Université d'Ottawa
Faculté de génie

Département de
Génie Mécanique

University of Ottawa
Faculty of Engineering

Department of
Mechanical Engineering

MCG4328
Manufacturing
Fall 2012

FINAL EXAM

3 problems; total: 100 pts

Professor: Dr. Michel Nganbe

(<u>3 hours</u>)

Family name : ____

First name : ____

Student number: ____

Signature : ____

<u>Instructions</u>:

- Closed book exam
- <u>Non-programmable</u> calculators *are* permitted
- Print your name and student number on this first page and on each other page you detach
- Some materials data, equations and other information are provided in the appendix at the end of the questionnaire
- Good luck!

Name:

Section 1:

Bulk deformation processes and sheet metal forming

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

1. Hot closed die forging (MF = 4)
2. Hot open die forging (MF = 1.5)
3. Hot rolling (MF = 4)
4. Hot extrusion
5. Cold closed die forging (MF = 3)
6. Cold impression die forging (MF = 3)
7. Cold open die forging (MF = 1.2)
8. Cold extrusion
9. Cold rolling (MF = 3)
10. Cold wire drawing
11. Deep drawing
12. Stretch-forming
13. Bending
14. Hydroforming

Name:

Section 1:

Section 1 - Problem 1: (36 pts)

You have a cylindrical rod with a diameter of 400 mm available (can be cut to length as needed).

a) Select a combination of two sub-processes from the list on the previous page for the manufacture of the component shown in figure 1 on the next page! There is no requirement for the surface finish! (2x2 pts)

b) For each sub-process, calculate the required processing force! Indicate and discuss any assumptions you make! (2x8 pts)

c) Indicate 2 methods to reduce the force requirement for each sub-process! (2x2 pts)

d) 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 2 design or manufacturing solutions to improve the 2 critical areas! (2x3 pts)

e) Add 2 sub-processes such as cutting; heat treatments; machining; pickling; etc. Indicate the objective of such sub-processes and at what stage you would use them without doing any force calculations or giving any further specifications! (2x3 pts)

Name:

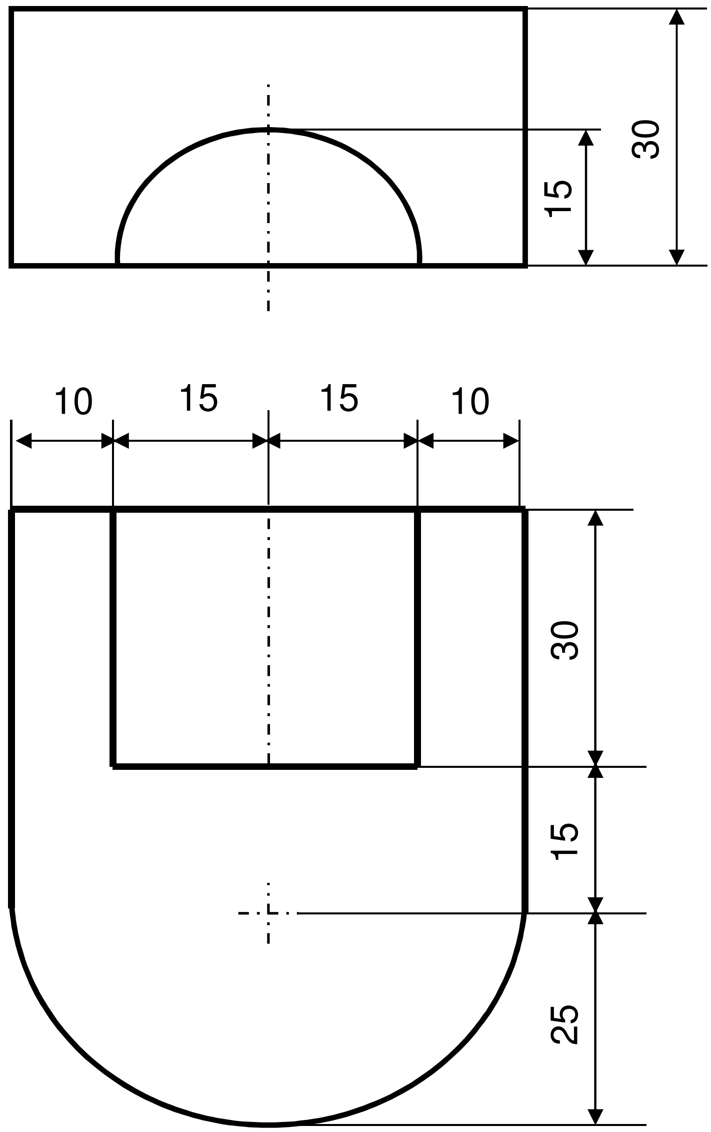


Figure 1: all dimensions are in mm

Name:

Section 1 - Problem 2: (31 pts)

A housing component has the shape sketched in Figure 2 on the following page. 100,000 pieces are to be manufactured per year for a period of 5 years. You have as start material a fully annealed 30 mm thick and 800 mm wide low carbon steel plate.

a) Select a combination of three sub-processes from the list on page 2 for the manufacture of this component! Cutting is not considered a sub-process! A smooth and slightly strain hardened final surface is required! (2x3 pts)

b) For each sub-process, calculate the required processing force! Indicate and discuss any assumptions you make! Make sketches to illustrate your process! (3x6 pts)

c) Using appropriate calculations, assess the risk of having cracks, thinning or other defects at the bend corner during bending! (4 pt)

d) Indicate 2 methods that can be used to eliminate the risk of tearing/cracking at the bend corner during bending if necessary! (3 pt)

Name:

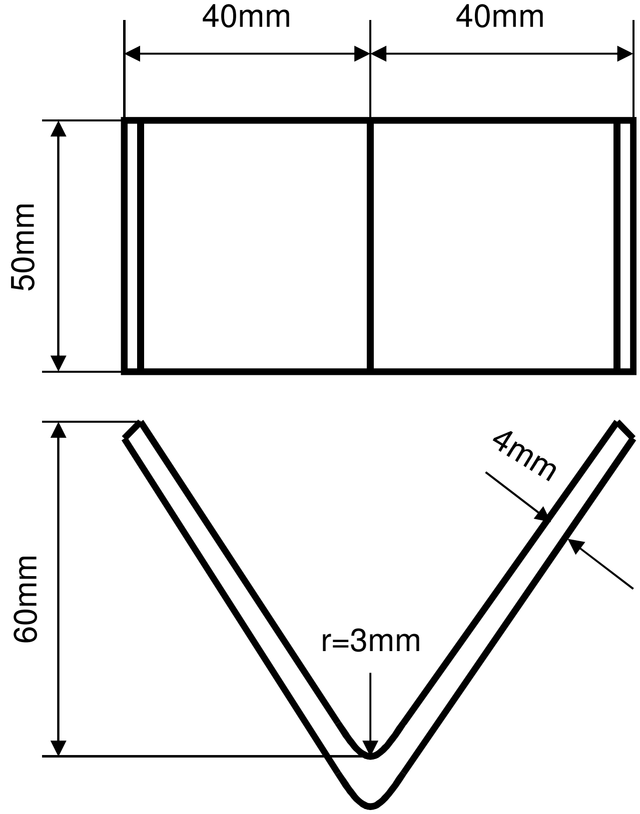


Figure 2

Name:

Section 2:

Casting and Machining

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

1. Sand casting (green sand)
2. Sand casting (sodium silicate sand)
3. Die casting
4. Investment casting
5. Single crystal casting
6. Drilling
7. Milling
8. Boring
9. Turning
10. Grinding
11. Threading

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: (33 pts)

You have as start material new 50mmx50mmx50mm pieces of gray cast iron as well as scrap of the same material. You need to manufacture the component of an engine block as shown in the simplified figure 3 on the next page! Only a single batch of 100 pieces is needed.

a) If no roughness requirement is considered, select a casting process for the manufacture of the component! (2 pts)

b) Discuss and justify each point of your casting design procedure including (**do all necessary calculations! If you use any core, consider that the cooling effect of the core is identical to that of the mold! Make sketches to illustrate your casting process!)**
1) The material you use for the mold (2 pts)
2) The material you use for pattern and core, respectively (2 pts)
3) The geometry of your sprue-cup assembly (4 pt)
4) The configuration of mold, mold cavity, and core if any (2 pt)
5) How you position sprue, runner, risers and vents if needed (9 pt)
6) 2 casting defects that may occur during casting, and what you have included in your design in order to avoid them (3x2 pt)

c) What cutting tool material would you use for finishing machining of this component? (2 pts)

d) For the cutting tool you have selected, experience has shown that extreme heat is to be expected and friction is not an issue! What cutting fluid would you use? (2 pts) Justify! (2 pt)

Name:

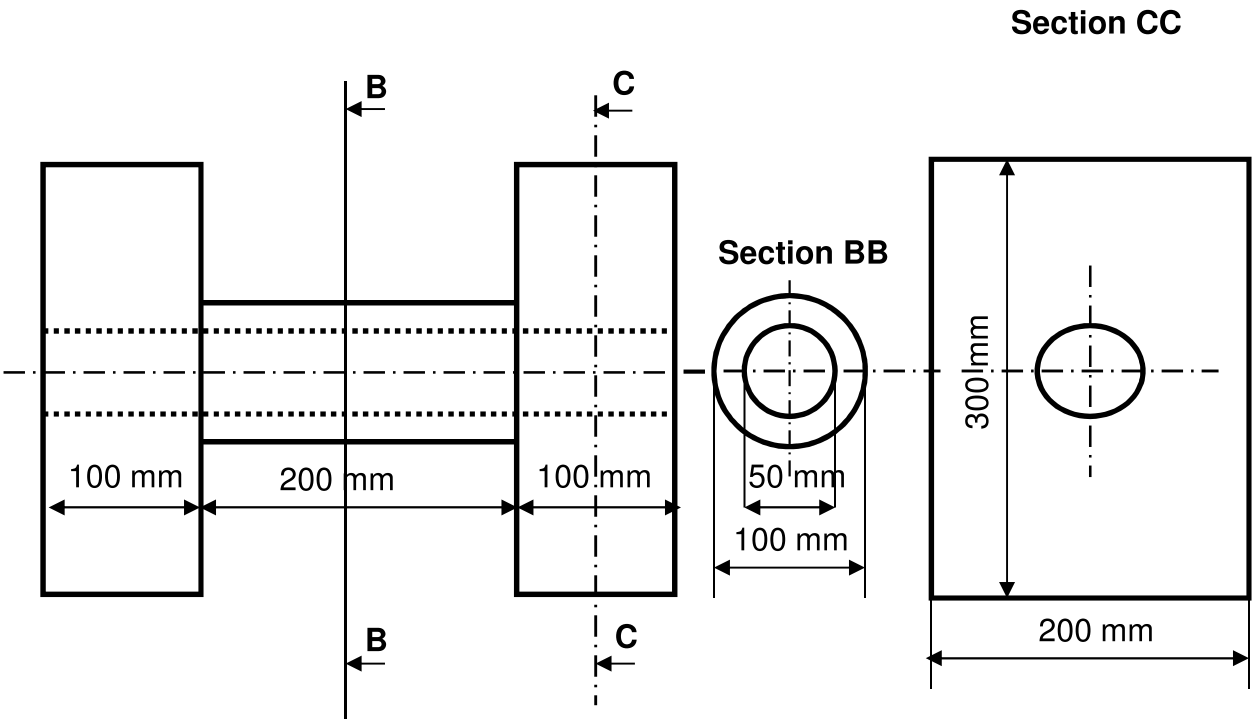


Figure 3

Name:

Appendix

Material data

Following process parameters apply for fully annealed low carbon steel:

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

K = 600 MPa; C = 50 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 = 1.2 m/sec

Extrusion speed = 0.12 m/sec.

Max. length of extruder = 5 m.

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

k= 0.7 (U-die); k= 1.3 (V-die)

Equations

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

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

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

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

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

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

$$\dot{\varepsilon}_T = \frac{V}{h_f}$$

$$VT^n = C$$

$$A = L \times w$$

$$P = \frac{kYLT^2}{W}$$

$$\frac{A_1}{A_2} = \sqrt{\frac{h_1}{h_2}}$$

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

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

$$h_{flash} = 0.015 * \sqrt{\text{Projected area of part (without flash)}}$$

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

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

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

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

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

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

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

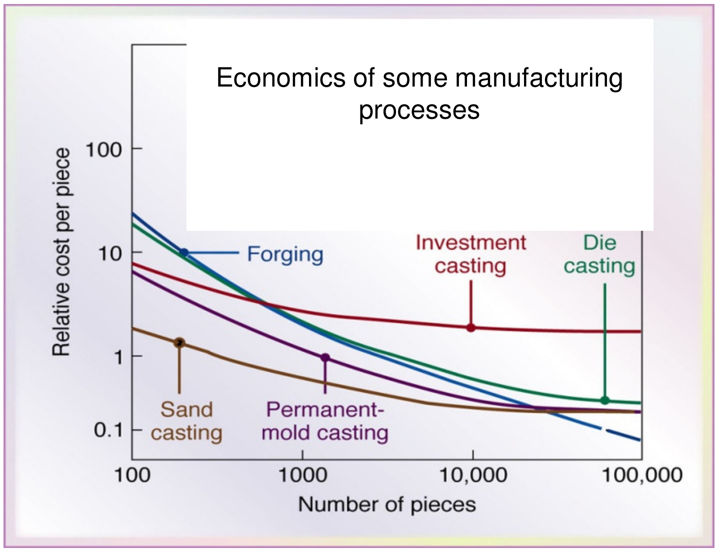
$$F_{average} = C\left[\frac{\left[6V\ln\left(\frac{A_{original}}{A_{final}}\right)\right]}{D_0}\right]^m A_{original}\left[0.8 + 1.2\ln\left(\frac{A_{original}}{A_{final}}\right)\right]$$

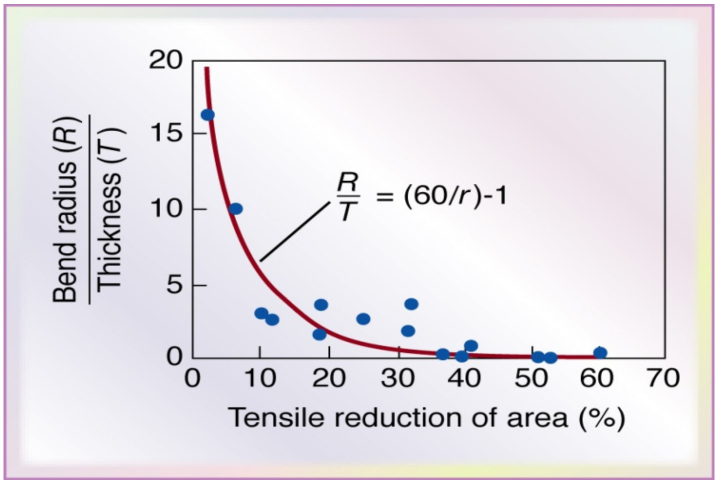
Other information

TABLE 16.3

Minimum Bend Radius for Various Materials at Room Temperature

Material	Condition: Soft	Condition: 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	$2.6T$	$4T$





General recommendation for machining operations

Workpiece material	Cutting tool	Depth of cut, mm (in.)	Feed, mm/rev (in./rev)	Cutting speed, m/min (ft/min)	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)