(or)

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

V = Cutting speed (m/min)

f = feed rate in mm/min

t = Depth of cut in mm

C = A constant.

a, b depends on mechanical properties of w/p material.

note:- If tool life is considered as const. the cutting speed (v) will decrease if the feed rate (f) and depth of cut (t) are increased.

3) Tool Geometry:-

Many geometrical parameters (tool angles) of a cutting tool influence its performance and life.

Ex: 1) Rake angle.

→ If it is increased in a +ve direction the cutting force and the amt of heat generated are reduced.

→ It helps to ↑ the tool life

But, increased tool much, cutting edge becomes weak & tool life ↓.

$\boxed{\text{decreasing rake angle} \propto \text{tool life}}$. $\boxed{\text{angles vary from } -5^\circ \text{ to } 10^\circ}$

Negative Rake angle

→ rake angle made by the cutting edge sloping upwards from the tip.

→ It provide a strong cutting edge and strong tool life.

→ cemented carbide & ceramic tools provide -ve rake angle.

2) Clearance angle.

→ These are provided to prevent rubbing of tool flank over the work

→ Thus amt of heat generated ↓ tool life ↑

but, very large relief angle — weakens tool & tool life ↓

$\boxed{\text{angles vary from } 5^\circ \text{ to } 8^\circ}$

but for carbide tipped tools, 10° is provided to prevent rubbing of shank.

3) Cutting edge angles

end cutting edge angle — effects tool wear. ↑ tool life

(or) front cutting edge angle.

Side cutting edge angle — complex effect on tool life.

4) Inclination angle :—
Tool life ↑ with ↑ in this angle up to an optimum level

5) Nose radius :- It helps in improving surface finish, tool strength and tool life.

4) Tool material :—

Main characteristics — hot hardness
wear resistance
impact resistance
abrasion resistance
heat conductivity
strength.

The tool which can withstand maximum cutting temp. without losing its principal mechanical properties and geometry will ensure max. tool life.

Note Increase the hot hardness/toughness — increases tool life.

5) W/p material :—
· Scale formation and presence of oxide

layer on the work surface serve as abrasives and detrimental effect on tool life.

→ increase in cutting temperature and power consumption vary directly the hardness of the w/p material

→ hardness of the work material ∝ tool wear and ↓ tool life.

6) Nature of cutting.

~~Rigidity of ... tool~~.

→ Tool life is also effected by the nature of cutting i.e., it is continuous or intermittent.

→ Due to repeated impact loading, tool life may decrease.

7) Rigidity of M/c tool and work:-

→ M/c tool & work remain rigid during machining operation

→ If not, vibrations will produce and cutting tool subjected to intermittent cutting instead of continuous cutting, due to the tool life decreases

8) Use of cutting fluids

→ used for helping the efficient performance of the operation

→ They may be liquid or gaseous form.

→ They cool the tool & work, reducing friction,

Factors

Improving surface finish, helping in breaking of chips & washing them away

→ Factor improve

tool life
permitting higher metal removal rate
improving the quality of S/f

Problems

1) A high speed steel tool is used for machining a w/p of mild steel. While machining at a cutting speed of 30m/min the useful life of the tool is found to be 1 hour. What will be the tool life if the same tool is used to cut at a speed of 40m/min, other parameters remaining the same. Assume the value of exponent (n) of standard Taylor's equation = 0.12

Given
$V_1 = 30m/min$
$V_2 = 40m/min$
$T_1 = 1hr$
$= 60min$
$n = 0.12$

Soln According to Taylor's Eqn,

$$VT^n = C$$

Sub, V, T and 1 for first machining operation,

$$V_1 T_1^n = C$$

$$30 \times 60^{0.12} = C \quad \text{—(1)}$$

for 2^{nd} machining operation,

$$V_2 T_2^n = C$$

$$40 \times T_2^{0.12} = C \quad \text{--- (2)}$$

equating (1) & (2)

$$30 \times 60^{0.12} = 40 \times T_2^{0.12}$$

$$\left(\frac{T_2}{60}\right)^{0.12} = \frac{30}{40}$$

$$T_2 = 5.45 \text{ min} \cong 5.5 \text{ min}.$$

2) In orthogonal cutting experiment with tool of rake angle 6° the chip thickness was found to be 3mm. when the uncut chip thickness was To 1mm find shear angle, friction angle.

Soln α = Rake angle = 6°

Chip thickness ratio $r = \frac{1}{3} = 0.33$

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

$$= \tan^{-1}\left[\frac{0.33\cos 6^\circ}{1 - 0.33\sin 6^\circ}\right]$$

Earnst - Merchant theory :-
based on principle of mini. energy consumption.

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

($\frac{\pi}{4}$ = 45°)

lee & Shaffer theory

$$\phi = 45^\circ + \alpha + \theta - \beta.$$

ϕ =

friction angle :-

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

β =

3) In orthogonal ~~cutting~~ turning of a 50 mm dia, mild steel bar on a lathe and following data were obtained; Rake angle = 15°, cutting speed (or velocity) = 100 m/min, feed = 0.2 mm/rev, cutting force = 180 kg, feed force = 60 kg. Calculate the shear plane angle (ϕ), Coeff. of friction (μ), cutting power, the chip flow velocity (V_f) and shear force, if the chip thickness = 0.3 mm.

Soln

WKT $r = \dfrac{t_o}{t_c}$

Given,

$t_o = 0.2\,mm$	$\alpha = 15^\circ$	$F_t = 60\,kg$
$t_c = 0.3\,mm$	$F_c = 180\,kg$	$V_c = 100\,m/min$

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

WKT,

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

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

$$= 0.7787$$

$$\phi = \tan^{-1}(0.7787) = 37^\circ 55'$$

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

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

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

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

$\mu = 0.66.$

$$\text{Cutting power} = \frac{\overset{F_c}{\text{Cutting force}} \times \overset{V_c}{\text{cutting speed}}}{4500}$$

$$= \frac{180 \times 100}{4500.}$$

$= 4\ HP.$

Chip flow velocity (V_f) = cutting velocity $(V_c) \times r.$

$= 100 \times 0.667$

$= 66.7\ m/min$

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

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

$= 142.074 - 36.87$

$= 105.20\ kg.$

4) The following data were recorded while turning a w/p on a lathe: cutting speed = 25 m/min, feed rate = 0.3mm/rev, depth of cut = 2.0mm, tool life = 100minutes. The following tool life equation is given for this operation

$VT^{0.12} f^{0.7} d^{0.3} = C$

If the cutting speed, feed and DOC are all increased by 25% each, and also collectively

What will be their effect on the tool life.

Soln

Given, $V = 25$ m/min

$f = 0.3$ mm/rev.

$d = 2$ mm

$T = 100$ min

The given tool life eqn is

$$VT^{0.12} f^{0.7} d^{0.3} = C.$$

$$C = 25 \times 100^{0.12} \times 0.3^{0.7} \times 2^{0.3}$$

$$= 23$$

When 3 parameters, cutting speed, feed & DOC increased by 25%, then

$$V = 25 \times 1.25 = 31.25 \text{ m/min}$$

Sub, new 'V' value in tool life eqn

$$C = VT^{0.12} . f^{0.7} . d^{0.3}$$

$$23 = 31.25 \times 0.3^{0.7} \times 2^{0.3} \times T^{0.12}$$

$$T^{0.12} = \frac{23}{31.25 \times 0.3^{0.7} \times 2^{0.3}}$$

$$= 1.387$$

$$T = (1.387)^{1/0.12}$$

Tool life, $T = 15.27$ min

By increasing the feed by 25% the new value of feed will be ;

$$f = 0.3 \times 1.25 = 0.375\,mm/rev$$

Tool life for new feed rate will be

$$25 \times (0.375)^{0.7} \times 2^{0.3} \times T^{0.12} = 23$$

$$T^{0.12} = (1.486)$$

$$T = (1.486)^{\frac{1}{0.12}}$$

$$T = 27.13\ min$$

By increasing the depth of cut by 25%,

$$d = 2 \times 1.25 = 2.5\,mm$$

Tool life for increased doc will be

$$T^{0.12} = \frac{C}{25 \times (0.3)^{0.7} \times (2.5)^{0.3}}$$

$$T^{0.12} = \frac{23}{25 \times 0.431 \times 1.316}$$

$$T^{0.12} = 1.622$$

$$T = (1.622)^{1/0.12} = 56.29\ min$$

The new values of v, f & d are

$V = 31.25\ m/min$

$f = 0.375\ mm/rev$

$d = 2.5\ mm$

$$T^{0.12} = \frac{23}{31.25 \times (0.375)^{0.7} \times (2.5)^{0.3}}$$

$$= \frac{23}{31.25 \times 0.503 \times 1.316}$$

$$T = (1.112)^{1/0.12}$$

$$= 2.42 \text{ min}$$

Conclusion

1) Max. reduction in tool life is due to increase in cutting speed

2) Mini. effect on tool life is due to ↑ in doc

3) The total reduction in tool life due to the combined effect of all the three increments is drastic

Formulas

1) Chip thickness ratio $(r) = \dfrac{\text{Chip thickness prior to deformation}}{\text{Chip thickness after deformation}}$

$$r = \frac{t_o}{t_c}$$

Shear angle (ϕ), $\tan\phi = \dfrac{r\cos\alpha}{1 - r\sin\alpha}$

From Velocity relations

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

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

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

$$V_f = V_c \times r$$

(or)

Vol. of material cut / unit of time

Vol. of material flowing up as chip

= Volume of material floating up as chip

$$V_c \cdot t_1 \cdot w = V_f \cdot t_2 \cdot w$$

$$\frac{V_c \cdot t_1}{t_2} = V_f$$

$$V_f = V_c \cdot r$$

μ = coefficient of friction $= \dfrac{F}{N}$

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

Resultant $= \sqrt{F_c^2 + F_t^2 + F_r^2}$ (oblique)

$R = \sqrt{F_c^2 + F_t^2}$ (ortho)

Shear stress

$$\tau_s = \frac{F_s}{A_s} = \frac{F_c \cos\phi - F_t \sin\phi}{t_0 \times w} \sin\phi \ \text{kg/mm}^2$$

Normal stress

$$A_s = \frac{A_0}{\sin\phi} = \frac{t_1 w}{\sin\phi}$$

$$\sigma_s = \frac{F_n}{A_s} = \frac{F_t \cos\phi + F_c \sin\phi}{t_0 \times w} \times \sin\phi \ \text{kg/mm}^2$$

Shear strain $\gamma = \dfrac{\cos\alpha}{\cos(\phi - \alpha)\sin\phi}$

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

Horse power in metal cutting $= \dfrac{\text{W.D in cutting/min}}{4500}$

$$= \frac{F_c \times V_c}{4500} \text{ H.P}$$

Angle of friction (β).

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

5) In an orthogonal turning operation on a lathe the following data were obtained. cutting force = 120 kg, feed force = 30 kg, back rake angle = 15°, feed rate = 0.2 mm/rev, chip thickness = 0.3 mm, cutting speed = 100 m/min, w/p diameter = 120 mm, depth of cut = 0.4 mm, calculate chip thickness ratio, Shear angle, coefficient of friction, friction angle, shear stress, shear strain, strain energy and chip flow velocity.

soln. $F_c = 120\,kg$ | $\alpha = 15°$ | $V_c = 100\ m/min$

$F_t = 30\,kg$ | $t_0 = 0.2\,mm/rev$ | $d = 120\,mm$

$t_c = 0.3\,mm$ | $w = 0.4\,mm$

Chip thickness ratio $r = \dfrac{t_0}{t_c} = \dfrac{0.2}{0.3} = 0.67$.

$$\tan\phi = \frac{r\cos\alpha}{1 - r\sin\alpha} = \frac{0.67 \times \cos 15}{1 - 0.67 \times \sin 15}$$

$$= 0.804$$

$$\phi = 38°48'$$

Coefficient of friction $(\mu) = \dfrac{F_c \sin\alpha + F_t \cos\alpha}{F_c \cos\alpha - F_t \sin\alpha}$.

$$= \frac{120 \times \sin 15 + 30 \times \cos 15}{120 \times \cos 15 - 30 \times \sin 15}$$

$$\mu = 0.55$$

from, $\mu = \tan\beta$

$\therefore$ friction angle $\beta = \tan^{-1}\mu = 28°48'$

Shear stress

$$\tau_s = \frac{F_c \cos\phi - F_t \sin\phi}{t_0 \times w} \times \sin\phi$$

$$= \frac{120 \times \cos 38^\circ 40' - 30 \times \sin 38^\circ 40'}{0.2 \times 0.4} \times \sin 38^\circ 4$$

$$\tau_s = 584.5 \text{ kg/mm}^2$$

Shear strain

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

$$= \frac{\cos 15^\circ}{\cos(38^\circ 48' - 15^\circ)\sin 38^\circ 48'}$$

$$\gamma = 1.623$$

Strain energy = Shear stress × shear strain

$$= \tau_s \times \gamma$$

$$= 584.5 \times 1.623$$

$$= 948.6 \text{ kg/mm}^2$$

Chip flow velocity (V_f) = Cutting speed × r

$$= 100 \times 0.67$$

$$= 67 \text{ m/min}$$