Université d'Ottawa
Faculté de génie

Département de
Génie Mécanique

uOttawa
L'Université canadienne
Canada's university

University of Ottawa
Faculty of Engineering

Department of
Mechanical Engineering

MCG4328
Manufacturing
Fall 2011

FINAL EXAM

Total: 100 pts

Professor: Dr. Michel Nganbe

December 16, 2011; 09:30 to 12:30 (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, on each other page you detach and on each of your booklets
- Some materials data and equations are provided in the appendix at the end of the questionnaire
- You may detach any questionnaire page for your convenience, but make sure to submit all pages at the end of the exam
- 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 impression 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
15. Trimming the flash

Name:

Section 1 - Problem 1: (30 pts)

the cylindrical component of a housing shown in the figure below has a uniform thickness of 2 mm, one hole with 30 mm diameter in the base, and four holes with 20 mm diameter each in the wall, which are positioned at equal distance from each other. 30,000 pieces are to be manufactured per year for a period of 5 years. You have as start material an annealed low carbon steel plate with 800 mm width and 30 mm thickness. Material parameters and equations are provided in the appendix. There is no surface finish requirement.

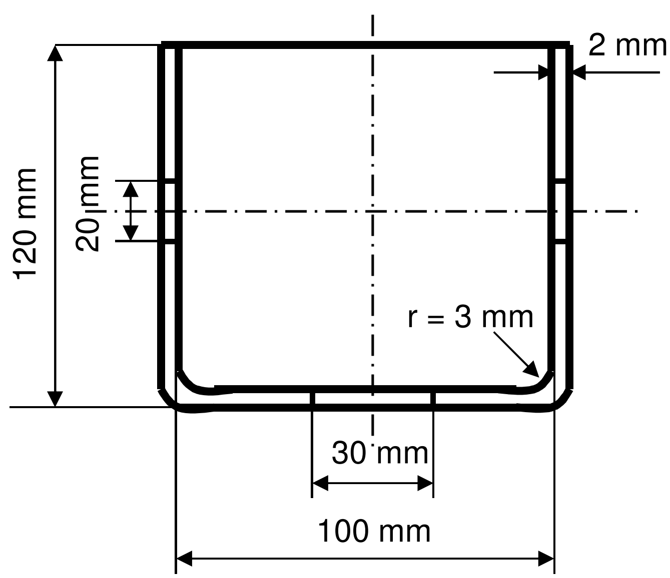
a) If the holes are not considered, select a combination of two sub-processes from the list on page 2 for the manufacture of this component! (6 pts)

b) For each sub-process, calculate the required processing force! Make sketches to illustrate your process! (10 pts)

c) Indicate 2 methods to reduce the force requirement for each sub-process! (4 pts)

d) In addition to the force requirements, indicate the 2 major limitations for the manufacture of this component! Are the 2 limitation conditions met? (6 pts)

e) At what stage would you drill the holes (before the first sub-process, between the 2 sub-processes or after the last sub-process)? (2 pts) Justify! (2 pts)



Name:

Section 1 - Problem 2: (35 pts)

You have as start material an annealed 140 mm diameter low carbon steel rod.

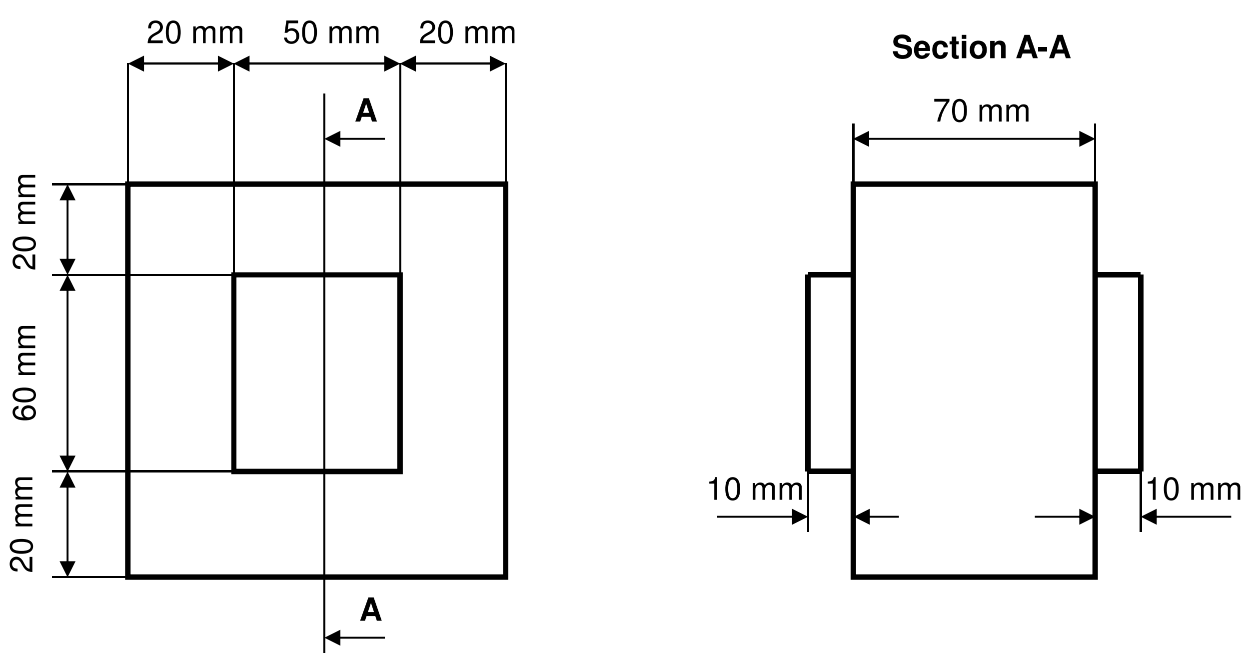
a) Select a sequence of two bulk deformation sub-processes followed by one additional sub-process from the list on page 2 for the manufacture of the component shown in the figure below! 100,000 pieces are to be manufactured per month for a period of 5 years. Material parameters and equations are provided in the appendix. There is no requirement for the surface finish! (7 pts)

b) For each of the bulk deformation sub-processes, calculate the required processing force! Make sketches to illustrate your process! (14 pts)

c) Indicate 2 methods to reduce the force requirement for each sub-process! (6 pts)

d) For each sub-process, indicate one potential defect, one of its potential causes and one possible method to avoid it! (4 pts)

e) Add 2 preparation, heat treatment or finishing sub-processes that can be used during the manufacture of the component. Indicate only at what stage you would use such processes without doing any force calculations or giving any further specifications! (4 pts)



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

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: (35 pts)

You have as start material new 50mmx50mmx50mm pieces of gray cast iron as well as scrap of the same material. Material parameters and equations are provided in the appendix. You need to manufacture the roughly cylindrical component shown in the simplified figure on the next page! A single batch of 1,000 pieces is needed. The roughness requirement on the top surface is R_a = 0.5 μm. There is no Surface finish requirement for all other surfaces.

a) Select a casting process and three subsequent machining sub-processes from the list on the previous page to manufacture the component! (7 pts)

b) Discuss and justify each point of your casting design procedure including (**do not do any calculations for solidification times; just estimate the solidification sequence visually. Make sketches to illustrate your casting process!)**
1) The material you use for the mold (2 pts)
2) The material you use for the pattern (2 pts)
3) The configuration of mold cavity (4 pt)
4) How you position sprue and risers if needed (4 pt)
5) The geometry of your sprue (2 pt)
6) 2 casting defects that may occur during casting, and what you have included in your design in order to avoid them (2x2 pt)

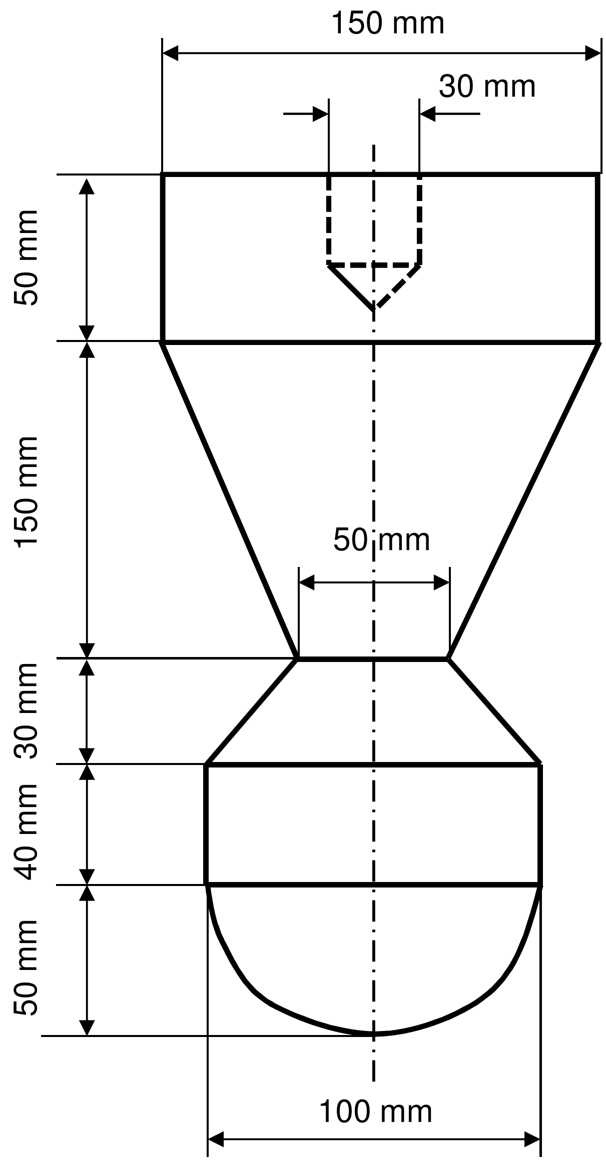
c) What cutting tool material would you use for creating the hole? (2 pts)

d) Estimate the service life of the selected tool knowing that it would fail after one minute if you use a speed of 200 m/min. **No unit conversion is required for this estimate. Use the values as provided!** (4 pts)

e) For the cutting tool and parameters you have selected, experience has shown that extreme heat as well as strong frictions are to be expected! What cutting fluid would you use (1 pts)? Justify! (1 pt)

f) What is the mechanically most critical cross-section of this component and what design change would you make to improve the strength of this cross-section? (2 pts)

Name:



Name:

Material data:

Following process parameters apply for annealed low carbon steel:

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

K = 600 MPa; C = 62 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.

$\alpha = 14'$ (for drawing)

Equations

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

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

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

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

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

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

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

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

$$A = L \times w$$

$$\tau_s \geq \frac{\sigma_{yield}}{2}$$

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

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

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

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

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

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

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

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

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

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

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

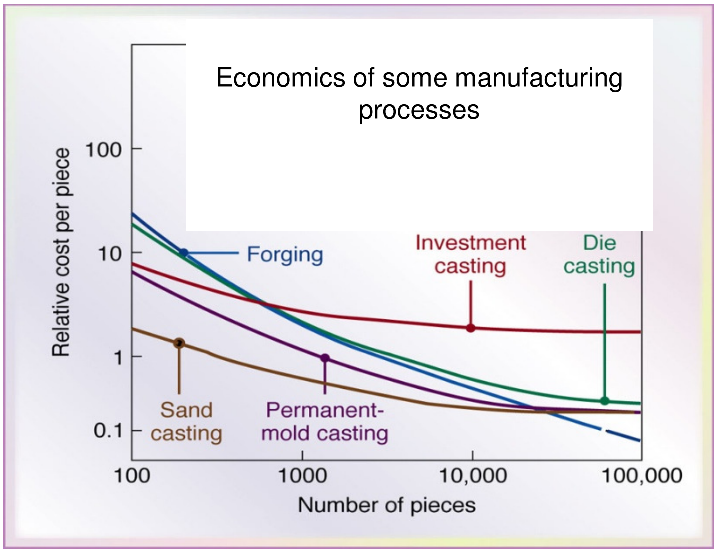
$$F_{average} = C\left[\frac{\left[6V\ln\left(\frac{A_{original}}{A_{final}}\right)\right]}{D_0}\right]^m A_{original}\left[0.8 + 1.2\ln\left(\frac{A_{original}}{A_{final}}\right)\right]$$

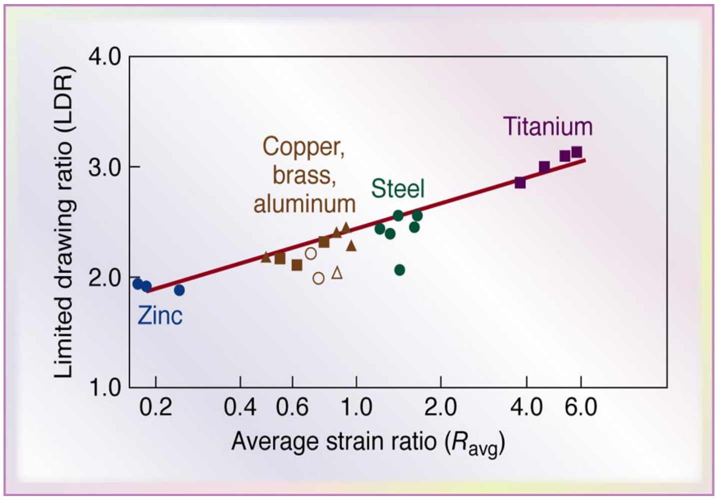
Appendix: Materials data

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	$2.6T$	$4T$



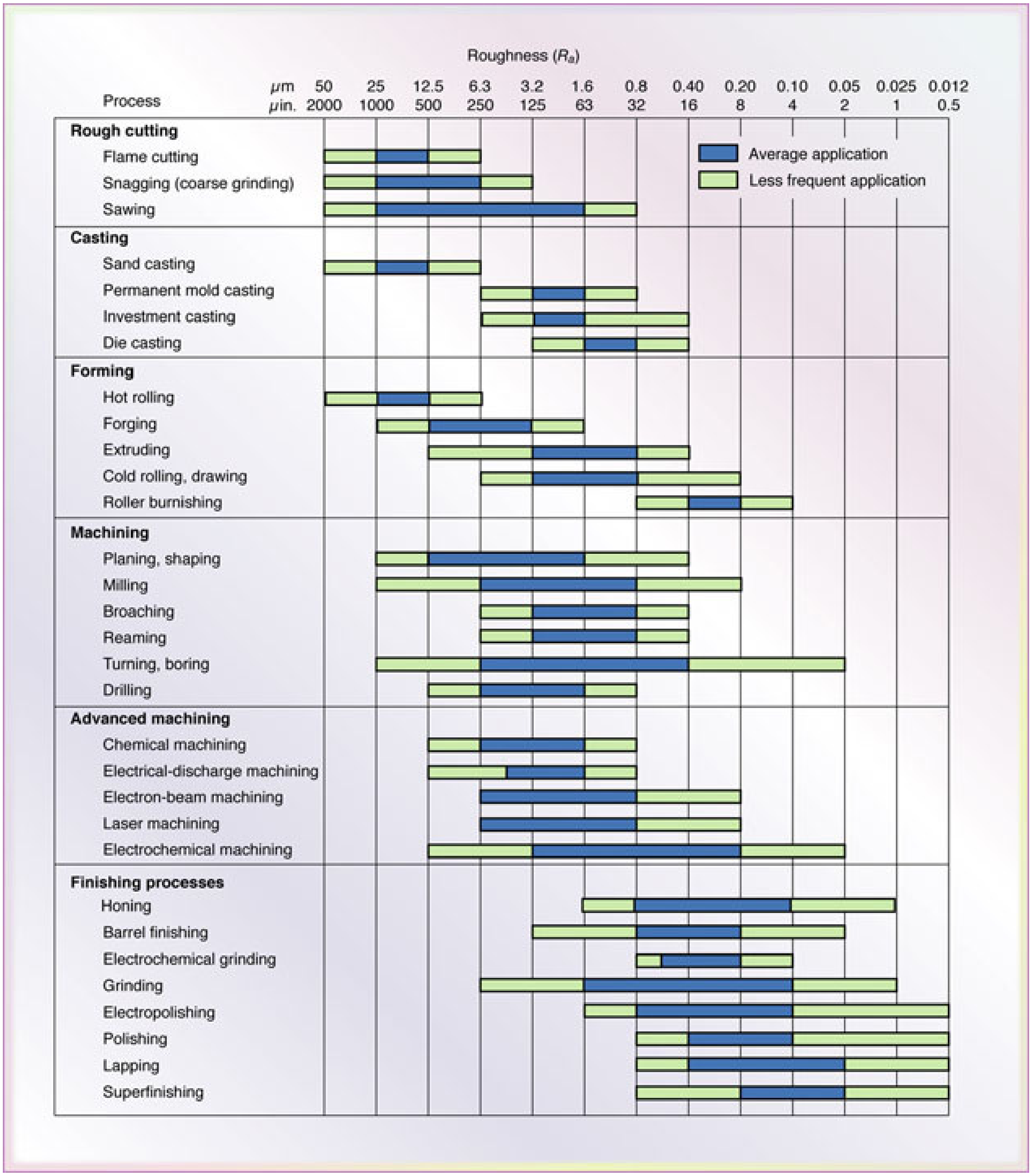


General recommendation for machining operations

Workpiece material	Cutting tool	Depth of cut, mm (in.)	Feed, mm/rev (in./rev)	Cutting speed, m/min (ft/min)
Low-C and free machining steels	Uncoated carbide	1.5–6.3 (0.06–0.25)	0.35 (0.014)	90 (300)
	Ceramic-coated carbide	"	"	245–275 (800–900)
	Triple-coated carbide	"	"	185–200 (600–650)
	TiN-coated carbide	"	"	105–150 (350–500)
	Al_2O_3 ceramic	"	0.25 (0.010)	395–440 (1300–1450)
	Cermet	"	0.30 (0.012)	215–290 (700–950)
Medium and high-C steels	Uncoated carbide	1.2–4.0 (0.05–0.20)	0.30 (0.012)	75 (250)
	Ceramic-coated carbide	"	"	185–230 (600–750)
	Triple-coated carbide	"	"	120–150 (400–500)
	TiN-coated carbide	"	"	90–200 (300–650)
	Al_2O_3 ceramic	"	0.25 (0.010)	335 (1100)
	Cermet	"	0.25 (0.010)	170–245 (550–800)
Cast iron, gray	Uncoated carbide	1.25–6.3 (0.05–0.25)	0.32 (0.013)	90 (300)
	Ceramic-coated carbide	"	"	200 (650)
	TiN-coated carbide	"	"	90–135 (300–450)
	Al_2O_3 ceramic	"	0.25 (0.010)	455–490 (1500–1600)
	SiN ceramic	"	0.32 (0.013)	730 (2400)

Exponents:

n = 0.15
m = 0.15
p = 0.6,


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