ASSIGNMENT 2
(DETERMINATION OF MACHINING PARAMETERS)

Due in Gradescope on Mar. 18, 2024 by 4:00 p.m.
Late penalties are 20% off per day.

Problem 1 (6 marks)

A slab milling operation is performed on the top surface of a steel rectangular workpiece L = 12 in long by w = 2.5 in wide. The helical milling cutter, which has a D = 3.0 in diameter and n_t = 10 teeth, is set up to overhang the width of the part on both sides. Cutting speed is v = 125 ft/min, feed is f_t = 0.006 in/tooth, and depth of cut d = 0.3 in. Determine:

a) Rotational speed of the tool (N). **(1 mark)**

b) Feed rate of the cut (f). **(1 mark)**

c) Machining time (T_m) to make one pass across the surface. Assume that T_m includes the time required to lower the cutter at the desired depth by starting from the top surface of the slab. **(1 mark)**

d) Maximum metal removal rate during the cut (Q). **(1 mark)**

e) If an additional approach distance of 0.5 in is provided at the beginning of the pass (before cutting begins), and an overtravel distance is provided at the end of the pass equal to the cutter radius plus 0.5 in, what is the duration of the feed motion (T_f)? Sketch a top view of this milling operation, in which clearly identify the initial and final positions of the tool. **(2 marks)**

Problem 2 (5 marks)

A face milling operation is performed on the top surface of a copper plate, which is 10” long and 3” wide. The intended depth of the cut is 15/64”. The milling cutter, which is 3½” in diameter, has 8 teeth. The cutter is to overhang the width of the work-piece on both sides. By referring to the tabulated cutting speeds and feeds shown in slides 7 and 9 of the lecture notes presented in Week 7 (use the upper extreme value for tool feed per tooth), determine:

a) Rotational speed of the tool (N). **(1 mark)**

b) Feed rate (f). **(1 mark)**

c) The time required to machine the entire top face of the slab (t). **(1 mark)**

d) Material removal rate (Q). **(1 mark)**

e) Torque at the spindle (T). Use a unit power of P_u = 1 HP·min/in^3. **(1 mark)**

Problem 3 (4 marks)

A slot/side rough milling operation is to be performed on a block of aluminum. The cut has a width w = 0.75 in and will be performed with a cutter with Z = 16 teeth at N = 200 RPM on a milling machine that can deliver a maximum power hp_s = 5 HP at the spindle. By using the tabulated data presented in Tables 1, 2 and 3 below (use the middle of the range for cutting speed), determine:

a) Material removal rate (Q). **(1 mark)**

b) Feed rate (*f*). **(1 mark)**

c) Depth of the cut (*d*). **(1 mark)**

c) Cutter diameter (*D*). **(1 mark)**

Hint: This problem assumes the horsepower at the spindle is determined by the following relationship: $hp_s = Q / K$ where *K* is a so called "metal removal factor" or "machinability factor" which in reality is nothing but the inverse of unit horsepower (P_u) at the spindle.

Table 1

Material	K(in³/min/(hp$_s$))
Cold drawn steel, SAE 1112, 1120, 1315	1.0
Forged and alloy steel, SAE 3120, 1020, 2320, 2345, 150-300 BHN	0.63 - 0.87
Alloy steel, 300 - 400 BHN	0.5
Malleable iron and cold drawn steel, SAE 6140	0.9
Cast irons:	
Soft	1.5
Medium	0.8 - 1.0
Hard	0.6 - 0.8
Stainless steel, AISI 416, free-machining	1.1
Stainless steel, austenitic, AISI 303, free-machining	0.83
Stainless steel, austenitic, AISI 304	0.72
Tool steel	0.51
Bronze and brass:	
Soft	1.7- 2.5
Medium	1.0 - 1.4
Hard	0.6 - 1.0
Aluminum and magnesium	2.5 - 4.0
Monel metal	0.55
Copper, annealed	0.84
Nickel	0.53
Titanium & alloys	0.75 - 1.1

NOTE: "K" values are in cubic inches per minute per cutter horsepower (in^3/min/hp$_c$)
"K" values for carbide cutters are approx. 25% higher.

Table 2

Suggested Feed per Tooth for Milling - High-Speed Steel Cutters (Tabulated Data in Inches)

Material	Face mills	Helical mills	Slot/side mills	End mills	Form-relieved cutters
Magnesium & alloys	0.022	0.018	0.013	0.011	0.007
Aluminum & Alloys	0.022	0.018	0.013	0.011	0.007
Free-cutting brasses & bronzes	0.022	0.018	0.013	0.011	0.007
Medium brasses & bronzes	0.014	0.011	0.008	0.007	0.004
Hard brasses & bronzes	0.009	0.007	0.006	0.005	0.003
Copper	0.012	0.010	0.007	0.006	0.004
Cast iron, soft (150-180 Bhn)	0.016	0.013	0.009	0.008	0.005
Cast iron, medium (180-220 Bhn)	0.013	0.010	0.007	0.007	0.004
Cast iron, hard (220-300 Bhn)	0.011	0.008	0.006	0.006	0.003
Malleable iron	0.012	0.010	0.007	0.006	0.004
Cast steel	0.012	0.010	0.007	0.006	0.004
Low-carbon steel, free-machining	0.012	0.010	0.007	0.006	0.004
Low-carbon steels	0.010	0.008	0.006	0.005	0.003
Medium-carbon steels	0.010	0.008	0.006	0.005	0.003
Alloy steel, ann'ld (180-220 Bhn)	0.008	0.007	0.005	0.004	0.003
Alloy steel, tough (220-300 Bhn)	0.006	0.005	0.004	0.003	0.002
Alloy steel, hard (300-400 Bhn)	0.004	0.003	0.003	0.002	0.002
Stainless steels, free-machining	0.010	0.008	0.006	0.005	0.003
Stainless steels	0.006	0.005	0.004	0.003	0.002
Monel metal	0.008	0.007	0.005	0.004	0.003
Titanium & alloys	0.008	0.007	0.005	0.004	0.003
Machinable plastics	0.013	0.010	0.008	0.007	0.004

NOTE: Tabular data in inches. For feed per tooth in millimeters, multiply tabular data by 25.4. For carbon-steel cutters, multiply tabular data by 0.50 or divide by 2. Source: Cincinnati Milicron, Inc.

Table 3

Milling Cutting Speeds for Various Materials

(sfpm) Surface feet per minute (High-speed steel tools only)

Material	High-speed steel tools	
	Rough	Finish
Cast iron	50 - 60	80 - 110
Semisteel	40 - 50	65 - 90
Malleable iron	80 - 100	110 - 130
Cast steel	45 - 60	70 - 90
Copper	100 - 150	150 - 200
Brass	200 - 300	200 - 300
Bronze	100 - 150	150 - 180
Aluminum	400 - 450	700 - 750
* Magnesium	600 - 800	1,000 - 1,500
SAE steels:		
1020 (coarse feed), low-carbon	60 - 80	60 - 80
1020 (fine feed), low-carbon	100 - 120	100 - 120
1035, medium-carbon	75 - 90	90 - 120
1330, alloy steel	90 - 110	90 - 110
1050, Med-high-carbon	60 - 80	100 - 125
2315, nickel steel	90 - 110	90 - 110
3150, nickel-chromium	50 - 60	70 - 90
4150, chrome-molybdenum	40 - 50	70 - 90
4340, nickel-chrome-molybdenum	40 - 50	60 - 70
Stainless steel	60 - 80	100 - 120
Titanium, hard alloy	80 - 100	110 - 130

NOTE: Tabular data ranges are in sfpm (surface feet per minute for HSS cutters only). For carbide cutters, increase sfpm by 25% (min.).
* A fire hazard is present when machining magnesium at high-speeds.