IE-352
Section 3, CRN: 48706/7/8
Section 4, CRN: 58626/7/8
Second Semester 1438-39 H (Spring-2018) – 4(4,1,2)
“MANUFACTURING PROCESSES – 2”

Saturday, March 10, 2018 (22/06/1439H)

Turning Exercise + ANSWERS

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Material-removal Rate and Cutting Force in Turning

A 150-mm-long, 12.5-mm-diameter 304 stainless steel rod is being reduced in diameter to 12.0 mm by turning on a lathe. The spindle rotates at N = 400 rpm, and the tool is travelling at an axial speed of 200 mm/min. Calculate the following:

a) cutting speed

b) material-removal rate

c) cutting time

d) power dissipated

e) cutting force

Given:

- Workpiece material: 304 stainless steel
- Turning on a lathe process
- $l = 150\ mm$
- $D_o = 12.5\ mm$
- $D_f = 12.0\ mm$
- $N = 400\ rev/min$
- $v = 200\ mm/min$ (note this is feed rate, NOT cutting speed, V)

Solution:

a) **cutting speed**, $V = \pi D_{avg} N$

$$D_{avg} = \frac{D_o + D_f}{2} = \frac{12.5\,mm + 12.0\,mm}{2} = 12.25\,mm$$

$$\Rightarrow V = \pi D_{avg} N = (\pi\,rad/\cancel{rev})(12.25\,mm)(400\,\cancel{rev}/min)$$
$$= 15393.80\,mm/min$$

► $\mathbf{V = 15.4\,m/min}$

$$Note, V_{max} = \pi D_o N = (\pi\,rad/\cancel{rev})(12.5\,mm)(400\,\cancel{rev}/min)$$
$$= 15707.96\,mm/min = 15.7\,m/min$$

b) **material-removal rate**, $MRR = dfV$

$$depth\ of\ cut, d = \frac{D_o - D_f}{2} = \frac{12.5\,mm - 12.0\,mm}{2} = 0.25\,mm$$

$$feed, f = \frac{v}{N} = \frac{200\,mm/\cancel{min}}{400\,rev/\cancel{min}} = 0.50\,mm/rev$$

$$\Rightarrow MRR = dfV = (0.25\,mm)(0.50\,mm)(15393.80\,mm/min)$$
$$= 1924.2\,mm^3/min$$

► $\mathbf{MRR = 1924\,mm^3/min}$

c) **cutting time**, $t = \frac{l}{fN}$

$$length\ of\ cut, l = 150\,mm$$

$$\Rightarrow t = \frac{l}{fN} = \frac{150\,\cancel{mm}}{(0.50\,\cancel{mm}/\cancel{rev})(400\,\cancel{rev}/min)} = 0.75\,min$$

► $\mathbf{t = 0.75\,min = 45.0\,s}$

d) **power dissipated**, Power

remember, $u_t = \frac{Power}{MRR}$

u_t can be obtained from specific power table in ch.21, for different workpiece materials

Approximate Range of Energy Requirements in Cutting Operations at the Drive Motor of the Machine Tool (for Dull Tools, Multiply by 1.25)

Material	Specific energy W · s/mm^3
Aluminum alloys	0.4–1
Cast irons	1.1–5.4
Copper alloys	1.4–3.2
High-temperature alloys	3.2–8
Magnesium alloys	0.3–0.6
Nickel alloys	4.8–6.7
Refractory alloys	3–9
Stainless steels	2–5
Steels	2–9
Titanium alloys	2–5

$\Rightarrow$ for stainless steel, we can use an average value of $4\ W \cdot s/mm^3$

$$\Rightarrow Power = u_t \cdot MRR = \left(4\ \frac{W \cdot s}{mm^3}\right) \cdot (1924.2\ mm^3/min) * \left(\frac{1\ min}{60\ s}\right)$$
$$= 128.28\ W$$

► $\boldsymbol{Power = 128\ W}$

e) **cutting force**, F_c

Remember, $Power = F_c \cdot V$

$$\Rightarrow F_c = \frac{Power}{V} = \frac{128.28\ N \cdot m/s}{15.3938\ m/min} * \frac{60\ s}{min} = 500.0\ N$$

► $\boldsymbol{F_c = 500\ N}$

Another solution, $Power = Torque \cdot \omega$

$$\Rightarrow Torque = \frac{Power}{\omega} = \frac{128.28\ W}{2\pi N} = \frac{128.28\ N \cdot m/s}{(2\pi)(400\ )\ rad/min} * \frac{60\ s}{min}$$
$$= 3.0625\ N \cdot m$$

Also, $Torque = F_c \cdot D_{avg}/2$

$$\Rightarrow F_c = 2\frac{Torque}{D_{avg}} = 2\frac{3.0625\ N \cdot m}{12.25\ mm} * \frac{1000\ mm}{m} = 500.0\ N$$

► $\boldsymbol{F_c = 500\ N}$