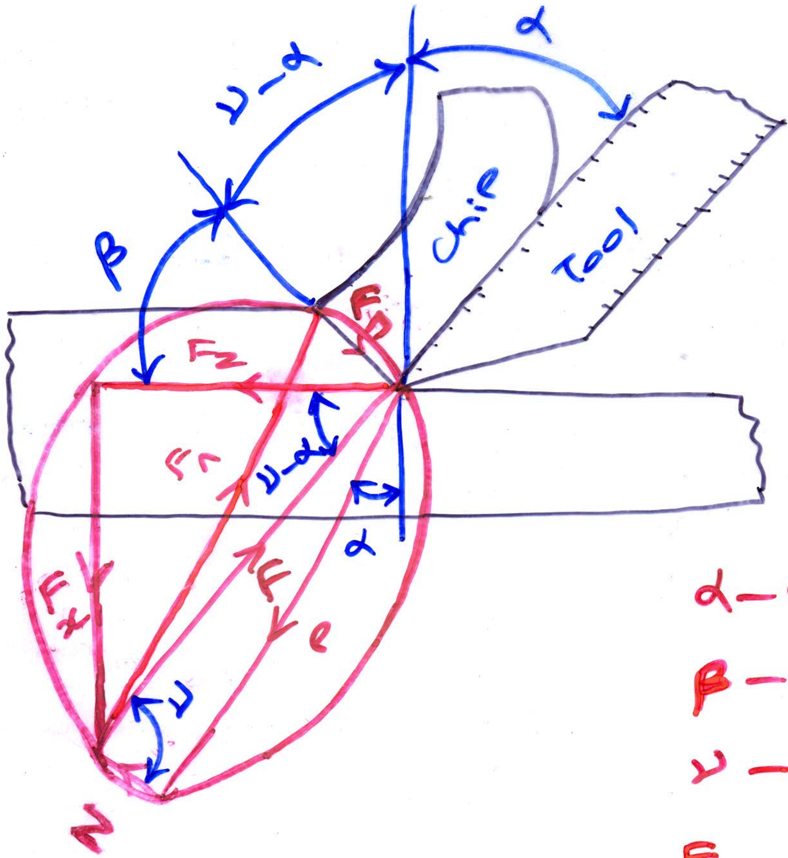
N = Normal force acting on the tool when the chip starts flowing over its rake face.

Merchant Circle Diagram of forces:-

This diagram is used to find the relation b/w various forces and angles.

The following assumptions are made while drawing the merchant circle Diagram.

1. The tool is perfectly Sharp and has no contact along the clearance face.
2. The Surface where Shear is occuring is considered as a plane.
3. The cutting edge is $\perp^r$ to the cutting Velocity Vector & generates a plane Surface as the work moves past it.
4. The chip doesn't flow to either side (or) no side spread.
5. Uncut chip thickness is constant.
6. The width of the tool is greater than the width of the w/p.
7. A continuous chip is produced without any Build-up edge (BUE).
8. The stresses on a shear plane are uniformly Distributed.



α – Rake angle

β – Shear angle

ν – Friction angle

F_z – Cutting force

F_x – Feed force

* Two force triangles is combined together. their resultant will be given by the resultant force 'F'.

* Feed force (F_x) & cutting force (F_z) are found out by tool force dynamometer & is drawn to the Suitable Scale. their resultant will be given by the resultant force 'F'.

* Merchant Circle is drawn with the diameter "F" & it is passing through the tool point.

Co-eff of friction (μ):—

when the chip slides over the tool face under pressure, there will be some friction b/w these two. Therefore kinematic co-eff of friction can be expressed as

$$\mu = P/N = \tan\lambda$$

Shear angle (β):—

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

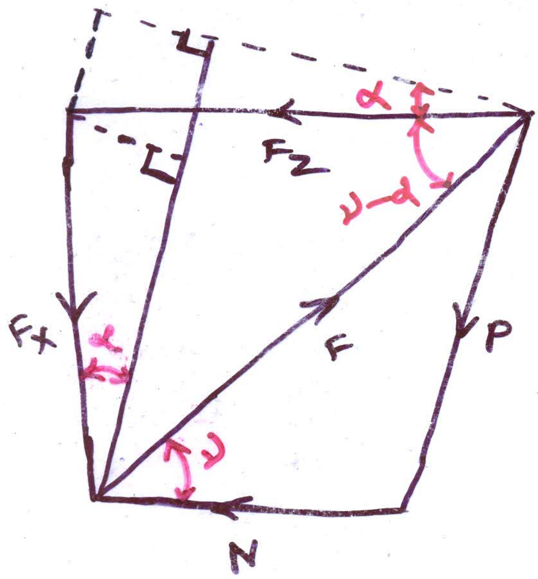
Chip-thickness ratio (r):—

$$r = \frac{t_1}{t_2}$$

$t_1 \Rightarrow$ uncut chip thickness

$t_2 \Rightarrow$ chip thickness which was cut.

Frictional force (P) & Normal force (N):–



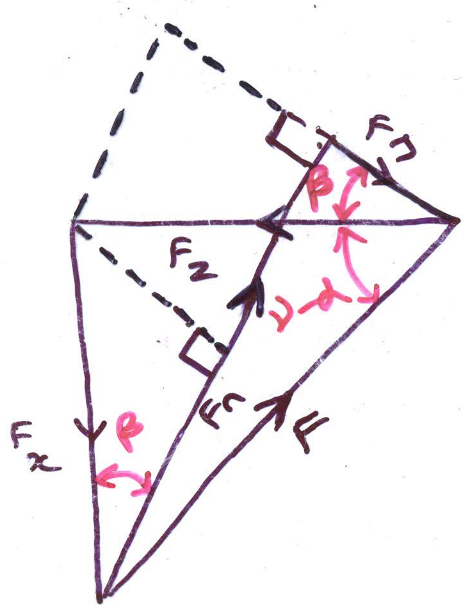
$$P = F_x \cos\alpha + F_z \sin\alpha$$

$$N = F_z \cos\alpha - F_x \sin\alpha$$

F = Resultant force

$$= \sqrt{F_z^2 + F_x^2}$$

Shear Resisting force (F_s) & Back-up force (F_n):–

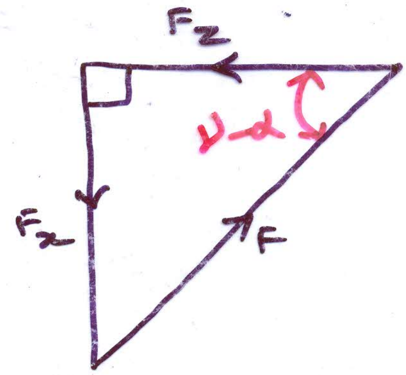


$$F_s = F_z \cos\beta - F_x \sin\beta$$

$$F_n = F_x \cos\beta + F_z \sin\beta$$

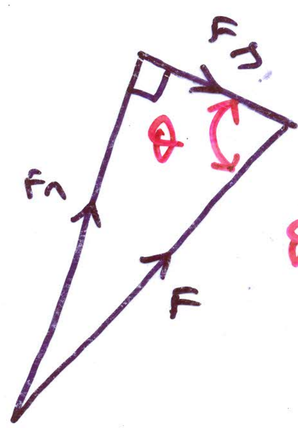
Cutting force (F_z):-

$$\cos(\nu-\alpha) = \frac{F_z}{F}$$



$$\boxed{F_z = F\cos(\nu-\alpha)}$$

$$\cos\theta = \frac{F_s}{F}$$



$\theta = \nu-\alpha+\beta$

$$\boxed{F = \frac{F_s}{\cos\theta}}$$

Substituting 'F' in F_z equation

$$F_z = \frac{F_s}{\cos\theta}\cos(\nu-\alpha)$$

$$\boxed{F_z = \frac{F_s\cos(\nu-\alpha)}{\cos(\nu-\alpha+\beta)}}$$

Co-eff of friction (μ):-

$$\mu = \tan\nu = F/N$$

$$\mu = \frac{F_z\sin\alpha + F_x\cos\alpha}{F_z\cos\alpha - F_x\sin\alpha}$$

÷ by $\cos\alpha$,

$$\boxed{\mu = \frac{F_x + F_z\tan\alpha}{F_z - F_x\tan\alpha}}$$

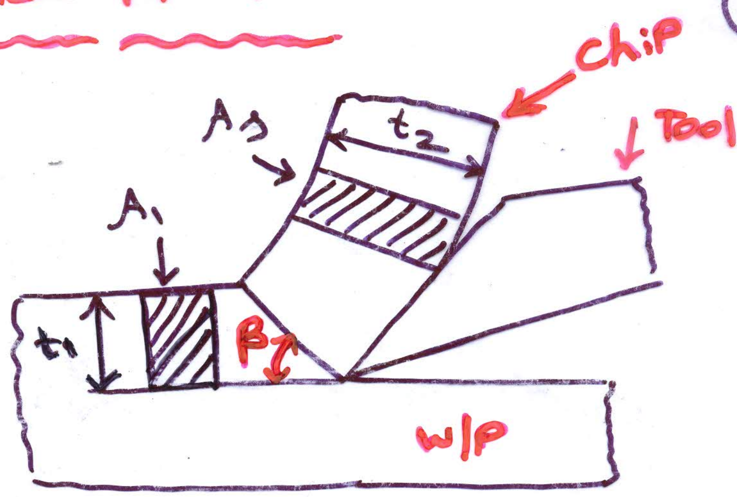
Shear Stress in Shear plane:-

Let

A_1 – Area of uncut chip

A_s – Shearing Area

τ – Shear Stress



$$\text{Shear Stress, } \tau = \frac{\text{Shear force}}{\text{Area}} = \frac{F_s}{A_s}$$

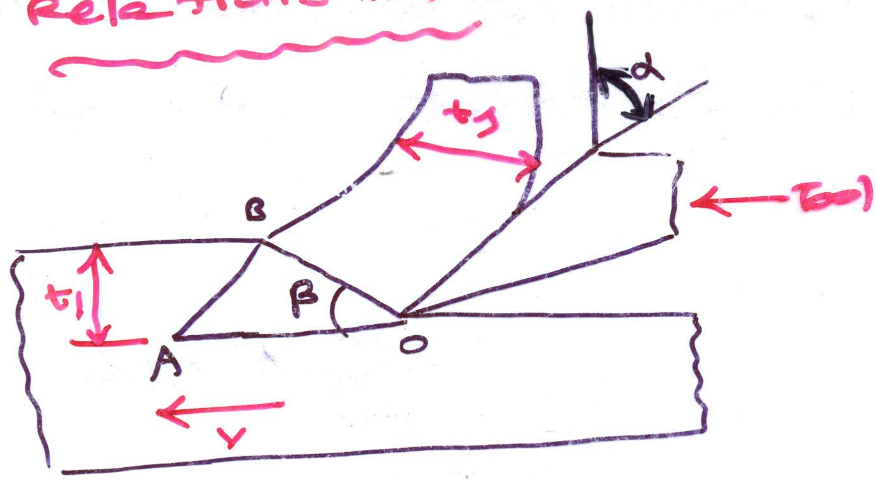
$$\sin\beta = \frac{A_1}{A_s} \Rightarrow A_s = \frac{A_1}{\sin\beta}$$

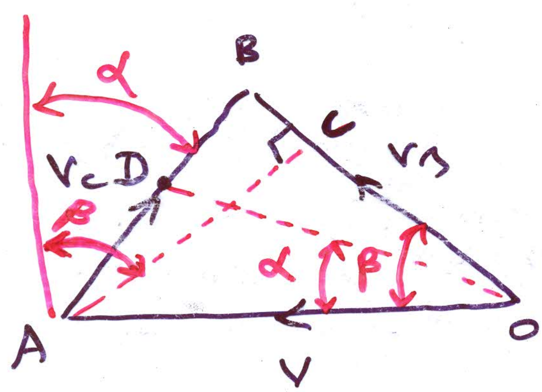
$$\therefore \tau = \frac{F_s \sin\beta}{A_1}$$

$$\tau = \frac{(F_z \cos\beta - F_x \sin\beta)\sin\beta}{A_1}$$

$$\left.\begin{array}{l}\text{Shear}\\ \text{stress}\end{array}\right\} \quad \tau = \frac{F_z \cos\beta \sin\beta - F_x \sin^2\beta}{A_1}$$

Velocity Relationship:—





The above figure shows the velocity relationship in orthogonal cutting. The various velocities are

1. Cutting Velocity (V)
2. Chip velocity (V_c)
3. Shear velocity (V_s)

* The chip velocity is the velocity of chip relative to the tool & is directed along the tool face.

* Shear velocity v_s is the velocity of chip relative to the w/p and is directed along the shear plane.

From OCA

$$\sin\beta = \frac{AC}{OA}$$

$$\therefore AC = OA \sin\beta$$

$$\boxed{AC = V \sin\beta} \quad \text{--- (1)}$$

From BAC

$$\cos(\beta-\alpha) = \frac{AC}{AB}$$

$$\boxed{\therefore AC = V_c \cos(\beta-\alpha)} \quad \text{--- (2)}$$

From (1) & (2),

$$V \sin\beta = V_c \cos(\beta-\alpha)$$

Chip Velocity

$$\boxed{\therefore V_c = \frac{V \sin\beta}{\cos(\beta-\alpha)}}$$

$$\boxed{V_c = V r} \quad \left[\because r = \frac{\sin\beta}{\cos(\beta-\alpha)}\right]$$

Similarly,

From ODA,

$$\cos\alpha = \frac{OD}{OA} = \frac{OD}{V}$$

$$\boxed{OD = V \cos\alpha} \quad \text{--- (3)}$$

From ODB,

$$\cos(\beta-\alpha) = \frac{OD}{OB} = \frac{OD}{V_s}$$

$$OD = V_s \cos(\beta - \alpha) \quad \text{--- (4)}$$

From (3) & (4),

$$V \cos\alpha = V_s \cos(\beta - \alpha)$$

Shear Velocity

$$\therefore V_s = \frac{V \cos\alpha}{\cos(\beta - \alpha)}$$

Formulae used in metal cutting:-

(1) Chip thickness ratio, $r = t_1/t_2 = l_2/l_1 = \frac{\sin\beta}{\cos(\beta - \alpha)}$

(2) Chip reduction co-efficient, $K = 1/r$

(3) Shear angle, $\beta = \tan^{-1}\left[\frac{r\cos\alpha}{1 - r\sin\alpha}\right]$

(4) Co-eff of friction, $\mu = \tan\gamma = P/N$

(5) Friction force, $P = F_z \sin\alpha + F_x \cos\alpha$

Normal force, $N = F_z \cos\alpha - F_x \sin\alpha$

(6) Shear force, $F_s = F_z \cos\beta - F_x \sin\beta$

Back-up force, $F_n = F_x \cos\beta + F_z \sin\beta$

(7) Shear stress, $\tau = \frac{F_s \sin\beta}{A_1}$ $A_1 \rightarrow$ Area of uncut chip

(8) Cutting force, $F_z = F\cos(\nu-\alpha)$

$$= \frac{F_s \cos(\nu-\alpha)}{\cos(\nu-\alpha+\beta)}$$

(9) Feed force $F_x = F\sin(\nu-\alpha)$

$$= \frac{F_s \sin(\nu-\alpha)}{\cos(\nu-\alpha+\beta)}$$

(10) Velocity of chip $V_c = \frac{V\sin\beta}{\cos(\beta-\alpha)}$

(11) Shear velocity $V_s = \frac{V\cos\alpha}{\cos(\beta-\alpha)}$

(12) Shear strain, $e = \cot\beta + \tan(\beta-\alpha)$

(13) [Total work done in metal cutting] = [Work done in shearing of material] + [Work done against friction]

$$F_z \times V = (F_s \times V_s) + (P \times V_c) - \left(\frac{N-m}{sec}\right)$$

(14) Material removal rate for turning opreation } [M.R.R]

$$= \begin{bmatrix} \text{Feed} \\ \text{in mm/rev} \end{bmatrix} \times \begin{bmatrix} \text{Depth of} \\ \text{cut in} \\ \text{mm} \end{bmatrix} \times \begin{bmatrix} \text{Cutting speed} \\ \text{in mm/min} \end{bmatrix}$$

$- \underline{\underline{mm^3/min}}$

(15) Machining constant $(C_M) = 2\beta + \gamma - \alpha$

<u>In metal cutting,</u>

Feed in mm/rev = uncut chip thickness

$= t_1$

Depth of cut = width of cut.

M.R.R is defined as the volume of material removed from the workpiece per unit time. It is measured in terms of mm^3/min.

Problems on metal cutting:-

① During an orthogonal turning opreation of C20 steel, the following data were recorded Rake angle =10°; Chip thickness = 0.48mm; width of cut = 2.0 mm; Feed = 0.25mm/rev; Tangential cutting force = 1200N; Feed thrust force = 300N; Cutting speed = 2.5m/s; Find the value of shear force at the shear plane; find also the kinematic co-eff. of friction at the chip-tool interface.

Given Data:-

$\alpha = 10°$; $t_2 = 0.48mm$;

$b = 2.0mm$; $f = 0.25 mm/rev$;

$F_z = 1200N$; $F_x = 300N$;

$V = 2.5 m/sec$;

To find:-

$F_s = ?$ $\mu = ?$

shear force, $F_s = F_z \cos\beta - F_x \sin\beta$

Co-eff of friction } $\mu = \tan\nu = F/N = \dfrac{\text{frictional force}}{\text{Normal force}}$

Shear angle (β):-

$$\beta = \tan^{-1}\left[\frac{r\cos\alpha}{1 - r\sin\alpha}\right]$$

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

$$= \frac{0.25}{0.48}$$

$$\boxed{r = 0.5208}$$

$$\beta = \tan^{-1}\left[\frac{0.5208 \times \cos 10^\circ}{1 - (0.5208 \times \sin 10^\circ)}\right]$$

$$\boxed{\beta = 29.41^\circ}$$

Shear force (F_s):-

$$F_s = F_z \cos\beta - F_x \sin\beta$$

$$= 1200\cos(29.41) - 300\sin(29.41)$$

$$\boxed{F_s = 898.03\ N}$$ — Ans —

Frictional force (F):-

$$F = F_z \sin\alpha + F_x \cos\alpha$$

$$= 1200(\sin 10^\circ) + 300(\cos 10^\circ)$$

$P = 503.82 N$

Normal force (N):-

$$N = F_z \cos\alpha - F_x \sin\alpha$$

$$= 1200 \cos 10 - 300 \sin 10$$

$$= 1129.67 N$$

Co-eff of friction (μ):-

$$\mu = P/N = \frac{503.82}{1129.67}$$

$$\boxed{\mu = 0.44}$$

—Ans—

Friction angle (ν):-

$$\mu = \tan\nu$$

$$\therefore \nu = \tan^{-1}(\mu) = 24.03^\circ$$

---

(2) In an orthogonal cutting test with a tool of rake angle 10°, the following observations were made

chip thickness ratio = 0.3

Horizontal component of cutting force = 1290N

Vertical component of cutting force = 1650N

From Merchant's thory, calculate the various components of the cutting forces and the coefficient of friction at the chip-tool interface. (39)

Given Data:-

Chip thickness ratio, $r = 0.3$

Horizontal component force, $F_z = 1290N$

Vertical component cutting force, $F_x = 1650N$

Find:-

frictional force (F) = ? normal force (N) = ?

Shear force (F_s) = ? Back-up force (F_n) = ?

Co-eff of friction (μ) = ?

Same as the previous problem.

---

(3) In an orthogonal cutting opreation on a workpiece of width 2.5mm, the uncut chip thickness was 0.25mm and the tool rake angle was zero degree. It was observed that the chip thickness was 1.25mm. The cutting force was measured to be 900N and the thrust force was found to be 810N.

(i) Find the shear angle & shear strength

(ii) If $\mu = 0.5$, what is machining constant (C_m) ?

Given :-

width, $b = 2.5mm$; uncut chip thick, $t_1 = 0.25mm$;

Chip thickness, $t_2 = 1.25mm$; Rake angle, $\alpha = 0°$;

Cutting force, $F_z = 900N$; Thrust force, $F_x = 810N$;

co-eff of friction, $\mu = 0.5$

Find:-

Shear angle, $\beta = ?$ Shear strength, $\tau = ?$

Machining constant, $C_m = ?$

Soln:-

① Chip thickness ratio, $r = \frac{t_1}{t_2} = \frac{0.25}{1.25} = 0.2$;

② Shear angle, $\beta = \tan^{-1}\left[\frac{r\cos\alpha}{1 - r\sin\alpha}\right]$

$$= \tan^{-1}\left[\frac{0.2\cos 0}{1 - 0.2\sin 0}\right]$$

$$\boxed{\beta = 11.31°}$$

-Ans-

③ Shear strength (τ):-

$$\tau = \frac{F_s}{A_1} \times \sin\beta$$

$A_1 = b \times t_1$

$$\boxed{A_1 = 2.5 \times 0.25 \ mm^2}$$

A_1 = Area of uncut chip

Shear force $F_s = F_z \cos\beta - F_x \sin\beta$

$$= 900\cos(11.31^\circ) - 810\sin(11.31^\circ)$$

$$F_s = 723.66\,N.$$

$$\therefore \tau = \frac{F_s}{A_1} \times \sin\beta$$

$$= \frac{723.66}{(0.25 \times 2.5)} \times \sin(11.31^\circ)$$

$$\boxed{\tau = 227.07\ N/mm^2}$$

Machining constant, $C_m = 2\beta + \nu - \alpha$

Friction angle, $\nu = \tan^{-1}(\mu)$

$$= \tan^{-1}(0.5)$$

$$\boxed{\nu = 26.56^\circ}$$

$$\therefore C_m = 2(11.31^\circ) + 26.56^\circ - 0^\circ$$

$$\boxed{C_m = 49.18^\circ}$$

Tool signature

Tool angles given in a definite pattern is called "Tool Signature". The Tool angles have been Standardized by the American Standards Association (ASA). As per ASA, the tool signature is given by the following order.

(i) Back Rake angle
(ii) Side Rake angle
(iii) End relief angle
(iv) Side relief angle
(v) End cutting edge angle
(vi) Side cutting edge angle
(vii) Nose radious.

example :- A tool having 8, 8, 5, 5, 6, 6 and 1 as Signature in ASA System will have

Back rake angle = 8°
Side rake angle = 8°
End relief angle = 5°
Side relief angle = 5°
End cutting edge angle = 6°
Side cutting edge angle = 6°
Nose Radious = 1 mm.

8. Orthogonal Test is conducted on mild steel tube of size 225mm diameter and 5mm thickness. The velocity of cutting is 105m/min and feed rate is 0.21mm/rev. The following observations were made (43)

Cutting force = 2300N; Feed force = 825N;

Chip thickness = 0.3mm; Rake angle = −10°;

Determine the shear strain and energy per unit volume.

Given:-

$D = 225mm$; $t = 5mm$; $V = 105 m/min$; $F = 0.21 mm/rev$;

$F_z = 2300N$; $F_x = 825N$; $t_2 = 0.3mm$; $\alpha = -10°$

Soln:-

(1) Chip thickness ratio, $r = \frac{t_1}{t_2} = \frac{0.21}{0.3} = 0.7$

(2) Shear angle, $\beta = \tan^{-1}\left[\frac{r\cos\alpha}{1 - r\sin\alpha}\right] = 31.57°$

(3) Shear strain, $e = \cot\beta + \tan(\beta - \alpha) = 2.513$

(4) Shear velocity, $V_s = \frac{V\cos\alpha}{\cos(\beta - \alpha)} = \frac{105\cos(-10)}{\cos[31.57 - (-10)]}$

$V_s = 138.2\ m/min$

(5) Shear energy / Unit volume $= \frac{\tau \times V_s}{V \times \sin\beta}$

[Shear stress] $= \frac{761.67 \times 138.2}{105 \times \sin 31.57}$

$= 1914.87\ N/mm^2$

(9) Mild steel is being machined orthogonally & the following results are obtained

Cutting force = 1000N; Feed force = 625N;

Cutting velocity = 165 m/min; Rake angle = 10°; (4-4)

Shear angle = 19°;

Determine the following (i) Shear velocity (ii) Chip flow velocity (iii) work done per min in shearing the metal and work done against friction (iv) Show that the work input is equal to sum of work done in shearing and against friction.

Given:-

$F_z = 1000N$; $F_x = 625N$; $v = 165$ m/min;

$\alpha = 10°$; $\beta = 19°$

Find:- v_s, v_c, W_s, W_f

Soln:-

(1) Shear velocity, $v_s = \dfrac{v\cos\alpha}{\cos(\beta-\alpha)} = 164.5$ m/min

(2) Chip velocity, $v_c = \dfrac{v\sin\beta}{\cos(\beta-\alpha)} = 54.38$ m/min

(3) Shear force, $F_s = F_z\cos\beta - F_x\sin\beta$

$F_s = 742N$

(4) Work done in shear, $W_s = F_s \times v_s = 742 \times 164.5$

$W_s = 122\times10^3$ N-m/min

$\therefore W_s = 2033.33$ watts

(5) Frictional force, $P = F_2 \cos\alpha + F_z \sin\alpha$ (45)

$P = 789.15N$

(6) Workdone in friction, $W_f = P \times V_c$

$= 715.23$ watts

(7) Work input, $W = F_z \times V$

$= 1000 \times 165$

$= 165000$ N-m/min

$= \frac{165000}{60} = 2750$ watts

$W = 2750$ watts

(8)

$W_s + W_f = 715.23 + 2033.33$

$W_s + W_f = 2748.56$ watts

$\therefore$ $W \approx W_s + W_f$ Hence Proved.

(10) While turning a C15 steel rod of 160mm dia at 315rpm, 2.5mm depth of cut and feed rate of 0.16 mm/rev by tool geometry 0, 10, 8, 9, 15, 75, 0, the following observations were made. (46)

Tangential component (P_z) of the cutting force = 500N

Radial component (P_x) of the cutting force = 200N

Chip thickness = 0.48 mm

(a) Draw schematically the merchant's circle diagram for the cutting forces in the present case.

(b) Determine the dynamic yield strength of the present work material.

Given:-

$D = 160mm$; $N = 315rpm$;

depth of cut = width of uncut chip

$b = 2.5mm$

feed rate = thickness of uncut chip

$t_1 = 0.16$ mm

Rake angle, $\alpha = 0°$ [from tool geometry]

$F_z = 500N$; $F_x = 200N$

Chip thickness, $t_2 = 0.48mm$;

Soln:-

Dynamic yield Strength, $\tau = \dfrac{F_s \times \sin\beta}{A_1}$

where β = Shear angle, A_1 = Area of uncut chip

F_s = Shear force

① **Chip thickness ratio (r):-**

$$r = \frac{t_1}{t_2} = \frac{0.16}{0.48} = 0.33$$

② **Shear angle (β):-**

$$\beta = \tan^{-1}\left[\frac{r\cos\alpha}{1-r\sin\alpha}\right] = 18.43^\circ$$

③ **Shear force (F_s):-**

$$F_s = F_z\cos\beta - F_x\sin\beta$$

$$\boxed{F_s = 411\,N}$$

④ **yield strength (τ):-**

$$\tau = \frac{F_s \times \sin\beta}{A_1} = \frac{411 \times \sin(18.43)}{b_1 \times t_1}$$

$$= \frac{411 \times \sin(18.43)}{2.5 \times 0.16}$$

$$\boxed{\tau = 324.92\ N/mm^2}$$

(11) During machining C 20 Steel with a carbide cutting tool having a tool geometry given by (48)

0 – 5 – 6 – 6 – 8 – 75 – 1 mm ORS, the following forces have been recorded by a two dimensional dynamometer:

Cutting force = 1300 N

Feed force = 800 N

Find (1) Frictional force (2) Normal force (3) μ

Here Rake angle, $\alpha = 5°$

---

(12) The following data from an orthogonal cutting test is available

Rake angle = 5°

Chip thickness ratio = 0.383

Uncut chip thickness = 0.5 mm

width of cut, b = 3 mm;

Yield stress of material in shear = 280 N/mm²

Average co-eff of friction on the tool face = 0.7

Determine the normal & tangential forces on the tool face

Given:-

$\alpha = 15^\circ$; $r = 0.383$; $t_1 = 0.5mm$; (49)

$b = 3mm$; $\tau = 280 N/mm^2$; $\mu = 0.7$

Find:-

Tangential force (F_z) = ? normal force (F_x) = ?

Soln:-

$$\beta = \tan^{-1}\left[\frac{r\cos\alpha}{1 - r\sin\alpha}\right] = 22.3^\circ$$

$$\tau = \frac{F_s \times \sin\beta}{A_1} = 280 N/mm^2;$$

$$F_s = 1105.63 N$$

$\mu = 0.7$ (Given)

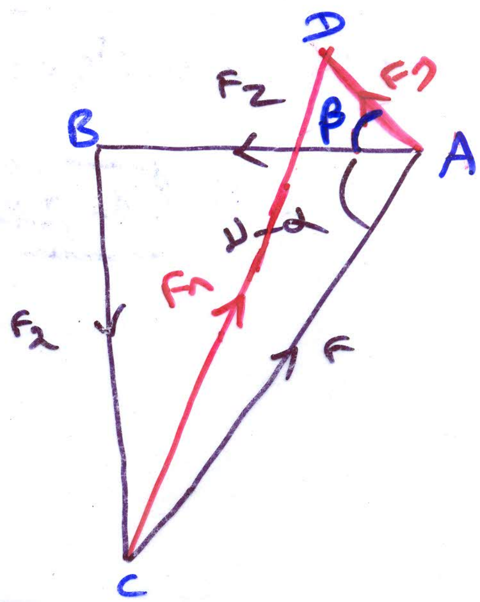
$$\nu = \tan^{-1}(\mu) = 35^\circ$$

Tangential force (or) cutting force (F_z):-

From ΔABC

$$\cos(\nu - \alpha) = \frac{F_z}{F}$$

$$F_z = F\cos(\nu - \alpha)$$



From ΔADC

$$\cos(\nu - \alpha + \beta) = \frac{F_s}{F}$$

$\therefore$ Resultant force, $F = \dfrac{F_s}{\cos(\nu - \alpha + \beta)}$

(50)

$= \dfrac{1105.63}{\cos(35 - 15 + 22.3^{\circ})}$

$\boxed{F = 1494.83\,N}$

Cutting force, $F_z = F \cos(\nu - \alpha)$

$= 1494.83 \cos(35 - 15)$

$\boxed{F_z = 1404.68\,N}$ — Ans —

Feed force (F_x) (or) normal force :—

Resultant force, $F = \sqrt{F_z^2 + F_x^2}$

$\therefore F_x = \sqrt{F^2 - F_z^2}$

$= \sqrt{1494.83^2 - 1404.68^2}$

$\boxed{F_x = 511.26\,N}$

Tool Life:-

* It is defined as the interval of time for which tool works satisfactorily b/w two consecutive resharpenings (Grindings).

* Tool life is used to calculate the tool material performance and machinability of the workpiece material.

* Tool life can be expressed in the following way.

✓ Time period in minutes b/w two consecutive resharpenings.

✓ Number of components machined b/w two consecutive Grindings

✓ Volume of material removed b/w two consecutive Grindings.

Tool life in terms of Volume of material removal:-

WKT Volume of material removed/min $= \pi D N t f \ mm^3/min$

where,

D – w/p diameter in mm

t – Depth of cut in mm

f – feed rate in mm/rev

N – No of revolution/min

If Tool life (T) in minutes, then

$$\left.\begin{matrix}\text{total volume of material} \\ \text{removed for tool failure}\end{matrix}\right\} = \pi D N t f T \ mm^3$$

(or)

$$= (V \times 1000)\, t f T$$

$$\therefore \text{Tool life } (T) = \frac{\text{Volume of material removed for Tool failure}}{(V \times 1000)\, t f}$$

Factors affecting the Cutting Tool life:–

(a) Cutting speed (b) feed & Depth of cut

(c) Tool Geometry (d) Tool material

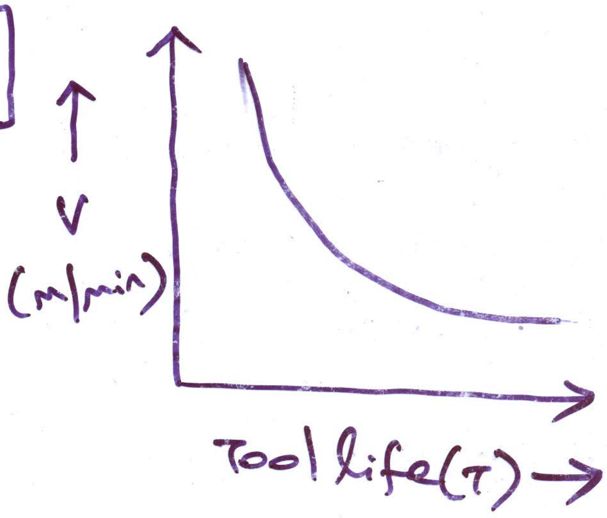
(e) work material (f) Nature of cutting

(g) Rigidity of m/c Tool & work (h) Cutting fluids

(a) Cutting Speed:—

* Major factor affecting the tool life.
* It Varies inversely with the tool life which leads to the generation of Parabolic Curve.
* the relation b/w the tool life and Cutting speed is invented by F.W. Taylor & hence Sometimes this equation is called as "Taylor's tool life equation".

$$\boxed{VT^n = C}$$



where

V – Cutting speed (m/min)

T – Tool life

C – Constant

n – Tool life index, which depends on tool material.

$n = 0.1$ for HSS, 0.2 – 0.25 for Carbide Tools, 0.4 – 0.55 for Ceramic tools

(b) Feed & Depth of cut:—

* Important Parameter affecting the tool life
* They are inversely proportional to tool life.

$$V = \frac{257}{T^{0.19} \times f^{0.36} \times t^{0.8}} \text{ m/min}$$

V – Cutting speed in m/min

T – Tool life in min

f – feed in mm/rev

t – Depth of cut in mm.

V can also expressed as

$$V = \frac{c}{f^a \times t^b}$$

f – feed in mm/min

t – Depth of cut in mm.

c – Constant.

a, b – Constant which depends on mechanical properties of workpiece material.

(c) Tool Geometry:–

* Tool angles of the cutting Tool affect the tool performance & Tool life.

* If the rake angle is increased in a positive direction, then the cutting force and heat generation is reduced which increases

the tool life whereas if it is too large, then it reduces the mechanical strength of the tool and hence tool life.

* Hence the rake angle should be in between -5 to $+10°$ where $-$ sign indicates negative rake angle. (55)

* Relief (or) clearance angle are used to prevent the rubbing of the tool flank against the w/p & if it is too large, weakening of the tool occurs. Generally it varies from 5° to 8°.

* Cutting edge angles also affect the tool life in the similar way. Hence it is kept in between 5° to 8°.

* Nose radious increases the abrasion which helps in improving the surface finish, tool strength & hence tool life

(d) Tool material:-

* Tool material which can withstand maximum cutting temperature without losing its mechanical properties & geometry will ensure maximum Tool life

* Hence higher the mechanical properties (mainly hardness and toughness) in the tool material, longer be the tool life.

(e) Work material:-

Higher the hardness of the work material, Greater will be the tool wear and hence shorter tool life

(f) Nature of Cutting:-

* Tool life is also affected by cutting nature (ie) whether it is continuous (or) intermittent.

* In continuous cutting, the tool life is more than the intermittent cutting.

(g) Rigidity of the m/c tool & work:—

* M/c Tool & w/p both should remain rigid while machining operation.

* If they are not rigid, then vibrations are developed and hence cutting tool will be subjected to intermittent cutting instead of continuous cutting and hence tool life will be shorter.

(f) Cutting fluids:—

* for efficient performance of the opreation, cutting fluids are used.

* Cutting fluids reduces the heat b/w the tool & the work, reduces the friction, improves surface finish, helps in removal of chips & hence increases the tool life.

(1) The Taylorian tool-life equation for machining C-40 steel with a 18:4:1 H.S.S cutting tool at a feed of 0.2 mm/min and a depth of cut of 2 mm is given by $VT^n = C$, where n and c are constants. The following V and T observations have been noted.

(58)

V (m/min)	25	35
T (min)	90	20

Calculate:-

(i) n and c

(ii) Hence recommend the cutting speed for a desired tool life of 60 minutes.

Soln:-

$V_1 = 25$ m/min ; $V_2 = 35$ m/min

$T_1 = 90$ min ; $T_2 = 20$ min ;

Taylor's equation:- $VT^n = \text{Constant}$

$$\therefore V_1 T_1^n = V_2 T_2^n$$

$$25 (90)^n = 35 (20)^n$$

$$\left(\frac{90}{20}\right)^n = \frac{35}{25}$$

$$(4.5)^n = 1.4$$

$$n \log 4.5 = \log 1.4$$

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$$n = \frac{\log 1.4}{\log 4.5} = 0.223$$

$$\boxed{n = 0.223}$$ — Ans —

Constant, $C = V_1 T_1^n = V_2 T_2^n$

$$C = 25(90)^{0.223}$$

$$\boxed{C = 68.19}$$ — Ans —

Cutting speed (V) for T = 60 minutes:—

$$V T^n = C$$

$$V (60)^{0.223} = 68.19$$

$$\boxed{V = 27.36 \text{ m/min}}$$ — Ans —

(2) During straight turning of a 24mm diameter steel bar at 300 r.p.m with an H.S.S. tool, a tool life of 9 min was obtained. When the same bar was turned at 250 r.p.m, the tool life increased to 48.5 min what will be the tool life at a speed of 280 r.p.m?

(60)

Given:-

Diameter of bar, $D = 24mm$;

Speed of bar, $N_1 = 300$ r.p.m;

Tool life, $T_1 = 9$ min

Speed of bar $N_2 = 250$ r.p.m;

Tool life, $T_2 = 48.5$ min;

Find:-

Tool life $T = ?$ when $N = 280$ r.p.m

Soln:-

(1) Speed in m/min (V):-

For $N_1 = 300$ r.p.m, $V_1 = \frac{\pi D N_1}{1000}$ m/min

$V_1 = 22.61$ m/min

For $N_2 = 250$ r.p.m, $V_2 = 18.84$ m/min

For $N = 280$ r.p.m, $V = 21.11$ m/min

② To find n and c in Taylor's eqn:-

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Taylor's eqn:- $VT^n = C$

$\therefore V_1 T_1^n = V_2 T_2^n$

$(22.61)(9)^n = (18.84)(48.5)^n$

$\left(\frac{9}{48.5}\right)^n = \frac{18.84}{22.61}$

$(0.1855)^n = 0.8332$

$n \log(0.1855) = \log(0.8332)$

$\therefore n = 0.1083$

Constant, $c = V_1 T_1^n$

$= 22.61 (9)^{0.1083}$

$c = 28.68$

③ Tool life (T) when N = 280 r.p.m:-

$VT^n = c$

$21.11 (T)^{0.1083} = 28.68$

$T^{0.1083} = (28.68 / 21.11)$

$T = (28.68/21.11)^{1/0.1083} = 16.93$ min

$T = 16.93$ min

(3) A cutting Tool when used for machining w/p at a cutting speed of 50 m/min lasted for 100 minutes. Taking n = 0.26 in the Taylor's tool life equation, determine (1) the life of the tool for an increase in cutting speed by 25%. (2) the cutting speed to obtain a tool life of 180 minutes.

(62)

Soln:-

$V = 50\ m/min$; $T = 100\ min$; $n = 0.26$

$\therefore \quad VT^n = constant$ (Taylor's eqn)

$$50\,(100)^{0.26} = 165.56$$

$$\boxed{C = 165.56}$$

(1) Tool life (T) when V = 1.25 (50):-

$$V = 62.5\ m/min$$

$$62.5\,(T)^{0.26} = 165.56$$

$$T = (165.56/62.5)^{1/0.26}$$

$$\boxed{T = 42.38\ min}$$

(2) Cutting Speed (v) when T = 180 min:-

$$v\,(180)^{0.26} = 165.56$$

$$\boxed{v = 42.91\ m/min}$$

(4) The following equation for Tool life is given for a turning opreation

$$VT^{0.13} f^{0.77} d^{0.37} = c$$

(63)

A 60 minute tool life was obtained while cutting at V = 30 m/min, f = 0.3 mm/rev; d = 2.5 mm

Determine the change in Tool life if the cutting speed, feed, and depth of cut are increased by 20%. Individually and also taken together

Soln:—

$$VT^{0.13} f^{0.77} d^{0.37} = c$$

$$30(60)^{0.13} [0.3]^{0.77} (2.5)^{0.37} = c$$

$$\boxed{c = 28.37}$$

(1) Tool life if v is increased by 20%:—

$$V = 1.2(30) = 36 \text{ m/min}$$

$$\therefore 36 (T)^{0.13} (0.3)^{0.77} (2.5)^{0.37} = 28.37$$

Tool life, $\boxed{T = 14.74 \text{ min}}$

(2) Tool life if f is increased by 20%:—

$$f = 1.2(0.3) = 0.36 \text{ mm/rev}$$

$$30\,(T)^{0.13}\,(0.36)^{0.77}\,(2.5)^{0.37} = 28.37$$

$$\boxed{T = 20.36\ \text{min}}$$

(4)

③ Tool life (T) if d is increased by 20%:–

$$d = 1.2\,[2.5]$$

$$\boxed{d = 3\text{mm}}$$

$$30\,(T)^{0.13}\,(0.3)^{0.77}\,(3)^{0.37} = 28.37$$

$$\boxed{T = 35.68\ \text{min}}$$

④ Tool life (T) if V, f, d are increased by 20%:–

$$36\,(T)^{0.13}\,(0.36)^{0.77}\,(3)^{0.37} = 28.37$$

$$\boxed{T = 2.98\ \text{min}}$$

Surface finish:-

Generally, Surface finish of any Component Produ-ced by m/cing depends on the following main factors.

a) Cutting Speed b) feed

c) Depth of cut d) M.R.R.

a) Cutting Speed:-

* It is defined as the rate at which the cutting edge of the tool passes over the Surface of the w/p in unit time.

* It is expressed in m/min.

* If the cutting Speed is too high, then the tool gets over-heated & the Cutting edge may blunt quickly which affects the Surface finish.

* At the Same time, if it is too low, then m/cing time is more & hence productivity decrease

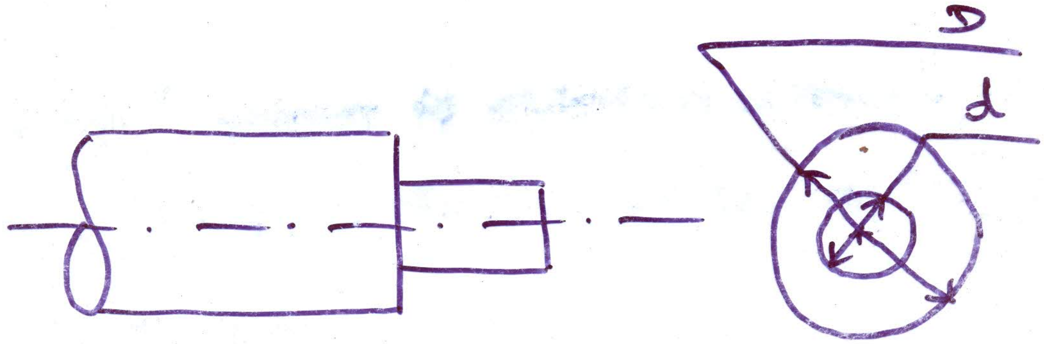
b) Feed:-

It is defined as the distance travelled by the tool along (or) into the w/p for each Pass of tool Point.

* Feed should be within certain range to get a good surface finish.

c) Depth of cut:-

* It is the penetration of the cutting edge of the tool into the material of the w/p, which is measured ⊥r to the machined surface.



$$\text{Depth of cut} = \frac{D-d}{2}$$

* If the depth of cut is high, it will affect the surface finish of the w/p.

d) M.R.R:-

* It denotes the volume of material removed per unit time.

M.R.R = feed × depth of cut × velocity

$= f \times t \times V \quad mm^3/min$

Machinability:-

"The ease with which the given material can be worked with cutting tool is "Machinability".

When it is stated that the material 'P' is more machinable than material 'Q', it means that

* Less power is required to machine material 'P'.
* Less tool wear is obtained with material 'P'.
* Better surface finish can be achieved with material 'P'.

Parameter affecting the machinability:-

M/c Variables

* cutting speed, feed & depth of cut
* Tool material.
* Tool Geometry.
* Cutting fluid
* Cutting type [Intermittent (or) Continuous]

Workpiece material Variables

* Hardness of the material
* Chemical composition of material

* Tensile strength
* Strain hardening
* Shape & size of the w/p.
* Rigidity of the w/p.

General criteria for evaluating the machinability are as follows.

1. Tool life:-

Longer tool life at a given cutting speed indicates better machinability.

(2) Surface finish:-

Better the surface finish, higher is the machinability

(3) Power consumption:-

If the power consumption is low, it indicates better machinability.

(4) Cutting force:-

Lesser the cutting force for removing the material, higher is the machinability.

5. Shear angle:—

Larger shear angle gives better machinability.

Machinability Index:—

* It is used for comparing machinability of different material.

$$M.I = \frac{\text{Cutting speed of metal for 20 min of tool life}}{\text{Cutting speed of standard free cutting steel for 20 min of tool life}} \times 100\%$$

Cutting Tool material:—

[P. no: 71]

Characteristics that the tool material Should have

1. Hot hardness
2. Wear resistance
3. Toughness
4. Cost & easiness in fabrication

Types of cutting Tool materials:— [P. no: 71]

(1) Carbon steels (2) Medium alloy steels

(3) High speed steels (H.S.S)

(4) Stellites (5) Cemented carbides

(6) Ceramics (7) Diamonds (8) Abrasives.

Cutting fluids:— [P. no: 76]

Purpose:—

(1) To cool the tool & w/p

(2) To lubricate & reduce friction

(3) To improve surface finish

(4) To protect the finished surface from corrosion

(5) To cause the chip break up into small parts

(6) To wash away the chip from the tool.

Properties of cutting fluids:—

1. High heat absorption
2. Good lubricating qualities
3. High flash point
4. neutral (5) odourless
6. Harmless to the Skin of the opreators
7. Non-corrosive to the work/Tool/machine
8. Transparency
9. Low Viscosity (10) Low Cost.

Choice of cutting fluid:—

1. Type of opreation (2) M.R.R
3. material of w/p & Tool.
4. Surface finish requirement.
5. Cost of cutting fluid.

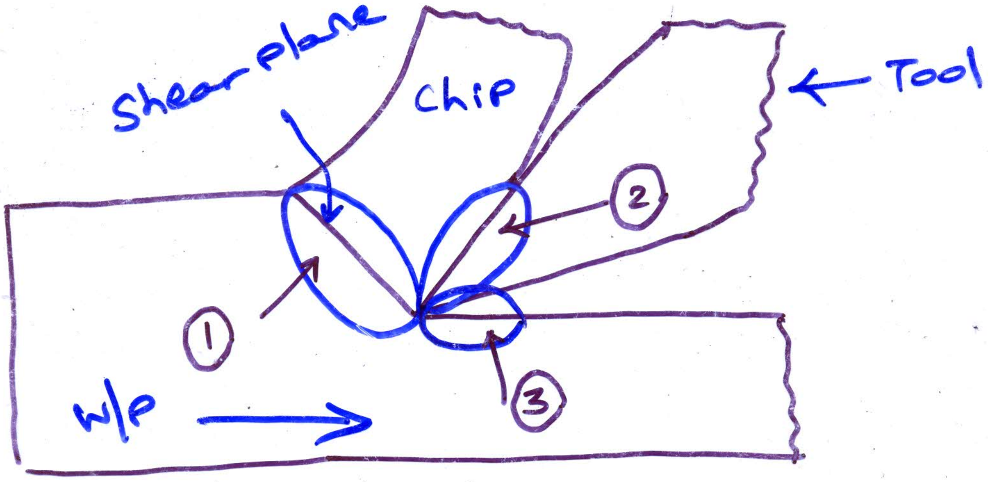
Types of Cutting fluids:—

1. Water (2) Soluable oils (3) Straight oils
4. Mixed oil (5) Solid lubricants etc.,

Sources of Heat in metal cutting:—

There are 3 regions in the metal cutting where heat is generated.

1. Around Shear Zone
2. Tool-Chip Interface
3. Tool - w/p Interface



① Shear Zone:—

* Called as "primary deformation Zone" in which Shearing of the metal (or) plastic deformation of the metal takes place.

* Heat produced in this Zone is Carried by the Chip & workpiece

(2) Tool-Chip Interface:-

* Called as " Secondary deformation zone" inwhich the heat is generated due to the friction between the Chip & tool face.

* The Heat produced in this Zone is Carried by the Chip & the tool.

(3) Tool - W/P Interface:-

* This is the Contact Area b/w the flank face of the tool & the workpiece.

* Here, the heat is generated due to the friction b/w the flank face of the tool & the workpiece.

* when the clearance angle is not sufficiently provided on the tools the heat generated in this Area will be more.

Tool failure:-

If the tool is not giving the satisfactory performance, then it is an indication of the "tool failure" which causes the following adverse effects.

* Poor surface finish of the w/p.
* High power consumption.
* Incorrect work dimension
* overheating of the cutting tool & the workpiece

The main causes of the failure of the tool are as follows.

(a) thermal cracking & softening
(b) Mechanical chipping
(c) Tool wear → a) Crater wear
→ b) Flank wear
→ c) Chemical wear.

(a) thermal cracking & softening:-

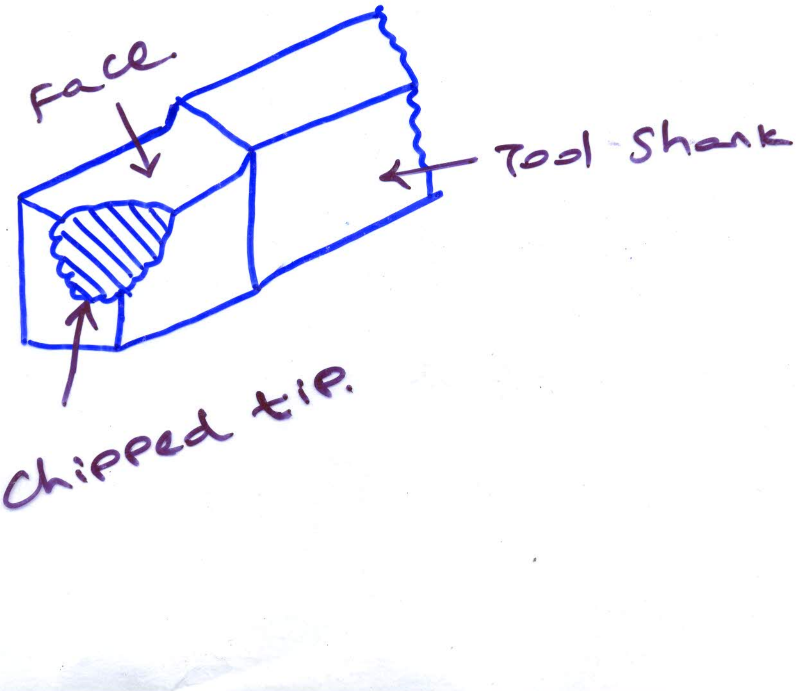
* During metal cutting, high heat is generated at the cutting edge & the tip of the tool. Due to this, plastic deformation takes place

at the cutting edge & the tool tip. Due to this, the tool cutting edge & its tips will become soft & it will lose its cutting ability. This is known as "softening".

* Sometimes, due to the high heat, there may be a chance of the cracks which is developed on the cutting edge of the tool. this is known as "Thermal cracking".

(b) Mechanical chipping:—

It denotes the breakage of the tool nose due to the high cutting pressure, mechanical impact, excessive wear & high vibration etc.,

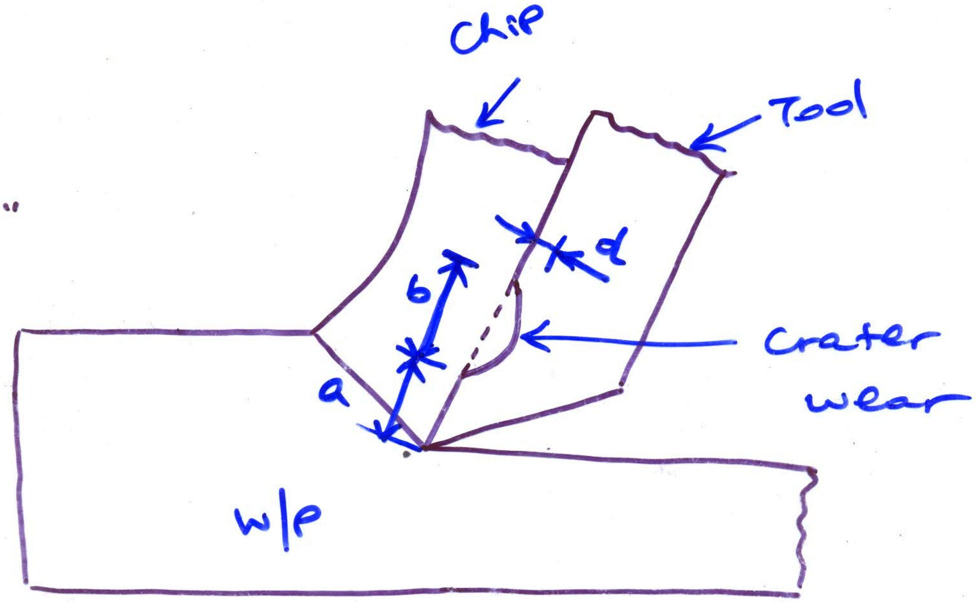


Tool wear:-

Sometimes, when the tool is in use, it will loose its weight, which means it has lost some material from it due to wear which are of the following types.

(i) Crater wear:-

depression width - "b" Depth - "d" Distance - "a" from the tool tip.



* The depression on the tool face is known as "crater wear". This type of wear takesplace during machining of ductile material inwhich continuous chip will be formed.

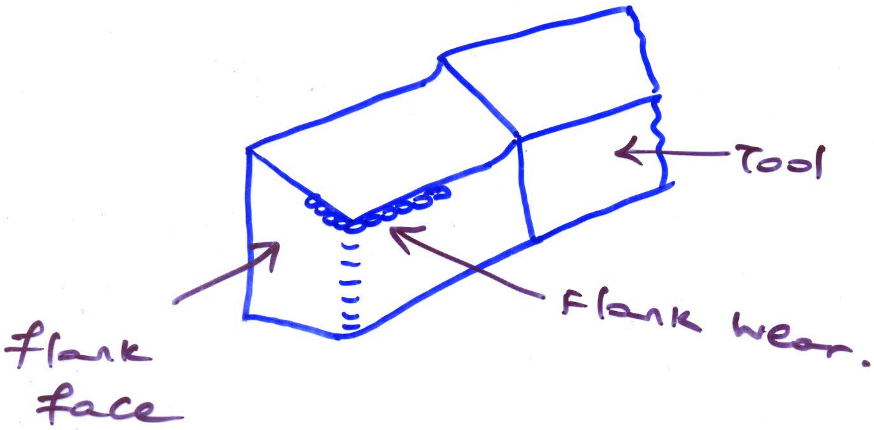
* The main cause for this depression (or) crater is due to the pressure by the hot chip sliding on the tool face.

(ii) Flank wear:-

* The flank face portion below the cutting edge is the region where an appreciable amount of wear occurs.

* "Flank wear" is due to the abrasion b/w the tool flank face & the w/p.

* This type of wear mainly occur when machining brittle material.



(iii) Chemical wear:-

* This type of wear occurs when a cutting fluid used is chemically reactive.

* Due to this, the chemical reaction takes place b/w the cutting Tool & cutting fluid & the erosion takesplace on the cutting tool.