# Problems for turning operation

## Problem 1

A shaper tool, making an orthogonal cut, has a 10° rake angle. The depth of cut $t_o$ = 0.6 mm, the width of cut = 3 mm. The cutting speed V = 40 m/min. Two components dynamometer is used to determine the main cutting force ($P_s$ = 3600 N), and the thrust force ($P_t$ = 2400 N). A high speed photograph shows a shear plane angle $\phi$ = 20°.

Calculate:
1. The expected chip thickness.
2. The shearing stress on the shear plane.
3. The machining power.
4. The specific cutting energy.

Draw to scale the Merchant force diagram and determine
1. Friction force on rake face
2. Shearing force on shear plane

## Problem 2

An orthogonal cut with 3.0 mm depth is made at a speed of 45 m/min and a feed rate of 0.25 mm/rev, with a high-speed steel tool having a 15° rake angle. The chip thickness ratio is found to be 0.58, the main cutting force is 1000 N and the thrust force is 280 N.

Calculate:
- chip thickness.
- shear plane angle
- resultant cutting force
- machining power
- specific cutting energy

Draw to scale the Merchant force diagram and determine
- coefficient of friction on the tool face
- the force component normal to the shear plane

## Problem 3

A workpiece is being cut at V = 100 m/min. The machining power is found to be 3 kW. The feed rate = 0.2 mm/rev, and depth of cut = 0.5 mm.

a) What is the main cutting force in Newtons.
b) What is the spec. cutting energy in $N/mm^2$.
c) Estimate the necessary machining time if the diameter of the machined bar is D = 50 mm and its length = 250 mm.

**Problem 4**

Calculate the main cutting force component for the following turning operation:

Material: mild steel

spec. cutting energy = 3500 $N/mm^2$
initial dia. of work = 80 mm
final dia. of work = 74 mm )
feed rate = 0.4 mm/rev,

Calculate then the machining power if the spindle speed n = 710 r.p.m.

**Problem 5**

In a test to determine the main cutting force through power measurement during turning operation, the following data are obtained.

Input power at full load = 2100 Watt
Input power at no load = 500 Watt

Calculate:

1- The spec. cutting energy of the machined material if cutting speed = 30 m/min, chip cross-section = 0.25 x 1.5 $mm^2$.
2- The lathe efficiency η under the given machining conditions.

Prob. 1:

$\alpha = 10^\circ$, $t_o = 0.6$ mm

$w = 3$ mm, $V = 40$ m/min

$P_s = 3600$ N, $P_t = 2400$ N

$\phi = 20^\circ$

(1) $t_c = ?$ (2) $\tau_s = ?$ (3) Power = ?

(4) $K_s = U_t = ?$

(1) $\because \frac{t_o}{t_c} = \frac{\sin\phi}{\cos(\phi-\alpha)} \Rightarrow t_c = \frac{\cos(\phi-\alpha)}{\sin\phi} \times t_o$

$t_c = \frac{\cos(20-10)}{\sin 20} \times 0.6 = 1.72$ mm

(2) Shear stress on shear plane = $\tau_s$

$\because \tau_s = \frac{F_s \sin\phi}{t_o w}$

$\because F_s = P_s \cos\phi - P_t \sin\phi$

$= 3600 \cos 20 - 2400 \sin 20$

$F_s = 2562$ N

now $\tau_s = \frac{2562 \times \sin 20}{0.6 \times 3} = 486.8$ N/mm$^2$

(3)

Cutting power $= P_s V$

$= 3600 \times 40/60$ $\left(\frac{m}{min \times 60}\ m/s\right)$

$= 2400$ Watts

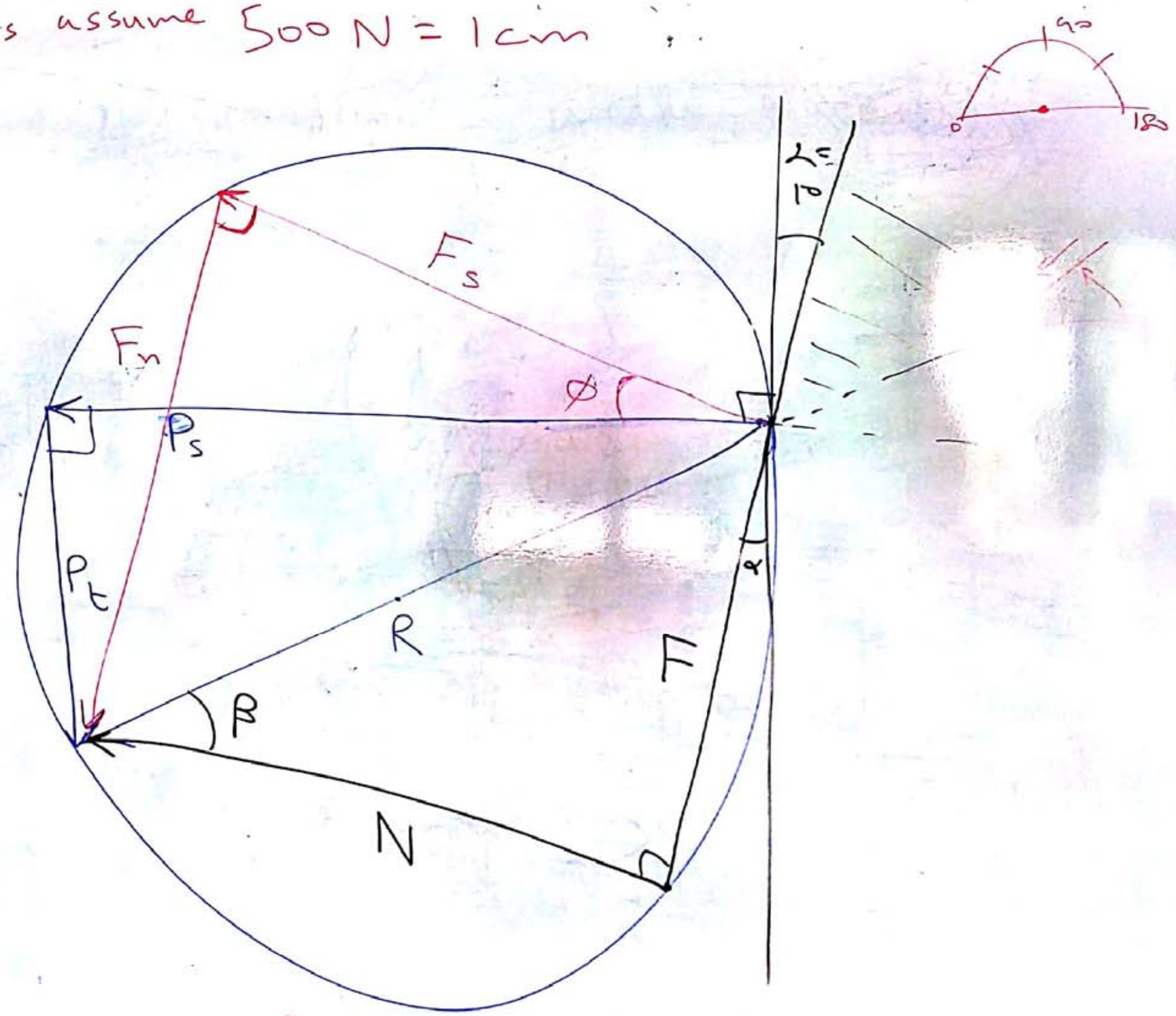
(4) $U_t = K_s = ?$

$U_t = \frac{P_s}{t_o w} = \frac{P_s l_o}{t_o w l_o} = \frac{Power}{MRR}$

$U_t = \frac{P_s}{t_o w} = \frac{3600}{0.6 \times 3}$

$= 2000$ N/mm$^2$

lets assume 500 N = 1 cm




o m/min

2400 N

ower = ?

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

$t_c = \frac{\cos(20-10)}{\sin 20} \times 0.6 = 1.72\text{mm}$

Prob 2: Turning

$t_o = 3$ mm, $V = 45$ m/min

$f = w = 0.25$ mm/rev, $\alpha = 15°$

$r = 0.58$, $P_s = 1000$ N

$P_t = 280$ N

(i) $t_c = ?$, (ii) $\phi = ?$, (iii) $R = ?$

(iv) Power $= ?$, (v) $U_t = K_s = ?$

الرجاء استخدام قلم سبورة قابل للمسح

Please Use Erasable White Board Marker

(i) $\because r = \dfrac{t_o}{t_c} \Rightarrow t_c = \dfrac{t_o}{r} = \dfrac{3}{0.58}$

$= 5.17$ mm

(ii) $\phi = \tan^{-1}\left(\dfrac{r\cos\alpha}{1 - r\sin\alpha}\right) = \tan^{-1}\left(\dfrac{0.58\cos 15}{1 - 0.58\sin 15}\right)$

$\Rightarrow \phi = 33.4°$

(iii) $R = \sqrt{P_s^2 + P_t^2}$

$= \sqrt{1000^2 + 280^2} = 1038$ N

(iv)

Machining

(iv) Power $= P_s V$

$= 1000 \times \dfrac{45}{60}$

Power $= 750$ Watts

(v) $U_t = \dfrac{P_s}{t_o w} = \dfrac{1000}{3 \times 0.25}$

$U_t = 1333.33$ N/mm²

Problem 2

$t_0 = f = 0.25$ mm/rev
$w = 3.0$ mm
$\alpha = 15^\circ$ , $V = 45$ m/min
$\gamma = 0.58$
$P_s = 1000$ N.
$P_t = 280$ N.

$t_c = ?$, $\phi = ?$, $R = ?$
Power = ?, $U_t = ?$

(i) $\gamma = \frac{t_0}{t_c} \Rightarrow t_c = \frac{t_0}{\gamma}$

$t_c = \frac{0.25}{0.58} = 0.893$ mm.

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

$= \tan^{-1}\left(\frac{0.58 \cos 15}{1 - 0.58 \sin 15}\right)$

$= 33.4^\circ$

(iii) $R = \sqrt{P_s^2 + P_t^2}$

$= \sqrt{1000^2 + 280^2}$

$= 1038.$

(iv) Power $= P_s \times V$

$= 1000 \times \frac{45}{60}$

$= 750$ watts

(v) $U_t = \frac{P_s}{t_0 w} = \frac{1000}{0.25 \times 3}$

$U_t = 1333.3$ N/mm$^2$

## Problem: 3 (Turning)

$V = 100\ m/min$, Cutting power $= 3\ KW = 3000\ Watts$

Feed rate $(f)$ = width of cut $= \omega = 0.2\ mm/rev$

Depth of cut $= t_o = 0.5\ mm$

(i) $P_s = ?$ (ii) $U_t = K_s = ?$

(iii) Machining time $= t = ?$ $\left( D = 50\ mm,\ L = 250\ mm \right)$



(i) $\because$ cutting Power $= P_s \times V$

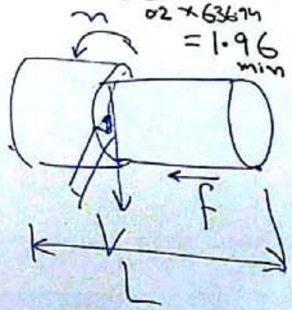
$3000 = P_s \times \frac{100}{60}$

$\Rightarrow P_s = 1800\ N$

(ii) $U_t = \frac{P_s}{t_o \times \omega} = \frac{1800}{0.5 \times 0.2} = 18000\ N/mm^2$

(iii) $\because$ M/cing Time $= \frac{L}{f\, n}$

Machining Time $= \frac{250}{0.2 \times n} = \frac{250}{0.2 \times 636.94} = 1.96\ min$




$\because n = \frac{V}{\pi D} = \frac{100 \times 1000}{3.14 \times 50} = 636.94\ rev/min$

Problem 3

$f = t_o = 0.2$ mm/rev.

$w = 0.5$ mm, $V = 100$ m/min.

Power = 3 kW

(a) $P_s = ?$, (b) $U_t = ?$

(c) Machining time = $t = ?$

$D = 50$ mm

$L = 250$ mm

(i) cutting power $= P_s \times V$

$$3000 = P_s \times \frac{100}{60}$$

$$\Rightarrow P_s = 1800 \text{ N.}$$

(ii) $$U_t = \frac{P_s}{t_o \times w} = \frac{1800}{0.2 \times 0.5}$$

$$= 18000 \text{ N/mm}^2$$

(c) $$\text{Machining time} = \frac{L}{fN}$$

$$= \frac{250}{0.2 \times N}.$$

$V = \pi D N$

$$N = \frac{V}{\pi D} = \frac{100 \times 1000}{3.14 \times 50}$$

$N = 636.94$ rev/min

$$\text{Machining time} = \frac{250}{0.2 \times 636.9}$$

$= 1.96$ min

Prob. 4: Turning

$U_t = 3500\ N/mm^2$

$D_i = 80\ mm,\ D_f = 74\ mm$

$f = w = 0.4\ mm/rev,\ n = 710\ rev/min$

$P_s = ?$ , Machining Power = ?

$\because U_t = \dfrac{P_s}{t_o w} \Rightarrow P_s = U_t \times t_o \times w = 3500 \times 3 \times 0.4$

$= 4200\ N$

Machining Power $= P_s \times V$

$\because V = \pi D n$

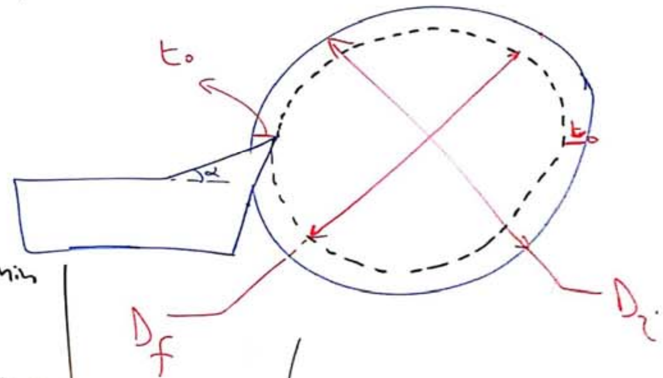
$V = 3.14 \times \dfrac{77}{1000} \times 710$

$= 171.66\ m/min$

Power $= 4200 \times \dfrac{171.66}{60}$

$= 12016.2$ Watts

Pow = 12 KW




$D = \dfrac{D_i + D_f}{2}$

$= \dfrac{80+74}{2} = 77\ mm$

$D_f = D_i - 2t_o$

$\Rightarrow t_o = \dfrac{D_i - D_f}{2}$

$t_o = \dfrac{80-74}{2} = 3\ mm$

Problem 4

$U_t = 3500\ N/mm^2$

$D_i = 80\ mm,\ D_f = 74\ mm$

$f = t_o = 0.4\ mm/rev.$

$N = 710\ rev/min$

$P_s = ?$, Machining Power $= ?$

$U_t = \frac{P_s}{t_o w} \Rightarrow P_s = U_t \times t_o \times w$

$P_s = 3500 \times 0.4 \times w$

~~$P_s = 4200\ N$~~

$D_f = D_i - 2w$

$w = \frac{D_f - D_i}{2}$

$w = 3\ mm.$

$P_s = 3500 \times 0.4 \times 3$

$= 4200N.$

$V = \pi D N$

$= 3.14 \times \frac{D}{1000} \times 710$

$D = \frac{D_i + D_f}{2}$

$D = \frac{80 + 74}{2} = 77\ mm$

$= 3.14 \times \frac{77}{1000} \times 710$

$= 171.66\ m/min$

$Power = 4200 \times \frac{171.66}{60}$

$= 12016.2$ watts

$= 12 kW.$

Prob. 5: input power at Full load = 2100 Watts

Input power at no load = 500 Watts

$V = 30 m/min$, $t_o \times w = 0.25 \times 1.5 \; mm^2$

① $K_s = U_t = ?$

② $\eta = ?$

→ Actual power consumed for cutting = 2100 − 500 = 1600 Watts

$\Rightarrow \eta = \frac{\text{Actual power consumed}}{\text{Total power consumed}} = \frac{1600}{2100} = 76\%$

$U_t = \frac{P_s}{t_o w} = \frac{\text{Energy}}{\text{Vol.}} = \frac{\text{Power}}{\text{MRR}}$

∴ Cutting power = $P_s \times V$

$1600 = P_s \times \frac{30}{60}$

$\Rightarrow P_s = \frac{1600 \times 60}{30}$

$P_s = 3200 \, N$

$U_t = K_s = \frac{3200}{0.25 \times 1.5} = 8533.3 \, N/mm^2$