IE-352
Section 1, CRN: 13536
Section 2, CRN: 30521
First Semester 1432-33 H (Fall-2011) – 4(4,1,1)
MANUFACTURING PROCESSES - 2

Machining Exercises

Name:	Student Number: 42

Answer ALL of the following questions [2 Points Each].

1. Let $n = 0.5$ and $C = 90$ in the *Taylor* equation for tool wear. What is the percent increase in tool life if the cutting speed is reduced by (a) 50% and (b) 75%?

2. Taking carbide as an example and using the equation for mean temperature in turning on a lathe, determine how much the feed should be reduced in order to keep the mean temperature constant when the cutting speed is doubled.

3. An orthogonal cutting operation is being carried out under the following conditions: $t_o = 0.1\,mm$, $t_c = 0.2\,mm$, width of cut $= 5\,mm$, $V = 2\,m/s$, $rake\ angle = 10°$, $F_c = 500\,N$, and $F_t = 200\,N$. Calculate the percentage of the total energy that is dissipated in the shear plane.

4. For a turning operation using a ceramic cutting tool, if the speed is increased by 50%, by what factor must the feed rate be modified to obtain a constant tool life? Use $n = 0.5$ and $y = 0.6$.

5. Using the equation for surface roughness to select an appropriate feed for $R = 1\,mm$ and a desired roughness of $1\,\mu m$. How would you adjust this feed to allow for nose wear of the tool during extended cuts? Explain your reasoning.

IE-352
Section 1, CRN: 13536
Section 2, CRN: 30521
First Semester 1432-33 H (Fall-2011) – 4(4,1,1)
MANUFACTURING PROCESSES - 2

Machining Exercises Answers

Name:	Student Number: 42

Answer ALL of the following questions [2 Points Each].

1. Let $n = 0.5$ and $C = 90$ in the *Taylor* equation for tool wear. What is the percent increase in tool life if the cutting speed is reduced by (a) 50% and (b) 75%?

Solution:

Taylor Equation for tool life:

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

$$n = 0.5; C = 90$$

$$\Rightarrow \boldsymbol{VT^{0.5} = 90 \Rightarrow V_1 {T_1}^{0.5} = V_2 {T_2}^{0.5}}$$

a) $\boldsymbol{V_2 = 0.5V_1}$

$$\Rightarrow \boldsymbol{V_1 {T_1}^{0.5} = 0.5V_1 {T_2}^{0.5}}$$

$$\Rightarrow \boldsymbol{{T_1}^{0.5} = 0.5{T_2}^{0.5}}$$

$$\Rightarrow \boldsymbol{\left(\frac{T_2}{T_1}\right)^{0.5} = 2}$$

$$\Rightarrow \boldsymbol{\sqrt{\frac{T_2}{T_1}} = 2}$$

$$\Rightarrow \boldsymbol{\frac{T_2}{T_1} = 4}$$

$$\Rightarrow increase\ in\ tool\ life = \frac{T_2 - T_1}{T_1} = \frac{T_2}{T_1} - 1 = 3$$

$\Rightarrow$ ***i.e. increase in tool life is* 300%**

b) $\boldsymbol{V_2 = 0.25V_1}$ **(since speed *decreases* by 75%)**

$$\Rightarrow \boldsymbol{{T_1}^{0.5} = 0.25{T_2}^{0.5}}$$

$$\Rightarrow \boldsymbol{\left(\frac{T_2}{T_1}\right)^{0.5} = 4}$$

$\Rightarrow \frac{T_2}{T_1} = 16$

$\Rightarrow \text{increase in tool life} = \frac{T_2 - T_1}{T_1} = 16 - 1 = 15$

$\Rightarrow$ ***i.e. increase in tool life is 1500% (i.e. 15 − fold)***

2. Taking carbide as an example and using the equation for mean temperature in turning on a lathe, determine how much the feed should be reduced in order to keep the mean temperature constant when the cutting speed is doubled.

Solution:

equation for mean temperature in turning on a lathe,

$T_{mean} \, \alpha \, V^a f^b$

Given: $T_{mean} = C_1; V_2 = 2V_1;$ *for carbide:* $a = 0.2, b = 0.125$

$\Rightarrow C_1 = C_2 V^{0.2} f^{0.125}$

$\Rightarrow V_1^{\,0.2} f_1^{\,0.125} = (2V_1)^{0.2} f_2^{\,0.125}$

$\Rightarrow \left(\frac{f_2}{f_1}\right)^{0.125} = 0.5^{0.2}$

$\Rightarrow \frac{f_2}{f_1} = 2^{-\left(\frac{0.2}{0.125}\right)} = 2^{-1.6} = 0.330$

$\Rightarrow \text{reduction in feed} = \frac{f_1 - f_2}{f_1} = 1 - 0.330 = 0.670$

$\Rightarrow$ ***i.e. reduction in feed is 67%***

3. An orthogonal cutting operation is being carried out under the following conditions: $t_o = 0.1\,mm$, $t_c = 0.2\,mm$, width of cut $= 5\,mm$, $V = 2\,m/s$, $rake\ angle = 10°$, $F_c = 500\,N$, and $F_t = 200\,N$. Calculate the percentage of the total energy that is dissipated in the shear plane.

Note, for detailed solution, see similar exercise:"cutting force exercise 2.PDF"

Givens: thicknesses: $t_o = 0.1\,mm$; $t_c = 0.2\,mm$

angles: $\alpha = 10°$

velocities: $V = 2\,m/s$

forces: $F_c = 500\,N$; $F_t = 200\,N$; $F_s = ?$; $F_n = ?$

Required: %ge of total energy dissipated in primary shearing zone

i.e. $\frac{U_s}{U_{tot}}(100) = \frac{Power_s}{Power_{tot}}(100) = ?$

Solution:

$$\frac{Power_s}{Power_{tot}} = \frac{F_s V_s}{F_c V}$$

Strategy: we have F_c *and* V, *and we need to find* F_s *and* V_s

- V_s *can be obtained if we have shear angle (*ϕ*), from,*

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

  - *and* ϕ *can be obtained from,*

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

  - *and r can be obtained from,*

$$r = \frac{t_o}{t_c} = \frac{0.1\,mm}{0.2\,mm} = 0.5$$

  - *now, working back* ⇒

$$\phi = \tan^{-1}\left[\frac{0.5\cos 10°}{1 - 0.5\sin 10°}\right] = \tan^{-1} 0.539 = 28.3°, \textit{ and:}$$

$$V_s = 2\, m/s \frac{\cos 10°}{\cos(28.3° - 10°)} = (2\, m/s) * 1.037 = 2.075 m/s$$

Note how shear velocity is higher (4%) than cutting speed

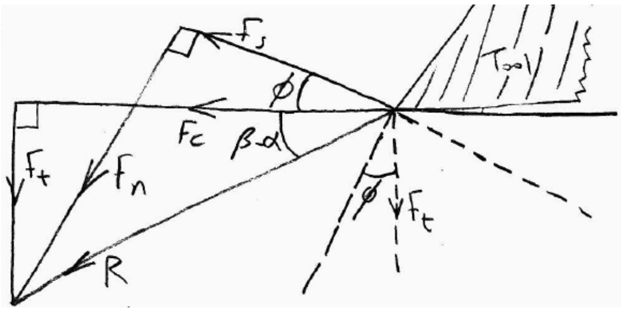
- *F_s is now required and can be obtained force circle,*

  by resolving component of

  F_c along F_s direction, and

  F_t opposite to F_s direction

  $\Rightarrow$



$$F_s = F_c \cos\phi - F_t \sin\phi$$
$$= (500\ N)\cos 28.3° - (200\ N)\sin 28.3°$$
$$= 440\ N - 94.9\ N = 345\ N$$

- Substituting values of V_s and F_s into $\frac{Power_s}{Power_{tot}} = \frac{F_s V_s}{F_c V} \Rightarrow$

$$\frac{Power_s}{Power_{tot}} = \frac{(345\ N)(2.075\ m/s)}{(500\ N)(2\ m/s)} = \frac{718.875}{1000} = 0.719$$

⇒%ge of total energy dissipated in shearing is approximately 72%

Note, you can check your answer by calculating %ge of energy dissipated due to friction (which should 28%; see "cutting force exercise 1.PDF"), and adding the two values, which should amount to exactly 100%.

4. For a turning operation using a ceramic cutting tool, if the speed is increased by 50%, by what factor must the feed rate be modified to obtain a constant tool life? Use $n = 0.5$ and $y = 0.6$.

Given:

$$V_2 = V_1 + 0.5V_1 = 1.5V_1$$

$$T_2 = T_1$$

$$n = 0.5;\ y = 0.6$$

Required: $\frac{f_2}{f_1} = ?$

Solution:

Taylor tool life equation for turning operation:

$$VT^n d^x f^y = C_1 \Rightarrow$$

$$V_1 T_1{}^n d_1{}^x f_1{}^y = V_2 T_2{}^n d_2{}^x f_2{}^y$$

since $T_2 = T_1$*, and assuming constant depth of cut (d)* $\Rightarrow$

$$V_1 f_1{}^y = 1.5 V_1 f_2{}^y \Rightarrow$$

$$\left(\frac{f_2}{f_1}\right)^{0.6} = \frac{1}{1.5} \Rightarrow$$

$$\frac{f_2}{f_1} = 1.5^{-\frac{1}{0.6}} = 0.509$$

⇒feed must be modified by a factor of 50.9%

5. Using the equation for surface roughness to select an appropriate feed for $R = 1\,mm$ and a desired roughness of $1\,\mu m$. How would you adjust this feed to allow for nose wear of the tool during extended cuts? Explain your reasoning.

Given:

$$R = 1\,mm = 1 * 10^{-3}\,m$$

$$R_t = 1\,\mu m = 1 * 10^{-6}\,m$$

Required:

- $f = ?$
- how to adjust feed to account for nose wear

Solution:

- *equation for surface roughness,*

$$R_t = \frac{f^2}{8R} \Rightarrow$$

$$f = \sqrt{(8R)R_t} = \sqrt{(8 * 10^{-3}\,m)(1 * 10^{-6}\,m)} = \sqrt{8 * 10^{-9}\,m^2} =$$

$$= 8.94 * 10^{-5}\,m/rev = 0.089 * 10^{-3}\,m/rev \Rightarrow$$

⇒ appropriate feed is 0.089 mm/rev

- *when nose wear occurs ⇒*

  radius (R) will increase ⇒

  to keep the surface roughness (R_t) the same

  ⇒ the feed must also increase