IE-352
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Second Semester 1438-39 H (Spring-2018) – 4(4,1,2)
"MANUFACTURING PROCESSES – 2"

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Milling Exercise + ANSWERS

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Material-Removal Rate, Power, Torque, and Cutting Time in Slab Milling

A slab-milling operation is being carried out on a $300-mm$-long, 100-mm-wide annealed mild-steel block at a feed f of 0.25 mm/tooth and a depth of cut $3.0\ mm$. The cutter is $D = 50\ mm$ in diameter, has 20 straight teeth, rotates at $100\ rpm$ and, by definition, is wider than the block to be machined. Calculate the following:

a) material-removal rate, MRR

b) estimated power dissipated, $Power$

c) estimated torque required for this operation, $Torque$

d) cutting time, t

Given:

- Process: slab-milling
- Workpiece material: annealed mild-steel
- $l = 300\ mm$
- $w = 100\ mm$
- $f = 0.25\ mm/tooth$
- $d = 3.0\ mm$
- $D = 50\ mm$
- $n = 20$
- $N = 100\ rev/min$

Solution:

a) **material-removal rate**, $MRR = wdv$

$$f = \frac{v}{Nn}$$

$$\Rightarrow v = fNn = \left(0.25\,\frac{mm}{tooth}\right)\left(100\,\frac{rev}{min}\right)\left(20\,\frac{teeth}{rev}\right) = 500\ mm/min$$

$$\Rightarrow MRR = wdv = (100\ mm)(3.0\ mm)\left(500\,\frac{mm}{min}\right)\left(\frac{1\ min}{60\ s}\right)$$
$$= 2500\ mm^3/s$$

► $\boldsymbol{MRR = 2500\ mm^3/s}$

b) **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

$\Rightarrow$ for *mild*-steel, we can assume a value of $3\ W \cdot s/mm^3$

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/mm³
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

$$\Rightarrow Power = u_t \cdot MRR = \left(3\,\frac{W \cdot s}{mm^3}\right) \cdot \left(2500\,\frac{mm^3}{s}\right) = 7{,}500\ W$$

► $\boldsymbol{Power = 7.5\ kW}$

c) **torque required**, $Torque$

$$Power = Torque \cdot \omega$$

$$\Rightarrow Torque = \frac{Power}{\omega} = \frac{7500\ W}{2\pi N} = \frac{7500\ N \cdot m/s}{(2\pi)(100\ )\ rad/min} * \frac{60\ s}{min}$$
$$= 716.2\ N \cdot m$$

► $\boldsymbol{Torque = 716\ N \cdot m}$

d) **cutting time**, t

$$t = \frac{l + l_c}{v}$$

For $D \gg d \Rightarrow l_c$ can be approximated using: $l_c = \sqrt{Dd}$

$$\Rightarrow l_c = \sqrt{Dd} = \sqrt{(50\ mm) \cdot (3\ mm)} = 12.247\ mm$$

$$\Rightarrow t = \frac{l + l_c}{v} = \frac{300\ mm + 12.247\ mm}{500\ mm/min} = 0.6245\ min$$

$$\blacktriangleright \quad \boldsymbol{t = 37.5\ s}$$

Note that if we did not do the above assumption for l_c

$$\Rightarrow l_c = \sqrt{d(D - d)} = \sqrt{(3.0\ mm) \cdot (50\ mm - 3.0\ mm)} = 11.873\ mm$$

$$\Rightarrow t = \frac{l + l_c}{v} = \frac{300\ mm + 11.873\ mm}{500\ mm/min} = 0.6237\ min$$

$$\blacktriangleright \quad \boldsymbol{t = 37.4\ s}$$

Thus the above assumption was justified.