ME 338
Manufacturing Processes II
HW#1

1. Consider the Merchant's Cutting Force diagram and tool-chip interface presented in the lecture notes. Consider the directions of the cutting force and the thrust force. Will the Fc, cutting force, be always positive and why? Is the thrust force, Ft, also positive at all times? If not, explain why. Show from force expressions how you can make Ft = 0 for a given friction coefficient between the tool and the work piece. Please provide physical explanations of your suggestions/recommendations.

Ft = R sin(β - α) and **Ft = Fc tan(β - α)**

The magnitude of Fc is always positive (since the direction of the feed is always towards the material); the sign of Ft can be either positive or negative, depending on the relative magnitudes of β and α. When β > α, the sign of Ft is positive (downward) and when β < α, it is negative (upward). Therefore, in order to make the thrust force = 0, we make β = α. This can be achieved in two ways:
1) Change the rake angle of the tool, α.
2) By adding lubricant, effectively changing the friction angle β.

It is the second step that we most commonly employ in machining when something is "wrong" in the cut.

2) Given,

$t_o = 0.25\,mm$ $w = 2.5\,mm$ $F_c = 950\,N$

$t_c = 0.75\,mm$ $\alpha = 0^\circ$ $F_t = 475\,N$

we have.

$F_t = F_c \tan(B - \alpha)$

$\Rightarrow \dfrac{475}{950} = \tan B = \mu$

$\Rightarrow \boxed{\mu = 0.5}$

we have cutting ratio $\dfrac{t_o}{t_c} = \dfrac{\sin\phi}{\cos(\phi - \alpha)}$

$\Rightarrow \dfrac{0.25}{0.75} = \tan\phi$

$\Rightarrow \phi = 18.43^\circ$

we have $\tau = \dfrac{F_c \sin\phi \cos(\phi + B - \alpha)}{w t_o \cos(B - \alpha)} = \dfrac{950 \times \sin(18.43) \cos(18.43 + 26.56)}{2.5 \times 0.25 \times 10^{-6} \times \cos 26.56}$

$= 379.951\,MPa$

By Tresca Criterion $\dfrac{\sigma_o}{2} = \tau \Rightarrow$ USstress $= 759.9\,MPa$

By VonMisces Criterion $\dfrac{\sigma_o}{\sqrt{3}} = \tau$ USstres $= 658\,MPa$.

(3). $V = 280\ m/min$

$\alpha = 10^\circ$

$t_0 = 2mm$

$feed = 0.2\ mm/rev.$

$\mu = 0.5$

$\tau_s = 400\ N/mm^2$

(a) Merchant's equation $2\varphi + \beta - \alpha = \pi/2$

$\beta = \tan^{-1}(0.5) = 26.565^\circ$

$2\varphi + 26.565 - 10 = 90$

$\varphi = 36.7175^\circ$

(b) $$F_c = \frac{\tau_s w t_0 \cos(\beta - \alpha)}{\sin\varphi \cos(\varphi + \beta - \alpha)} = \frac{\tau_s w t_0 \cos(\pi/2 - 2\alpha)}{\sin\varphi \cos(\pi/2 - \varphi)}$$

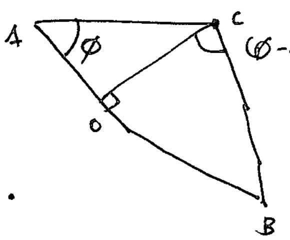
$$= \frac{2\tau_s w t_0\ [\text{illegible}]}{2\sin^2\varphi} = 429\ N$$

$$F_t = F_c \tan(\beta - \alpha)$$

$$= F_c \tan(16.565^\circ)$$

$$= 127.56 N$$

4. The shear plane diagram for the orthoganal cutting is



a) Shear strain in chip

$$\gamma = \frac{AB}{OC} = \frac{AO}{OC} + \frac{OB}{OC} = \cot\phi + \tan(\phi-\alpha)$$

Cutting ratio $r = \frac{\sin\phi}{\cos(\phi-\alpha)}$ from $r = \frac{t_0}{t_c}$

b) For minimum strain condition

$$\frac{\partial\gamma}{\partial\phi} = 0 \Rightarrow \cancel{\sec(\phi-\alpha)\tan(\phi-\alpha)(-1) \neq 0}$$

$$\cancel{\Rightarrow \phi = \quad \sec^2(\phi-\alpha)}$$

$$-\cot\phi\,\mathrm{cosec}(\phi) + \tan(\phi-\alpha)\sec(\phi-\alpha) = 0$$

$$\Rightarrow \frac{\cos(\phi)}{\sin^2\phi} = \frac{\sin(\phi-\alpha)}{\cos^2(\phi-\alpha)}$$

$$+\mathrm{cosec}^2(\phi) = \sec^2(\phi-\alpha)$$

$$\Rightarrow \cancel{\alpha \ \tan}\ \cos^2(\phi-\alpha) = \sin^2(\phi)$$

$$\Rightarrow \sin\phi = \cos(\phi-\alpha)$$

(or) $\sin\phi = -\cos(\phi-\alpha)$

~~2^st not possible as it gives~~

1st gives $\pi/2 - \phi = \phi - \alpha$ [Taking basic solution only and avoiding $n\pi/2$ n ε odd].

$\Rightarrow \pi/2 = 2\phi - \alpha$.

2nd gives $\pi/2 \cancel{+\phi} = \phi - \alpha$

$\Rightarrow \alpha = -\pi/2$ (not possibe)

$$\Rightarrow \phi = \left(\frac{\pi/2+\alpha}{2}\right) = \boxed{\left(\pi/4 + \alpha/2\right)}$$

c) we have $r = \frac{\sin\phi}{\cos(\phi-\alpha)}$

put $\phi = \pi/4 + \alpha/2$

$$\Rightarrow \boxed{r = \frac{\sin(\pi/4 + \alpha/2)}{\cos(\pi/4 - \alpha/2)}}$$

d) Expected value is 1 for $\alpha = \pi/2$

It is physically realisable understanding that the tool just slices off the workpiece and no shear strain is needed to move the chip.

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Rake angle, $\alpha = 0°$

$l_c = t_c$.

$\tau_f = K \tau_s$.

$$\Rightarrow \frac{t_o}{t_c} = \frac{\sin\phi}{\cos(\phi - \alpha)} = \frac{\sin\phi}{\cos\phi} = \tan\phi.$$

$$\Rightarrow \boxed{t_c = \frac{t_o}{\tan\phi}}$$

Contact area of tool chip interface.

$$\boxed{A = \frac{w t_o}{\tan\phi}}$$

Shear force $\underline{F_s = F_c \cos\phi - F_t \sin\phi}$ — (1)

Friction force $F = F_c \sin\alpha + F_t \cos\alpha$.

$\therefore F = F_t$.

$\Rightarrow \underline{F \sin\phi = F_t \sin\phi}$. — (2)

Adding (1) & (2)

$F_s + F\sin\phi = F_c \cos\phi$.

$\Rightarrow \tau_s A_s + \tau_f A \cdot \sin\phi = F_c \cos\phi$.

$$\Rightarrow F_c = \frac{\tau_s A_s + \tau_f \cdot A \sin\phi}{\cos\phi}$$

$$= \frac{\tau_s A_s + K \tau_s A \sin\phi}{\cos\phi}$$

$$= \tau_s \left[A_s + \frac{K A \sin\phi}{\cos\phi} \right]$$

$$\Rightarrow F_c = \tau_s \left[\frac{\omega t_0}{\sin\phi \cos\phi} + \frac{k\omega t_0}{\tan\phi \cos\phi} \sin\phi \right]$$

$$= \tau_s \left[\frac{2\omega t_0}{\sin 2\phi} + k\omega t_0 \right]$$

$$\Rightarrow \boxed{F_c = \tau_s \omega t_0 \left[\frac{k \sin 2\phi + 2}{\sin 2\phi} \right]}$$

Since, $\frac{F}{A} = k \cdot \frac{F_s}{A_s}$ $\quad (\tau_f = k \cdot \tau_s)$.

$$\Rightarrow \frac{F}{\omega t_0} \tan\phi = \frac{k F_s}{\omega t_0} \sin\phi.$$

$$\Rightarrow \boxed{F = k F_s \cos\phi}$$

Now, $F = F_t$.

$$\Rightarrow k F_s \cos\phi = F_t$$

$$\Rightarrow F_s = \frac{F_t}{k \cos\phi}.$$

From (1).

$$F_c \cos\phi - F_t \sin\phi = \frac{F_t}{k \cos\phi}.$$

$$\Rightarrow F_c \cos\phi = F_t \left[\frac{1 + k \sin\phi \cos\phi}{\cos\phi} \right]$$

$$\Rightarrow F_t = \left[\frac{F_c \cos^2\phi}{1 + k \sin\phi \cos\phi} \right]$$

$$= \left(\frac{2 \cos^2\phi}{k \sin 2\phi + 2} \right) \times \tau_s \omega t_0 \left(\frac{k \sin 2\phi + 2}{\sin 2\phi} \right)$$

$$\boxed{F_t = \tau_s \omega t_0 \cot\phi}$$

7. The top view of as tube being turned orthogonally is shown in the Figure 1. Rake angle is + 10° and the dynamometer shows Fx = 1259 N, Fy = 0 and Fz = 1601 N. The axial feed is 100 mm/min and the rotational speed of the spindle is 1000 rpm. The chip thickness is 0.28 mm. Estimate the shear strength of the workpiece material and list the assumptions underlying the theory you are using.

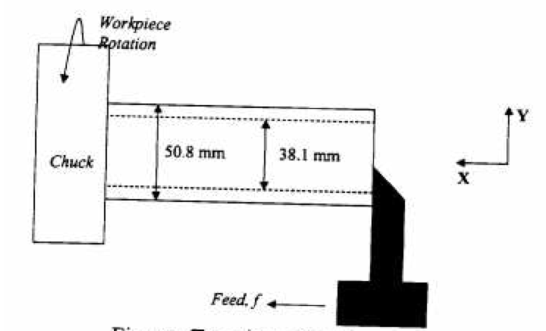

Figure. Top view of cutting process

Given $\alpha = 10^\circ$, $F_y = F_t = 1259\,N$, $F_z = F_c$ 1601N

$t_o = \frac{100}{1000} = 0.1$ mm/rev; $w = 6.35$ mm

$R = \sqrt{F_c^2 + F_t^2} = \sqrt{1601^2 + 1259^2}$ N

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

$$\frac{0.1}{0.28} = \frac{\sin(\phi)}{\cos(\phi-\alpha)} \Rightarrow \phi = 0.35\,r$$

$$F_c = R\cos(\beta-\alpha) \Rightarrow \beta = 0.84\,r$$

$$\tau_s = \frac{F_s}{w t_o/\sin\phi} = \frac{R\cdot\cos(\phi+\beta-\alpha)}{w t_o/\sin}$$

$$\tau_s = 584\,MPa$$