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

$$\therefore \boxed{\mu = \frac{F}{N} = \tan\beta = \frac{F_t + F_c \tan\alpha}{F_c - F_t \tan\alpha}}$$

Note:-

1. From $\angle ACP$, we get

$$\tan(\beta - \alpha) = \frac{F_t}{F_c}$$

2. $$^{*}\boxed{R = \sqrt{F_c^2 + F_t^2} = \sqrt{F_s^2 + F_{N_s}^2} = \sqrt{F^2 + N^2}}$$

2. from right angled Δ^{le} ABC, we also have

$$\frac{F}{N} = \tan\beta = \mu.$$

$$\beta = \tan^{-1}(\mu)$$

$$\beta = \tan^{-1}\left(\frac{F}{N}\right)$$

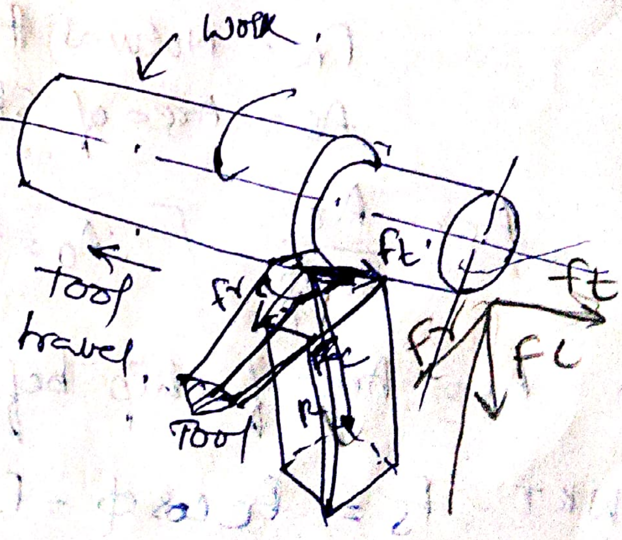
Forces on a single point tool in turning

In oblique cutting, 3 forces acts on a tool pt.

F_t - Thrust force (or) feed force.

F_r - Radial force.

F_c = Cutting force.



out of 3 forces

F_c - largest

F_r - smallest.

F_t varies b/w $0.3F_c$ to $0.6F_c$.

F_r between $0.2F_c$ to $0.4F_c$

for, orthogonal cutting, 2 forces come into play F_r is zero.

Resultant $R = \sqrt{F_c^2 + F_t^2 + F_r^2}$

for, orthogonal, $R = \sqrt{F_c^2 + F_t^2}$

Stress and Strain in the chip :-

A chip is supposed to experience both the stress and strain during metal machining because it is produced as a result of plastic deformation.

Consider two mutually $\perp$lar forces F_s and F_N act on the shear plane.

Mean shear stress $(\tau_s) = \frac{F_s}{A_s}$ (N/mm^2) — ①

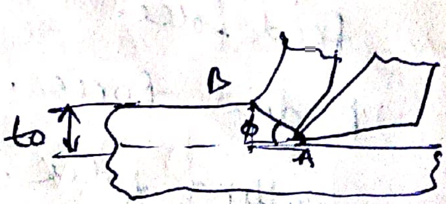
Mean normal stress $(\sigma_s) = \frac{F_n}{A_s}$ (N/mm^2) — ②

F_s = Shear Force

F_n = Normal force

A_s = Area of Shear plane

$A_s = \frac{A_0}{\sin\phi}$ $[\because A_0 = t_0 \cdot w]$



A_0 = Area of chip before removal

WKT $F_s = F_c \cos\phi - F_t \sin\phi$

By sub, F_s in eqn ①

$$\tau_s = \frac{F_s}{A_s}$$

$$= \frac{F_c \cos\phi - F_t \sin\phi}{\frac{t_o \cdot w}{\sin\phi}}$$

$$\tau_s = \frac{F_c \cos\phi - F_t \sin\phi}{t_o \cdot w} \times \sin\phi \text{ kg/mm}^2$$

WKT, $F_n = F_t \cos\phi + F_c \sin\phi$

Sub, F_n in eq (2)

$$\sigma_s = \frac{F_n}{A_s}$$

$$= \frac{F_t \cos\phi + F_c \sin\phi}{\frac{t_o \cdot w}{\sin\phi}}$$

$$\sigma_s = \frac{F_t \cos\phi + F_c \sin\phi}{t_o \cdot w} \times \sin\phi \text{ Kg/mm}^2$$

Now, let the shear strain $= \gamma$.
Consider no loss of work during shearing

Work done in shearing per unit vol. of the metal $=$ shear stress X shear strain.

Work done in shearing per unit volume of metal removed in unit time $= \dfrac{\text{Total W.D in Shearing / unit time}}{\text{Vol. of metal removal in unit time}}$

$$= \frac{F_s \times V_s}{A_0 \times V_c}$$

$$\therefore \quad \frac{F_s \times V_s}{A_0 \times V_c} = \tau_s \times \gamma$$

$$\gamma = \frac{F_s \cdot V_s}{t_0 \times w \times V_c \times \tau_s}$$

but, $\tau_s = \dfrac{F_s}{A_s} = \dfrac{F_s}{A_0} \sin\phi = \dfrac{F_s}{t_0 \cdot w} \sin\phi$

$$\gamma = \frac{F_s \cdot V_s}{\frac{F_s}{t_0 \cdot w} \sin\phi \times t_0 \times w \times V_c}$$

$$= \frac{\cancel{F_s}\,\cancel{(t_0 \times w)}}{\cancel{F_s} \sin\phi} \cdot \frac{1}{\cancel{t_0 \times w}} \times \frac{V_s}{V_c}$$

$$= \frac{V_s}{V_c \sin\phi}$$

We know that

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

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

<u>Work done in cutting</u>:-

Total work done = work done in shearing the metal
+
work done in over coming the friction

$$W = W_s + W_f$$

If no work is lost,

Tot work done = work supplied by the motor

∴ work supplied by the motor = $W_s + W_f$

Now, the work supplied by the motor is partly used in cutting and partly in feeding the tool,

If W_m, is the work supplied by the motor,

W_m = work consumed in cutting + work spent in feeding

$$= F_c \times V_c + F_t \times \text{feed velocity}$$

In comparison, the cutting velocity and feed velocity is very nominal

III^{ly}, F_t is very small than F_c

So, the work spent in feeding can be negligible.

i.e. $W_m = F_c \times V_c$

$W_s = F_s \times V_s$ (Shear force × shear velocity)

$W_f = F \times V_f$ (frictional force × Vel. of chip flow)

or, $F_c \times V_c = F_s \times V_s + F \times V_f$.

If forces – kgs, velocities – m/min

then W.D will be in kgf m/min.

Work done per unit vol. in unit time $= \dfrac{\text{Tot W.D in cutting per unit time}}{\text{Vol. of metal removed in unit time}}$

$= \dfrac{F_c \times V_c}{A_o \times V_c}$ [A_o = c/s area of chip before removal]

$= \dfrac{F_c}{A_o}$.

Horse power calculation :

H.P required in cutting $= \dfrac{\text{W.D in cutting/min}}{4500}$

1 hp. = 0.7457 KW

$= \dfrac{1}{1.36}$ KW

$= \dfrac{F_c \times V_c}{4500}$ h.p

F_c – kg

V_c – m/min

$= \dfrac{F_c \times V_c}{4500 \times 1.36}$ KW

Cutting speed, feed, Depth of cut

Cutting speed – Rate at which its cutting edge passes over the surface of the w/p in unit time.

feed – The distance it travels along & in to the w/p for each pass

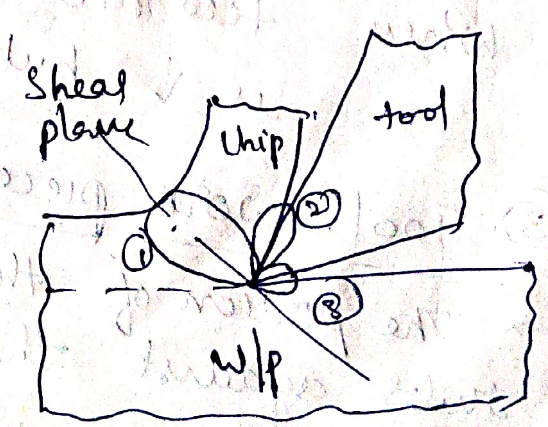
depth of cut – It is the indicative of the penetration of the cutting edge of the tool in to the w/p.

Influencing factors :-

1. Material being machined
2. Material of the cutting tool
3. Geometry of the cutting tool
4. Required degree of surface finish
5. Rigidity of the machine tool being used
6. Type of coolant being used

Sources of heat in Metal cutting :-

During metal cutting, heat is generated in 3 regions.



1. Around shear plane :-

– It is the region in which actual plastic deformation of metal occurs during machining

– Due to the deformation

heat is generated.

- A portion of this heat is carried away by the chip, due to which its temp is raised.
- The rest of the heat is retained by the w/p.
- It is known as primary deformation zone.

② **Tool chip interface:—**

- As the chip slides upwards along the face of the tool friction occurs b/w their surfaces. due to which heat is generated.
- A part of this heat is carried by the chip, which further raises the temp of the chip, and the rest transferred to the tool and the coolant.
- This area is known as secondary deformation zone.

when cutting speed ↑ heat generated due to friction ↑ and ↑DOC not much effect the heat generated.

when feed rate ↑ frictional heat generated is ↓ but S/F is inferior.

③ **Tool-work piece interface!—**

→ The portion of the tool flank which rubs against the work surface is another source of heat generation due to friction.

→ This heat also shared by tool, w/p and the coolant used

→ 70% of heat is carried away by the chip
15% of heat is transferred to the tool.
15% of heat to the w/p.

Note:-
1) Increase in the cutting speed :-
higher amount of heat is absorbed by the chip and lesser amount is transferred to the tool & w/p.
2) The shear angle also effects the heat generation
3) A larger shear angle leads to a smaller heat generation in the primary deformation zone.

Amount of heat generated / unit of time = Thermal equivalent of the mechanical work done

Mechanical W.D = cutting force (kgf) × cutting Velocity (m/min)

$$W.D = F_c \times V_c \text{ kgf} \cdot \text{m/min}.$$

Amt of Total heat generated in cutting the metal

$$Q = \frac{W.D (\text{in kgf} \cdot \text{m/min})}{427}$$

$$Q = \frac{F_c \times V_c}{427} \text{ Kcal/min}$$

Tool failure

A properly designated and ground Cutting tool is expected to perform the metal cutting operation in an effective and smooth manner.

Tool failure has some following adverse effects observed during the operation

1) Extremely poor surface finish on the w/p
2) Higher consumption of power
3) Work dimensions not being produced as specified
4) over heating of cutting tool.
5) Appearance of a burnishing band on the work surface.

A cutting tool may fail due to one or more of the following reasons.

1) Thermal cracking and softening
2) Mechanical chipping
3) Gradual wear.

1) Thermal Cracking and softening:-

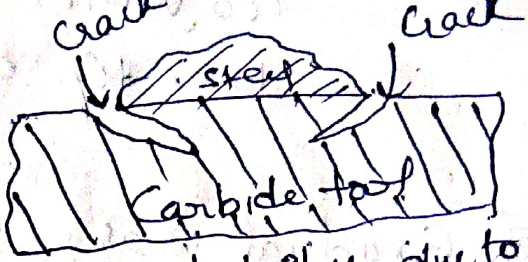
→ The tool tip and the area closer to the Cutting edge becomes very hot when temp exceeds the limit of elevated temp.

→ The tool material starts deforming plastically at the tip and adjacent to the Cutting edge

Under the action of cutting pressure and high temp(..

→ The tool loses its cutting ability and is said to have failed due to softening.

<u>Main factors</u> :—



Tool failure due to thermal cracking

high cutting speed
high feed rate.
excessive depth of cut.
Smaller nose radius..
choice of wrong tool material.

The temp(.. ranges with out losing their hardness

Carbon tool steels	200°c – 250°c
High Speed steels	560°c – 600°c
Cemented carbides	800°c – 1000°c

→ On account of fluctuations in temperatures and severe temp(.. gradients, the tool material is subjected to local expansion and ~~contractions~~. contraction

→ This gives rise to the setting up of temperatures stresses or thermal stresses, due to which cracks are developed in the material.

2) <u>Mechanical Chipping</u> :—

Mechanical chipping of the nose and the cutting edge of the tool are commonly observed causes of tool failure

Reasons :-

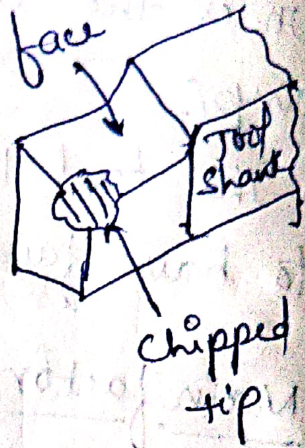
too high cutting pressure

Mechanical impact

excessive wear

too high vibrations and chatter

weak tip and cutting edge.



3) Gradual wear :-

When a tool is in use for sometime it is found to have lost some weight of mass which is due to wear.

There are two types

1) crater wear

2) flank wear

1) Crater wear :-

→ Due to pressure of the hot chip sliding up the face of the tool, crater (or) a depression is formed on the face of the tool

→ By diffusion shape of crater formed corresponding to the shape of underside of the chip

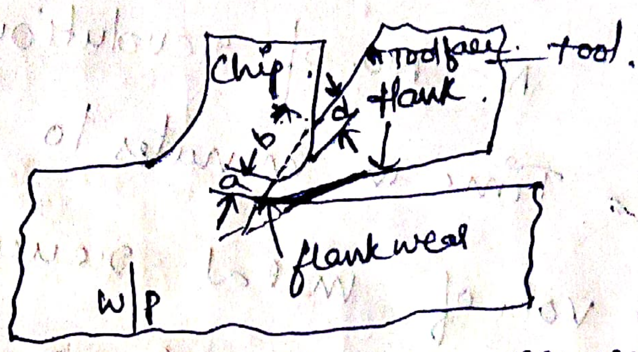
2) flank wear :-

→ It occur b/w tool & w/p interface. Due to abrasion b/w tool flank & w/p

→ Hard micro constituents of cut material & broken parts of BUE

→ common in brittle material

→ The entire area subjected to flank wear is known as wear land. Occurs on the tool nose front & side relief face.



Principal types of wear occuring in the cutting tool.

Tool Life:-

It is defined as the time interval for which the tool works satisfactorily b/w two successive grindings (sharpenings).

Expressing tool life in

① As time period in minutes b/w two successive grindings

② In terms of no. of components machined b/w two successive grindings (sharpenings) (when tool operates continuously.)

③ In terms of volume of material removed b/w two successive sharpenings (tool is primarily used for heavy stock removal)

Vol. of metal removed per minute

$= \pi D t f N \ mm^3/min$

$D =$ Dia of w/p in mm

$t =$ depth of cut in mm

$f =$ feed rate in mm/rev

$N =$ No. of revolutions of work per min.

$T =$ Time in minutes to tool failure,

Total vol. of metal removed to tool failure

$= \pi D t f N T \ mm^3$

Cutting speed $V = \frac{\pi D N}{1000}$ m/min

$\pi D N = V \times 1000$

Total vol. of metal removed to tool failure

$= V \times 1000 \times t \times f \times T \ mm^3$

$$\boxed{\text{Tool life } (T_L) = V \cdot 1000 \cdot t \cdot f \cdot T} \ (mm^3)$$

Factors affecting tool life:-

1) Cutting speed
2) Feed and depth of cut
3) Tool Geometry
4) Tool material
5) Work material
6) Nature of cutting
7) Rigidity of m/c tool & work
8) Use of cutting fluids

1) Effect of cutting speed

→ Max. effect on tool life is of cutting speed.

$$C.S \propto \frac{1}{\text{tool life}}.$$

According to Taylor's eqn,

$$VT^n = C$$

V = Cutting speed (m/min)

T = Tool life (minutes)

n = An exponent

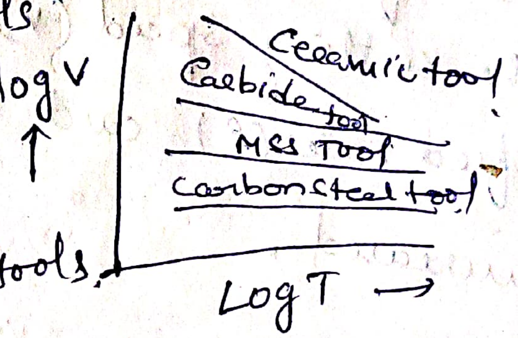
C = Machining constant (which is equal to cutting speed in m/min. tool life of one minute)

n for common tool materials

"n = 0.1 to 0.15 for HSS tools

n = 0.2 to 0.5 for cemented carbide tools

n = 0.6 to 1.0 for ceramic tools.



2) feed and Depth of cut :-

An increase in feed rate and DOC reduces tool life. when C.S ↑

$$V = \frac{257}{T^{0.19} \times f^{0.36} \times t^{0.80}} \text{ m/min}$$

V = Cutting speed in m/min

T = Tool life in min.

f = Feed rate in mm/min

t = Depth of cut in mm