Université d'Ottawa
Faculté de génie

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uOttawa
L'Université canadienne
Canada's university

University of Ottawa
Faculty of Engineering

Department of
Mechanical Engineering

MCG4323
Manufacturing
Fall 2008

FINAL EXAM

3 problems; total: 100 pts

Professor: Dr. Michel Nganbe

Tuesday, December 16, 2008; 14:00 to 17:00 (3 hours)

Family name : ____________________

First name : ____________________

Student number : ____________________

Signature : ____________________

Instructions:

- Closed book exam
- Non-programmable calculators *are* permitted
- Print your name and student number on this first page and on each exam booklet you use
- Some materials data and equations are provided in the appendix at the end of the questionnaire
- Good luck!

Name:

Section 1:

All Manufacturing processes

Equipment for the following manufacturing processes is available in your company:

1. Hot closed die forging (MF = 4 ; max. 500 tonnes)
2. Hot open die forging (MF = 1.5 ; max. 500 tonnes)
3. Hot rolling (MF = 2 ; max. 500 tonnes)
4. Hot extrusion (max. 2000 tonnes)
5. Cold closed die forging (MF = 3 ; max. 500 tonnes)
6. Cold impression die forging (MF = 3 ; max. 1000 tonnes)
7. Cold open die forging (MF = 1.2 ; max. 1000 tonnes)
8. Cold extrusion (max. 1000 tonnes)
9. Cold rolling (MF = 3 ; max. 1000 tonnes)
10. Wire drawing (max. 500 tonnes)
11. Deep drawing (max. 500 tonnes)
12. Stretch-forming (max. 500 tonnes)
13. Bending (max. 500 tonnes)
14. Hydroforming (max. 500 tonnes)
15. Blanking (max. 500 tonnes)
16. Punching (max. 500 tonnes)
17. Continuous casting (The width of the cast strip is 400 mm. only thicknesses above 8 mm can be cast; it can be assumed that heat escapes only though the large top and bottom surfaces; C = 1 min/mm)
18. Sand casting (only thicknesses above 15 mm can be cast; it can be assumed that heat escapes though all surfaces; C = 6 min/mm)

Name:

Section 1 - Problem 1: (44 pts)

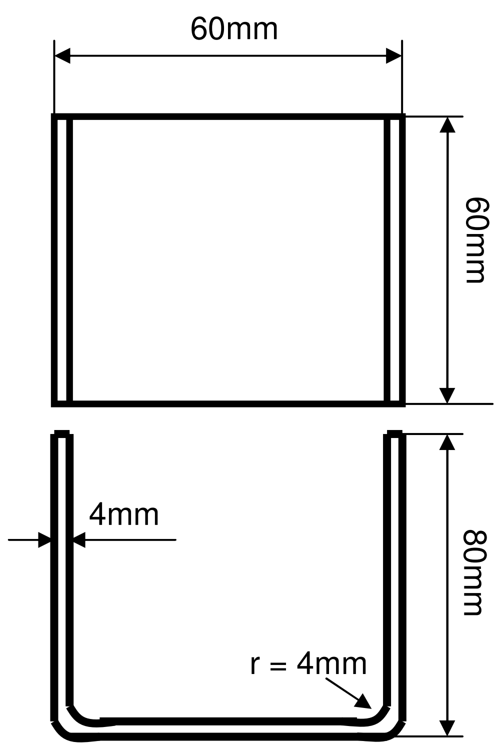
You possess as start material low carbon steel scrap of different sizes as well as new spherical balls of 3 mm diameter made of the same material.

a) If 5,000,000 pieces of the rectangular component shown in the figure below are needed, select a combination of 4 sub-processes from the list on the previous page for the manufacturing process. Make sketches illustrating the process and showing the geometry and the thickness of the workpiece after each sub-process! (you don't need to calculate or indicated any dimension other than the thickness). There are no surface requirements! (4x2 pts)

b) Each of the sub-processes selected in a) has one critical aspect that is most crucial for process and equipment design. Select the aspect from the list below that is the most important for each of the selected sub-processes and calculate its value assuming that each of the sub-processes is made in one step! (4x7 pts)

1) Process force
2) Solidification time
3) Minimum radius

c) How critical is the value calculated in b) for each of the corresponding sub-process? Would you expect any difficulties? If yes, what would be your solution? (4x2 pts)



Name:

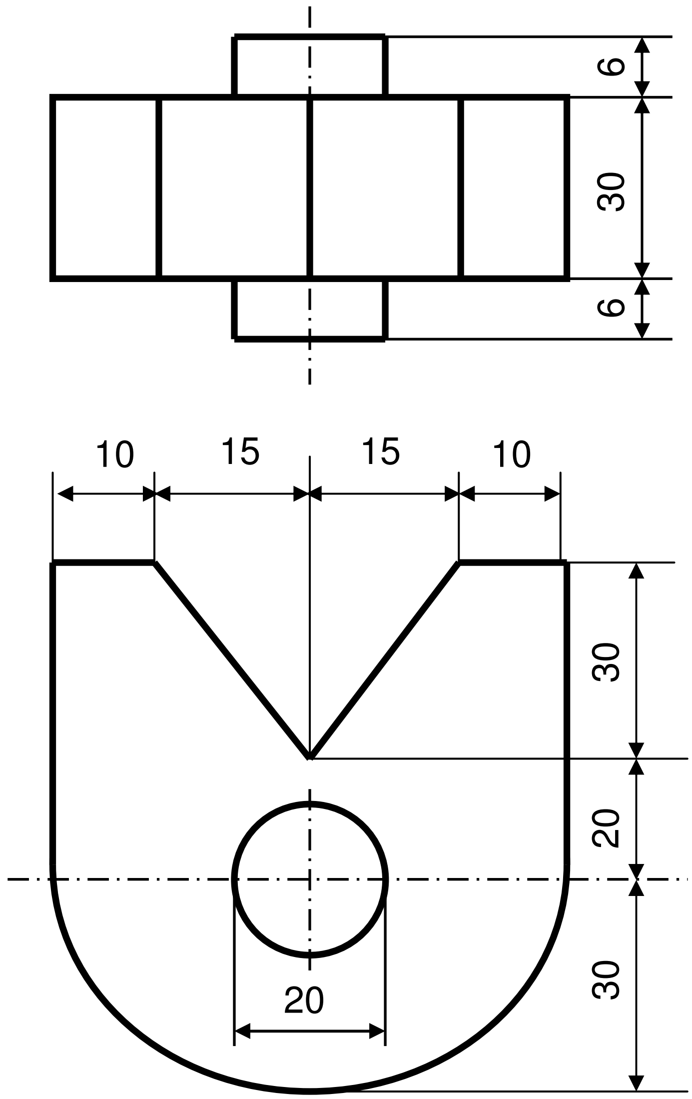
Section 1 - Problem 2: (22 pts)

You have a cylindrical rod of fully annealed low carbon steel with a diameter of 100 mm available (can be cut to length as needed).

a) Select a combination of 2 sub-processes from the list on page 2 for the manufacture of the component shown in the figure on the next page! Cutting is not considered to be a sub-process for this problem. There is no requirement for the surface finish! (2x3 pts)

b) For each sub-process, make sketches to illustrate the process and calculate the required processing force! (2x6 pts)

c) Indicate 2 critical areas of the component that would be difficult or impossible to realize using the sub-processes selected; or which would represent weak points during use! Suggest 1 design or manufacturing solution to improve each of the 2 critical areas! (2x2 pts)



- All dimensions are in mm

Name:

Section 2:

Casting and Machining

You manage production in a company possessing equipment for the following processes:

1. Sand casting
2. Die casting
3. Investment casting
4. Single crystal casting
5. Drilling
6. Milling
7. Boring
8. Turning
9. Grinding
10. Threading
11. Lapping

For all machining processes, you have the choice between oil, water, and emulsion (a mixture of water and oil) as cutting fluid.

Name:

Section 2 - Problem 3: (34 pts)

To manufacture the component shown in the figure on the next page made of cast iron, you decide to first use casting and then drill the 2 holes. Only a single batch of 2000 pieces is needed. The surface roughness requirements in the holes are < 0.1 μm and on all other surfaces < 1.6 μm.

a) Compare casting using either a metal or a sand mold regarding the following aspects. Which one (sand or die casting) would you prefer? Justify! **Only qualitative, do no calculations**! (4x3 pts)
   1) Solidification time
   2) Type of microstructure you would expect (dendrites, equiaxial, fine grain, coarse grain)
   3) Economics
   4) Need for finishing the surface using machining processes

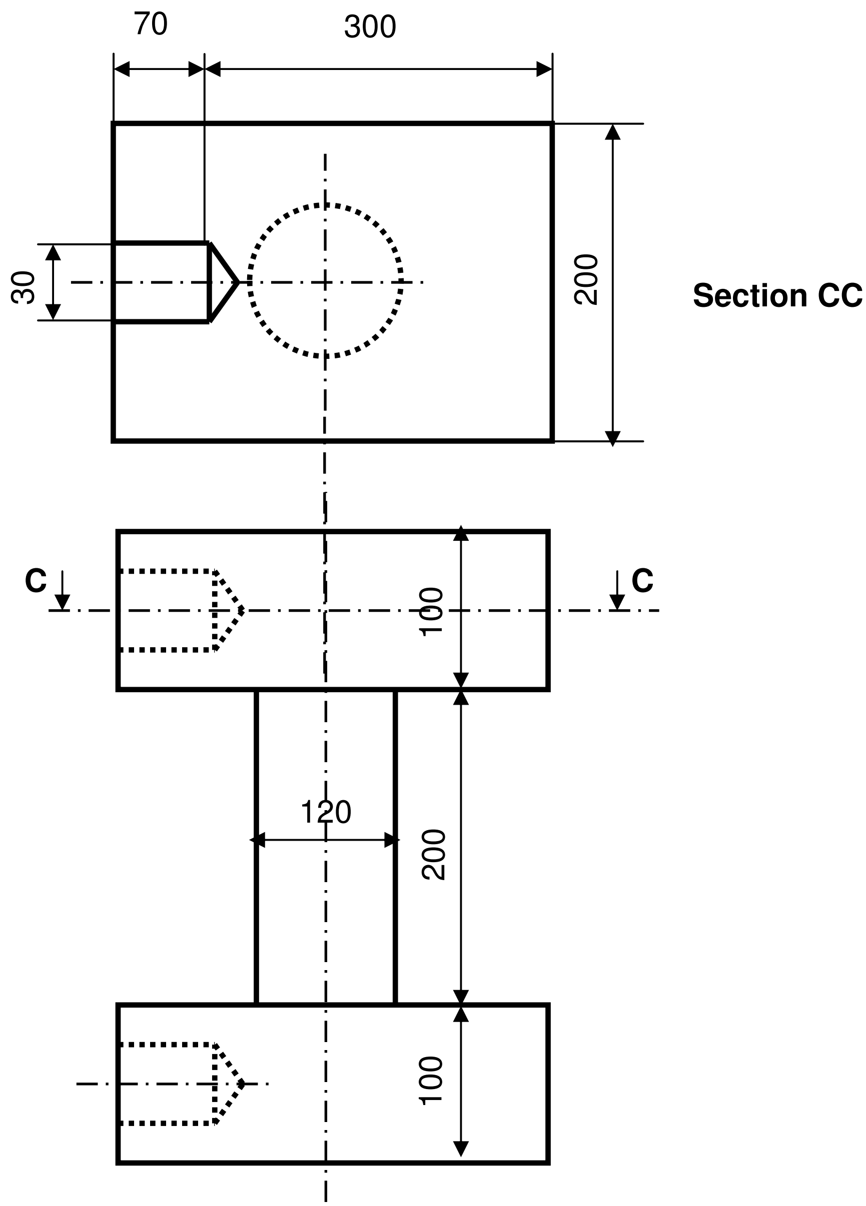
b) Indicate and draw sketches for:
   1) The configuration of mold and mold cavity (3 pt)
   2) How you position sprue and riser (4 pt)

c) After solidification, you detect hot tears and one large macropore in each of the first 5 components.
   1) At what component locations would you expects each of the 2 defect types? (3 pts)
   2) Explain what may have caused each of those 2 defect types! (4 pts)
   3) What would you do to reduce the risk of each of those 2 defect types? (4 pts)

d) Considering that cast iron does not conduct heat well, what type of cutting fluid would you use? Justify your answer! (2 pts)

e) What finishing processes, if any, would you use as last manufacturing step to meet the surface requirements? (2 pt)

Name:



All dimensions are in mm

Name:

Appendix - Materials data:

Following process parameters apply for annealed low carbon steel:

Coefficient of friction = 0.6 (hot)
= 0.15 (cold)

K = 200 MPa; C = 32 MPa; n = 0.27; m = 0.13

Radius of rolls in rolling stand = 0.6 m

Shear yield strength of low carbon steel = 20 MPa (hot)
= 320 MPa (cold)

Tensile yield strength of low carbon steel = 40 MPa (hot)
= 620 MPa (cold)

Ultimate tensile strength of low carbon steel = 60 MPa (hot)
= 820 MPa (cold)

Forging speed = 0.25 m/sec

Roll surface speed = 0.5 m/sec

Extrusion speed = 0.12 m/sec.

Max. length of extruder = 2 m.

$\alpha = 14^\circ$ (for drawing)

Tools: n = 0.15; m = 0.15 and p = 0.6

Equations

$$\sigma_{Taverage} = \frac{K\,\varepsilon_T^{\,n}}{n+1}$$

$$\sigma_T = K\varepsilon_T^n$$

$$\sigma_T = C\,\dot{\varepsilon}_T^{\,m}$$

$$\varepsilon_T = \left|\ln\left(\frac{h_f}{h_0}\right)\right|$$

$$L = \sqrt{R(h_o - h_f)}$$

$$w_{flash} = 3 \text{ to } 5 \times h_{flash}$$

$$\dot{\varepsilon}_T = \frac{V}{h_{faverage}}$$

$$V*T^n*d^m*f^p = C$$

$$A = L \times w$$

$$V*T^n*d^m*f^p = C$$

$$F_s = \pi D_0 l\,\tau_s$$

$$F = \sigma_{Taverage} * \mu R * w * MF$$

$$F = \sigma*A*MF$$

$$F = 0.7TL(\text{UTS})$$

$$\varepsilon_T = \left|\ln\left(\frac{h_{faverage}}{h_0}\right)\right|$$

$$\varepsilon_T = \ln\left(\frac{A_{original}}{A_{final}}\right)$$

$$F_{average} = 1.7 * A_0 * \sigma_{Taverage} * \ln\left(\frac{A_o}{A_f}\right)$$

$$h_{faverage} = \frac{V_o}{A_{fprojected}}$$

$$\dot{\varepsilon}_{Taverage} = \frac{\left|\ln\left(\frac{h_f}{h_0}\right)\right| V_r}{L}$$

$$F = UTS*\pi D_p T[(D_o/D_p - 0.7]$$

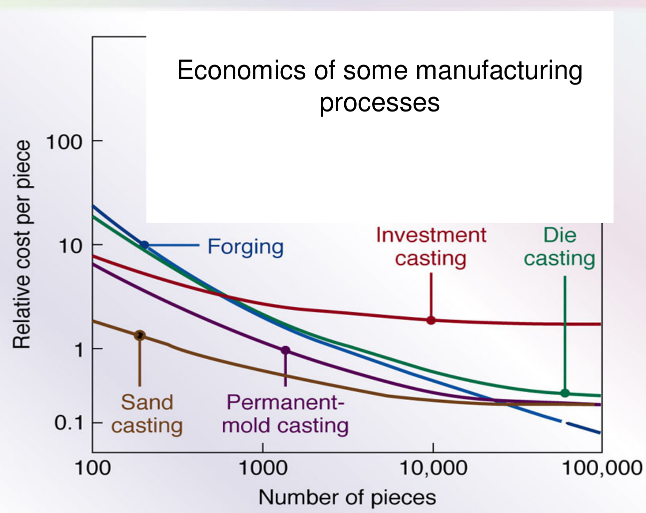
$$t = C\left(\frac{V_i}{A_i}\right)^2$$

$$F_{average} = C\left[\frac{6V\ln\left(\frac{A_{original}}{A_{final}}\right)}{D_{original}}\right]^m A_{original}\left[0.8+1.2\ln\left(\frac{A_{original}}{A_{final}}\right)\right]$$

TABLE 16.3

Minimum Bend Radius for Various Materials at Room Temperature

	Condition	
Material	Soft	Hard
Aluminum alloys	0	$6T$
Beryllium copper	0	$4T$
Brass (low-leaded)	0	$2T$
Magnesium	$5T$	$13T$
Steels		
Austenitic stainless	$0.5T$	$6T$
Low-carbon, low-alloy, and HSLA	$0.5T$	$4T$
Titanium	$0.7T$	$3T$
Titanium alloys	$2.6T$	$4T$



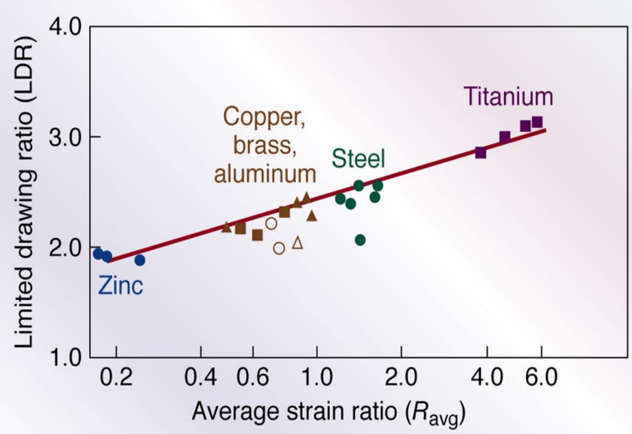
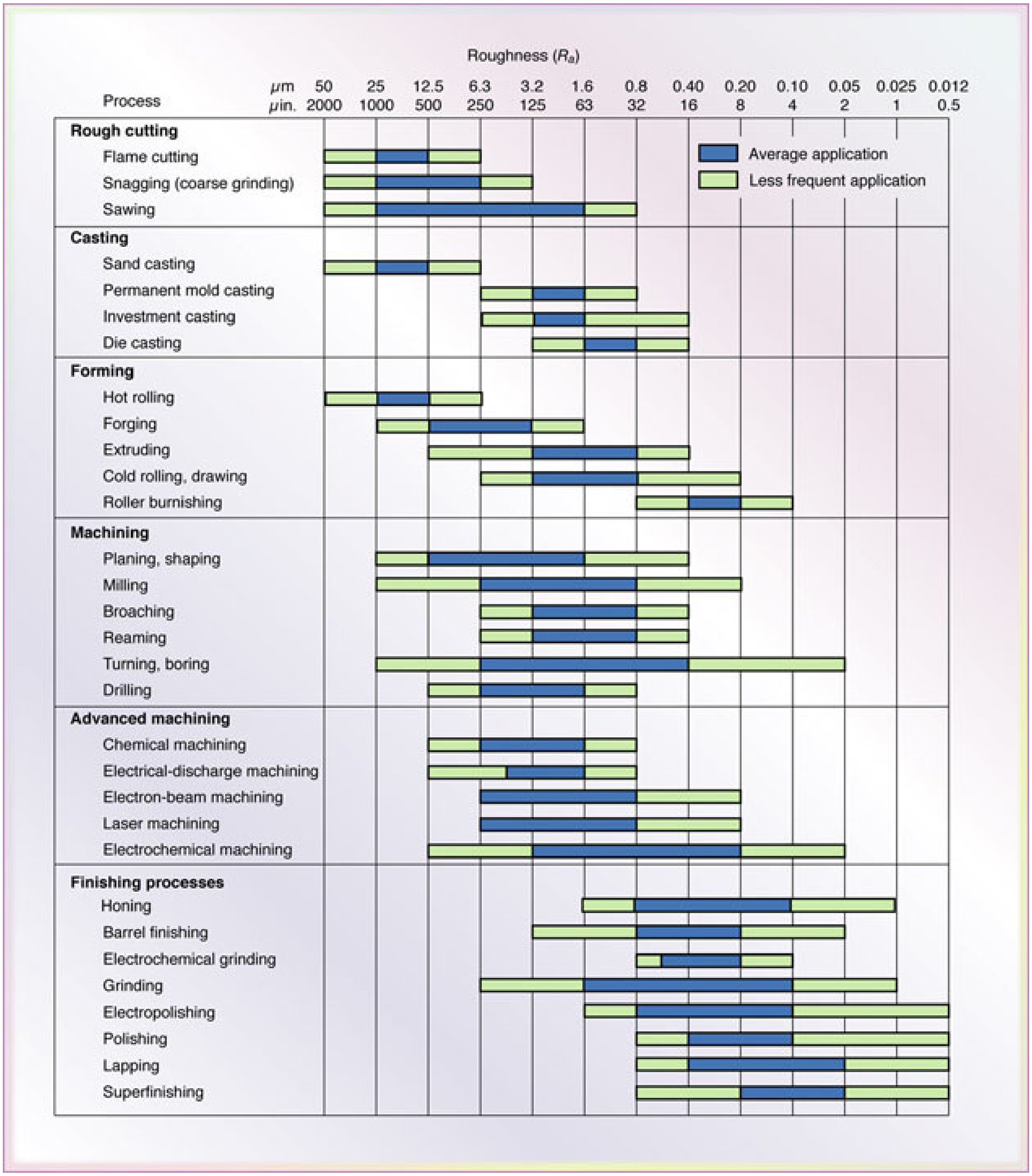


TABLE 23.4

General Recommendations for Turning Operations

Workpiece material	Cutting tool	General-purpose starting conditions: Depth of cut, mm (in.)	Feed, mm/rev (in./rev)	Cutting speed, m/min (ft/min)	Range for roughing and finishing: Depth of cut, mm (in.)	Feed, mm/rev (in./rev)	Cutting speed, m/min (ft/min)
Low-C and free machining steels	Uncoated carbide	1.5–6.3 (0.06–0.25)	0.35 (0.014)	90 (300)	0.5–7.6 (0.02–0.30)	0.15–1.1 (0.006–0.045)	60–135 (200–450)
	Ceramic-coated carbide	"	"	245–275 (800–900)	"	"	120–425 (400–1400)
	Triple-coated carbide	"	"	185–200 (600–650)	"	"	90–245 (300–800)
	TiN-coated carbide	"	"	105–150 (350–500)	"	"	60–230 (200–750)
	Al_2O_3 ceramic	"	0.25 (0.010)	395–440 (1300–1450)	"	"	365–550 (1200–1800)
	Cermet	"	0.30 (0.012)	215–290 (700–950)	"	"	105–455 (350–1500)
Medium and high-C steels	Uncoated carbide	1.2–4.0 (0.05–0.20)	0.30 (0.012)	75 (250)	2.5–7.6 (0.10–0.30)	0.15–0.75 (0.006–0.03)	45–120 (150–400)
	Ceramic-coated carbide	"	"	185–230 (600–750)	"	"	120–410 (400–1350)
	Triple-coated carbide	"	"	120–150 (400–500)	"	"	75–215 (250–700)
	TiN-coated carbide	"	"	90–200 (300–650)	"	"	45–215 (150–700)
	Al_2O_3 ceramic	"	0.25 (0.010)	335 (1100)	"	"	245–455 (800–1500)
	Cermet	"	0.25 (0.010)	170–245 (550–800)	"	"	105–305 (350–1000)
Cast iron, gray	Uncoated carbide	1.25–6.3 (0.05–0.25)	0.32 (0.013)	90 (300)	0.4–12.7 (0.015–0.5)	0.1–0.75 (0.004–0.03)	75–185 (250–600)
	Ceramic-coated carbide	"	"	200 (650)	"	"	120–365 (400–1200)
	TiN-coated carbide	"	"	90–135 (300–450)	"	"	60–215 (200–700)
	Al_2O_3 ceramic	"	0.25 (0.010)	455–490 (1500–1600)	"	"	365–855 (1200–2800)
	SiN ceramic	"	0.32 (0.013)	730 (2400)	"	"	200–990 (650–3250

(Continued)


Roughness (R_a)
Process
μm 50 25 12.5 6.3 3.2 1.6 0.8 0.40 0.20 0.10 0.05 0.025 0.012
μin. 2000 1000 500 250 125 63 32 16 8 4 2 1 0.5
Average application
Less frequent application
Rough cutting
Flame cutting
Snagging (coarse grinding)
Sawing
Casting
Sand casting
Permanent mold casting
Investment casting
Die casting
Forming
Hot rolling
Forging
Extruding
Cold rolling, drawing
Roller burnishing
Machining
Planing, shaping
Milling
Broaching
Reaming
Turning, boring
Drilling
Advanced machining
Chemical machining
Electrical-discharge machining
Electron-beam machining
Laser machining
Electrochemical machining
Finishing processes
Honing
Barrel finishing
Electrochemical grinding
Grinding
Electropolishing
Polishing
Lapping
Superfinishing