ORDRE DES INGÉNIEURS DU QUÉBEC

SESSION MAI 2012

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

98-IND-B2 MANUFACTURING PROCESSES

Problem 1 (4 points)

The force-elongation diagram of an AL 3105-H0 sample (65 mm gage length, specimen width of 10 mm and specimen thickness of6.25 mm) is shown on Figure 1 (left). The true-stress – true-strain diagram is then plotted on a log-log scale (Figure 1, right).

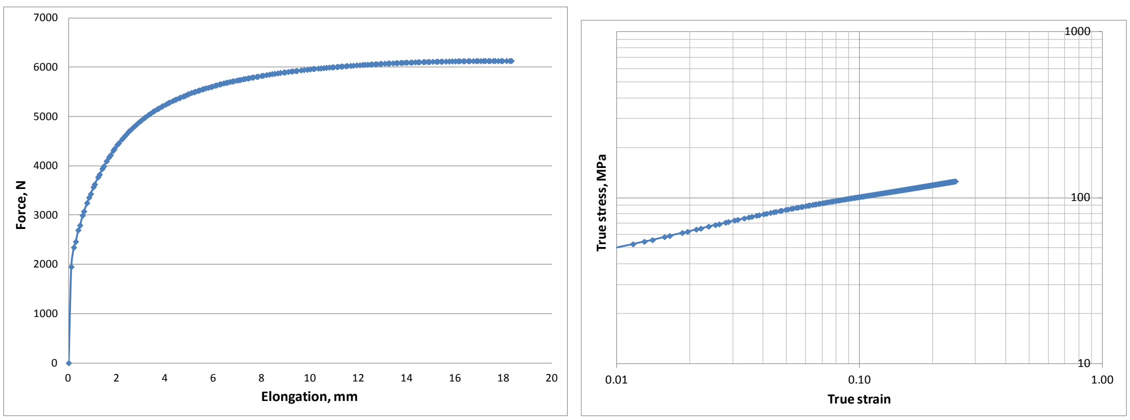


Figure 1 Force-elongation diagram (left); true-stress – true-strain diagram (right)

a) Compare true and engineering values for stress and strain at a specimen elongation of 10 mm (2 p.)

b) Determine strain-hardening exponent and strength coefficient (2 p.)

Problem 2 (4 points)

In a copper wiring drawing process, a 150 mm diameter billet is drawn down to a final wire diameter of 2 mm.

a) What is the ductility measured in terms of area reduction? (1 pt)

b) If the original billet is 2 meters long, how long is the final wire? (1 pt)

c) What is the final engineering strain of the wire? (1 pt)

d) What is the final true strain of the wire? (1 pt)

Problem 3 (3 points)

Review Figure 2 and explain why external draft angles are smaller than internal draft angles. Is this also true for sand mold casting?

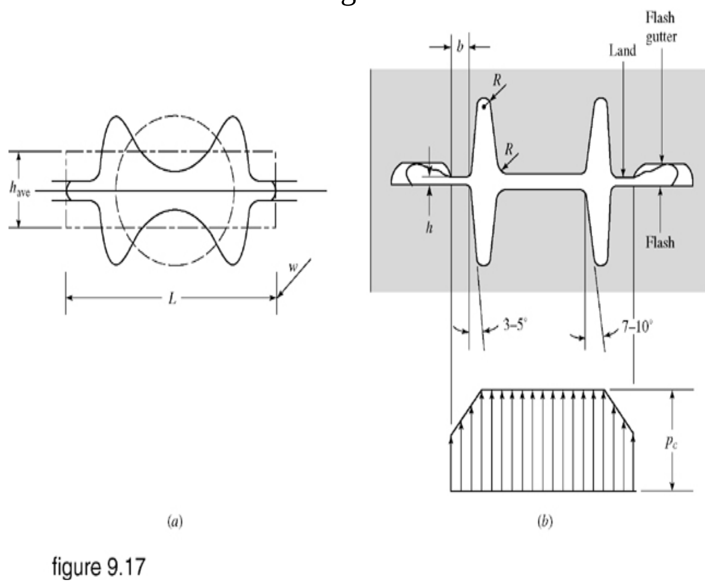


Figure 2. Schematic of the impression-die cavity

Problem 4 (2 points)

A cylindrical specimen of 40 mm of diameter and 80 mm of height is compressed with a constant press speed of 20 mm/s. Calculate the strain rate of compression for a 50% reduction of the specimen height.

Problem 5 (4 points)

Generally the smaller the grain size, the stronger the material.

1. Draw a Hall-Petch diagram indicating the expected trends for strength as a function of grain size for: (a) cold deformation and (b) slow hot deformation (2 pt)

2. On the diagram built for point 1, state what grain size is better for (a) an aluminum alloy operating at room temperature and (b) superalloy operating at temperatures close to the melting point. (Consider that in both cases operation conditions imply low strain rates.) (2 pt)

Problem 6 (5 points)

A simple workpiece made of annealed 1045 steel is impression-die forged at 1000^{o}C on a hydraulic press (ram speed 200 mm/s). The height of the initial blank is 50 mm, its volume 10000 mm^3, and the projected area of the die without flash land area 900 mm^2. Assuming that 10% of metal is lost in flash, and the flash land width is 5 mm and circumference 200 mm, calculate the force required at the end of the stroke.

Problem 7 (4 points)

a) Identify which solidification curve presented on Figure 3a or Figure 3b belongs to pure metal or to solid solution? Justify your answer. (1 pt.)

b) Give physical reasons for appearance of two plateaus at temperature T_m and T_A and of a slope between temperatures T_L and T_S. (3 pt.)

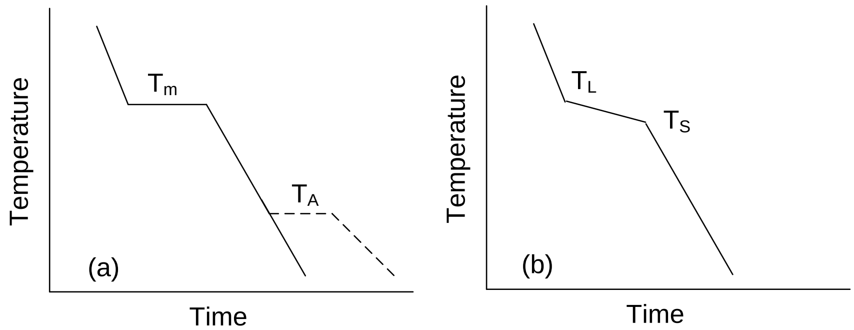


Figure 3 Temperature-time curves for solid solution and pore metal solidification

Problem 8 (3 points)

Using Taylor equation for tool life and letting n=0.5 (ceramic tool) and C=1000 ft/min, calculate the percentage increase in tool life if the cutting speed is reduced by 50%. Recalculate the effect of this speed decrease for WC cutting tool (n=0.3).

Problem 9 (3 points)

Using the diagram for fine copper powder sintering (Figure 4), explain why the higher the sintered density, the greater the product’s mechanical and electrical properties?

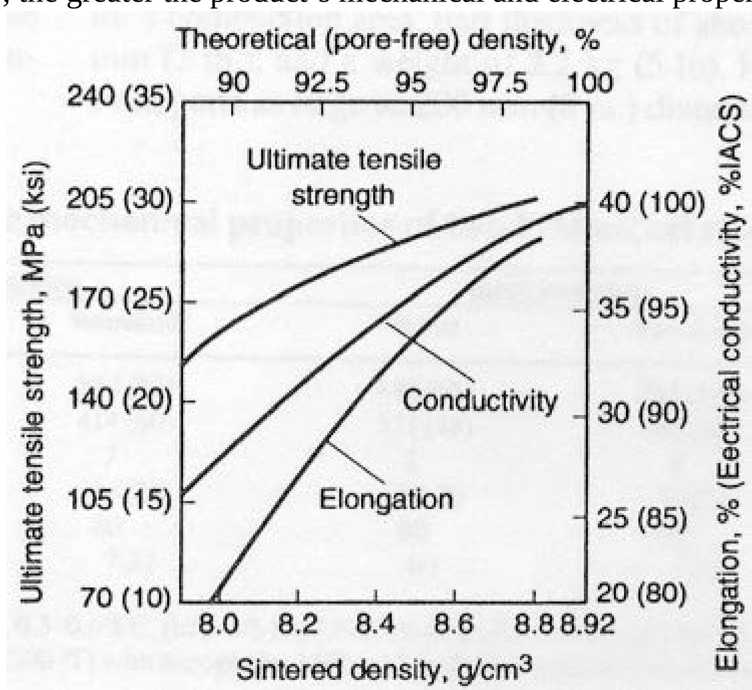


Figure 4 Properties of the powder metallurgy cupper product as a function of sintered density

Problem 10 (3 points)

In Figure 5, Sendzimir rolling mill is presented schematically and on photo. Explain why we need so many cylinders (up to 20) to produce thin metal products.

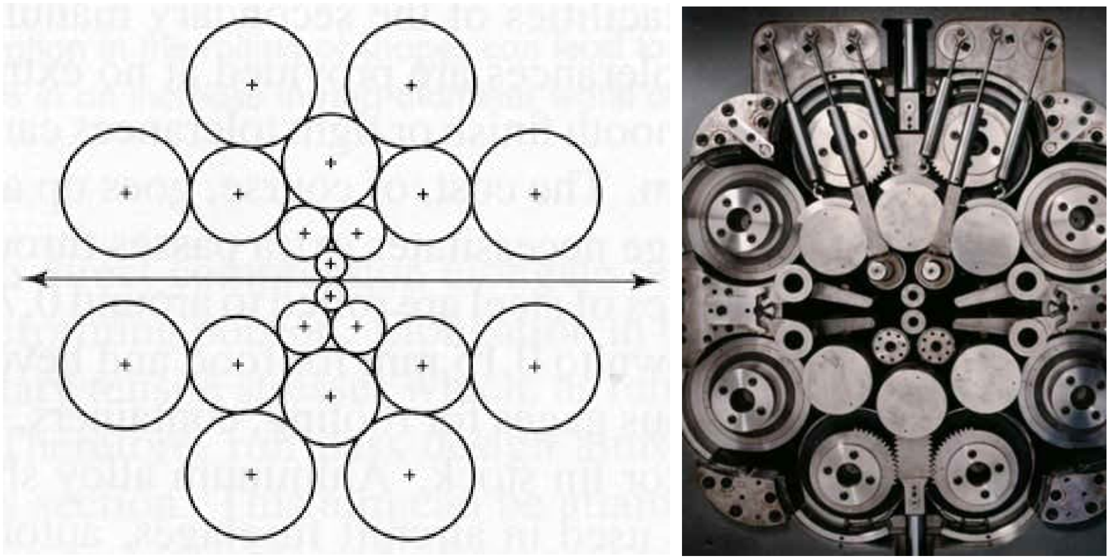


Figure 5 Sendzimir rolling mill: (a) schematic representation and (b) photography

Problem 11 (3 points)

Respond to three following questions on polymers:

1. Using the diagram representing Young modulus and specific volume (enthalpy) as a function of temperature (enclosed), indicate which curve belongs to the amorphous and which to the crystalline polymer, and justify your selection. (1 pt.)
2. The same piece can be produced by injection of a thermoplastic or thermosetting polymer. For these two cases, should one cool or heat the mould to fix the shape of the piece? Justify. (1pt)
3. Many oils are paraffins and are formed of the same monomers as polyethylene. Explain why, at room temperature, polyethylenes are solid, while oils are liquid? (1 pt.)

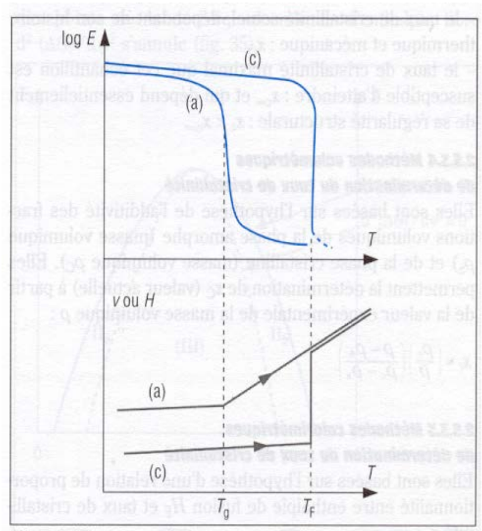


Fig. 28. Allure des variations de module d'élasticité (en haut) et de volume spécifique v ou d'enthalpie (H) (en bas) pour un polymère amorphe (a) et pour un polymère cristallin (c).

Problem 12 (4 points)

Optical grid analysis is used to determine critical points on the stretched piece. Square grid of 4 mm diameter circles is etched on the sheet surface. After stretching, two measurements of deformed circles are made in two distinctive zones of the stretched piece: (4.2 mm by 5.6 mm) and (5.6 mm by 6.0 mm). Considering the *Forming Limit Diagram* (FLD) of sheet steel shown in Figure 6, determine which case is more critical in terms of localized necking.

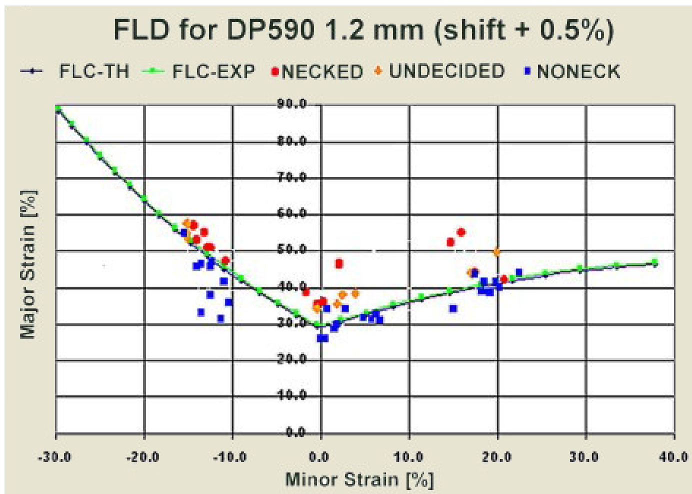


Figure 6 FLD of the high strength DP5901.2 sheet steel

Problem 13 (2 points)

On Figure X, temperature-time diagram is plotted for three welding technologies: electron beam welding (welding energy 0.57 kJ/cm), arc welding (1.76 kJ/cm) and TIG welding (0.73 kJ/cm).

1. Identify which diagram corresponds to each technology (1pt).
2. What welding technology results in the smallest heat affected zone (HAZ)? (1 pt).

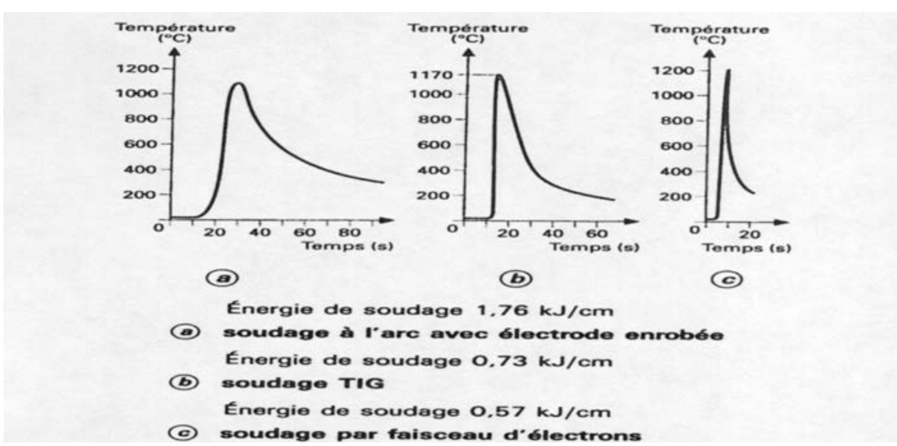


Figure 7 Temperature-time diagrams for electron beam welding, arc and TIG welding (order is arbitrary)

Problem 14 (3 points)

Residual stresses and distortion appear in the frame of Figure 8 after welding. Explain physical reasons of these phenomena.

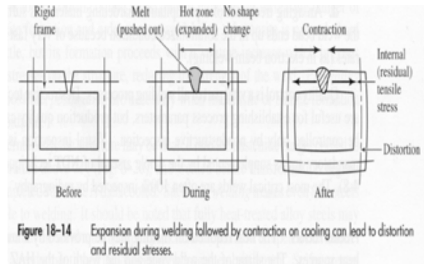
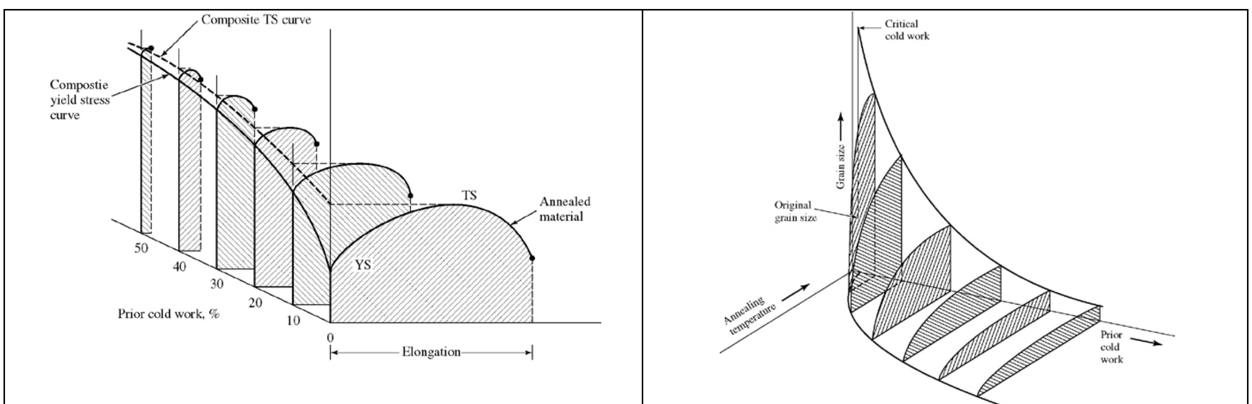


Figure 8 Welded frame

Problème 15 (3 points – one per question)

Use critical judgment to three following sentences by respond by “True” or “False”**.** Refer to the diagrams of Figure 9 for support.

Questions	Answer
1. The greater the cold work, the more resistant and ductile the material	
2. The greater the cold work, the higher the recrystallization temperature.	
3. The greater the cold work and the lower the recrystallization temperature, the smaller the grain size.	



(a)	(b)

Figure 9 (a) Schematic stress-strain diagrams as a function of the cold work intensity; (b) Grain size as a function of the cold work intensity and annealing temperature.