ORDRE DES INGÉNIEURS DU QUÉBEC

SESSION DE MAI 2011

Open book examination
Calculators: only authorized models
Duration: 3 hours

98-IND-B2 MANUFACTURING PROCESSES

Problem 1 (6 points: 1 per each diagram)

The stress-strain diagrams of Figure 1 represent different mechanical behavior. Identify each diagram using the following terms: linear elasticity, nonlinear elasticity, elastoplasticity, viscoelasticity, creep and stress relaxation.

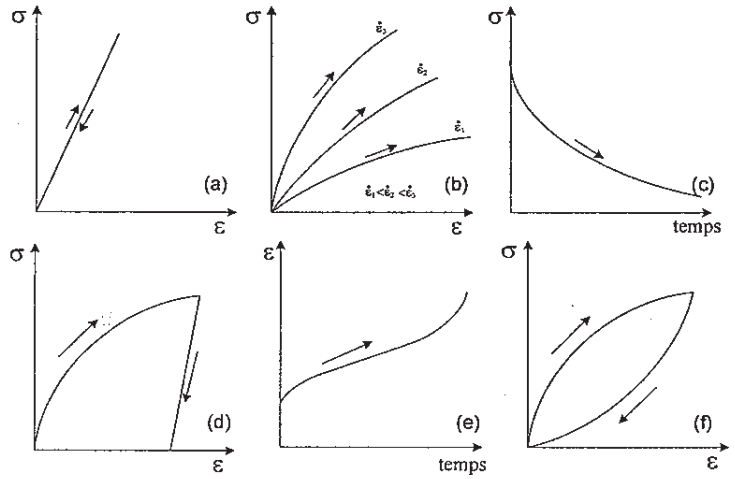

Figure 1. Schematic stress-strain diagrams of engineering materials

Problem 2 (6 points)

Discuss the causes of the deep drawing defects shown in Figure 2:
a) wrinkles (2 points),
b) ears (2 points),
c) rupture (2 points).
Enumerate the measures that can prevent their appearance.

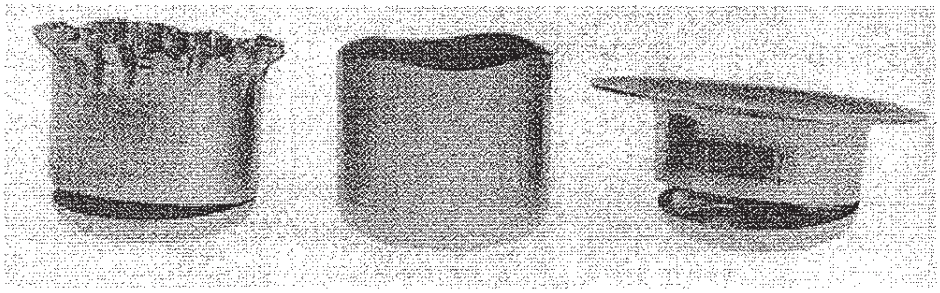

Figure 2 Deep drawing defects

Problem 3 (8 points: 1 per question) *(it could be more than one right answer for each question)*

Questions	Answers
1. How would you classify the lost-wax casting: a) expendable-pattern – expendable-mold process, b) permanent-pattern – expendable-mold process, c) permanent-mold process ?	
2. It is known that deformation behavior of materials is temperature dependant and in this respect, hot and cold deformation processes are distinguished. If a medical implant is forged at 700°C using either pure Ti (T_m = 1660°C) or Ta (T_m = 3017°C), whether one could say that: a) Ti and Ta are hot-worked b) Ti is hot-worked, whereas Ta is cold-worked c) Ti and Ta are cold-worked?	
3. To assembly two or multiples pieces by welding, brazing or soldering, filler metal is generally used. If the melting temperature of the filler metal is about 300°C, and this temperature is lower than that of the base material, this joining technique is called: a) brazing b) welding c) soldering?	
4. During impression-die forging, the flash serves to: a) compensate thermal dilatation of the forged material b) contain an extra material c) facilitate cavity filling	
5. Rank the following powder compaction techniques based on the decreasing green product homogeneity: a) double-action pressing b) simple-action pressing c) floating-die pressing	
6. Rank the following welding processes in order of decreasing heat-affected zone: a) TIG welding b) electron beam welding c) electric arc welding	
7. Metal extrusion processes are used for: a) producing elongated semi-products with variable cross-section b) destroying the cast-metal structure c) deforming materials which cannot be deformed by drawing	
8. Rank the following cutting techniques based on the decreasing surface quality: a) laser b) EDM-wire c) plasma	

Problem 4 (4 points)

- Explain why the higher the cold work, the higher the yield stress (YS) and the tensile strength (TS) of metallic materials, while the lower the TS-YS difference and the material elongation to failure (Figure 3a). – 1 point
- Explain how the cold work intensity affects material toughness and resilience (**Figure 3a**) – 1 point
- Explain why the higher the cold work intensity, the lower the annealing temperature and the smaller the grain size (**Figure 3b**) – 1 point
- Explain how the grain size affects materials strength and ductility – 1 point.

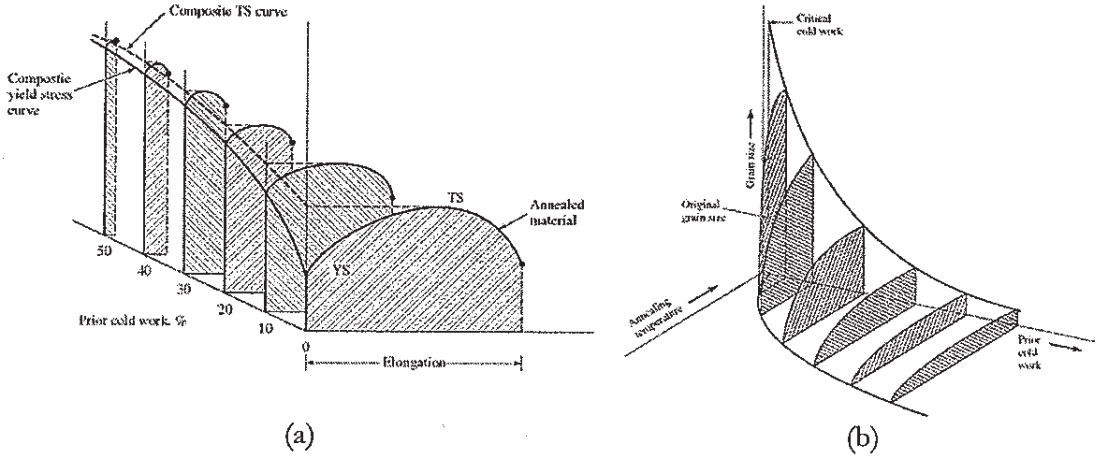

Figure 3 Influence of the cold-work intensity on (a) mechanical properties and (b) annealing temperature and grain size

Problem 5 (3 points)

Estimate the springback in making 90° bend to 5 mm radius of the Al 6061-T4 and 5052-0 sheets with identical 2 mm thickness

(a) Calculate for each material: radius of the final bend and the angle after springback and comment on the differences observed -- 2 points.
(b) Propose two techniques to combat springback, make a sketch, if necessary – 1 point.

Problem 6 (9 points)

The length of the steel tubular bar (hardness 40HRC) is 200 mm, its external diameter is 100 mm and internal, 50 mm. The bar is machined to obtain internal diameter of 51.3 mm using WC tooling.

a) Suggest cutting speed and feed – 1 point.
b) Evaluate the time necessary for machining – 1 point.
c) Using Taylor's equation, calculate WC tool life using cutting speed and feed found in point (a) and the number of pieces that can be machined with one tool – 2 points.
d) Determine whether the lath available in the shop and having power of 6kW will suffice for this operation – 2 points.

e) Calculate the force of cut and evaluate the thrust force – 2 points.

f) From Taylor's equation, find the effect of decreasing in half the cutting speed on the WC tool life – 1 points.

Problem 7 (3 points)

Iron-titanium (Fe-Ti) alloy is precipitation hardenable. From the phase diagram of Figure 4:

a) Specify the range of compositions over which these alloys may be precipitation hardened. – 1 point

b) Select one composition within the range determined in a). – 1 point

a) Briefly describe the heat treatment procedures in terms of sequence and temperatures that should be used to precipitation harden the alloy having composition of b). – 1 point

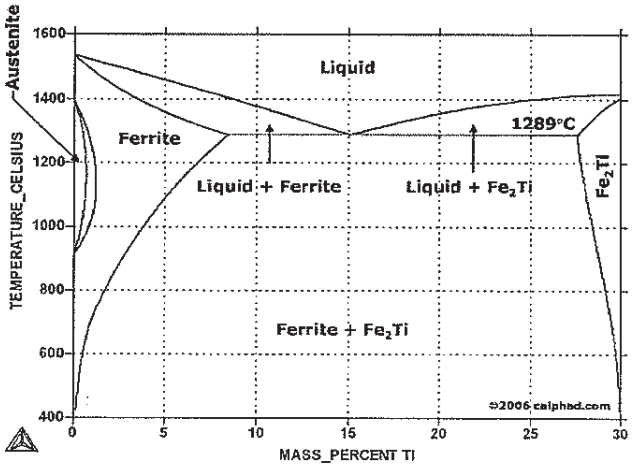

Figure 4 Phase diagram of iron-titanium (Fe-Ti) alloys

Problem 8 (3 points)

Using diagram of Figure 5, determine for a polymer having molar mass of M:

a) Maximum injection temperature – 1.5 points

b) Minimum thermoforming temperature? – 1.5 points

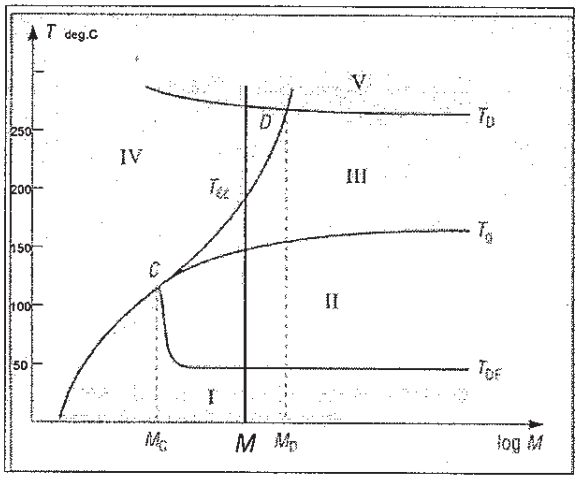

Figure 5 Molar mass-characteristic temperatures diagram for polymers

Problem 9 (2 points)

Review Figure 6 and explain why internal draft angles are larger than external draft angles. Is this also true for permanent mold casting?

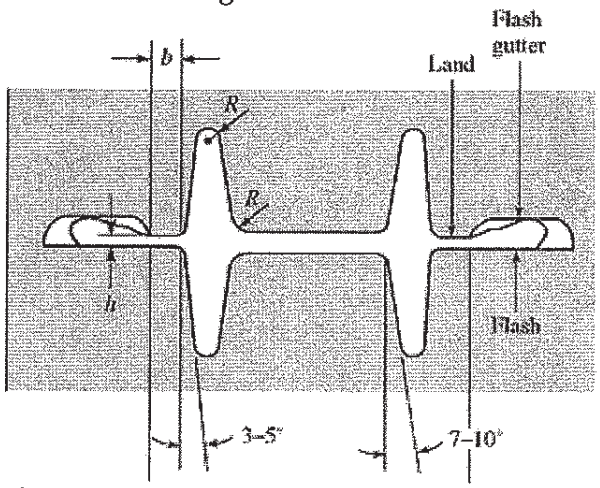

Figure 6. Schematic of the impression-die cavity

Problem 10 (3 points)

Explain why the stress–strain rate diagram of a hot-deformed metal is generally expressed by the equation $\sigma = C\dot{\varepsilon}^m$, where C is the strength coefficient (MPa) and m is the strain-rate sensitivity exponent, whereas stress–strain diagram of a cold-deformed metal is expressed by the equation $\sigma = K\varepsilon^n$, where K is the strength coefficient (MPa) and n is the strain-hardening exponent.