GX640

OLLSCOIL NA hÉIREANN
The National University of Ireland

National University of Ireland, Galway

Michaelmas Examinations, 2000/01

Third Year Mechanical and Biomedical Engineering Examination

MECHANICAL ANALYSIS & DESIGN

Professor J.J. O'Connor
Professor J.F. McNamara
Dr. P. Molloy

Attempt *Five* Questions
Time Allowed: 3 Hrs.
Graph Paper is available and a set of Useful Formulae is provided.

1(a) Derive equations for the principal stresses and maximum shearing stresses on plane AB as shown in Figure 1(a). ***(10)***

(b) Sketch a Mohr circle for the stress state shown in Figure 1(b) and find the principal stresses, the maximum shear stress and the angular orientation of the planes upon which these stresses act. ***(10)***

σ_x = 8 MPa compressive
σ_y = 12 MPa tensile
τ_{xy} = 3 MPa (cw)
τ_{yx} = 3 MPa (ccw)

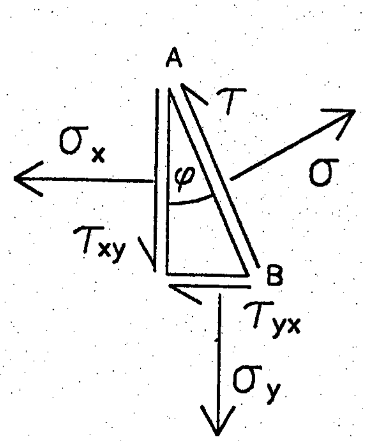

Figure 1(a)

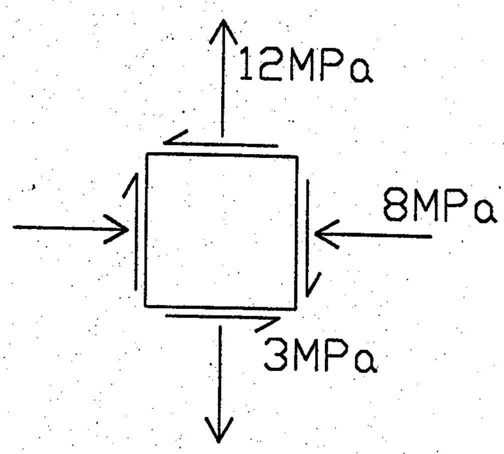

Figure 1(b)

2. The torsion bar spring below is to be loaded statically by forces **F** = 40N and by a torque **T** which varies from O to 10N. The material has a yield strength of 800 MPa, an ultimate strength of 1200MPA and the unmodified endurance limit Se^1 may be taken as 600MPa. The 2.5m long body of the spring has a hot-rolled surface finish. The geometric stress concentration factors at the shoulders are 1.68 for bending and 1.42 for torsion. Determine a suitable diameter D of the nearest millimetre using a factor of safety of 2.5

(20)

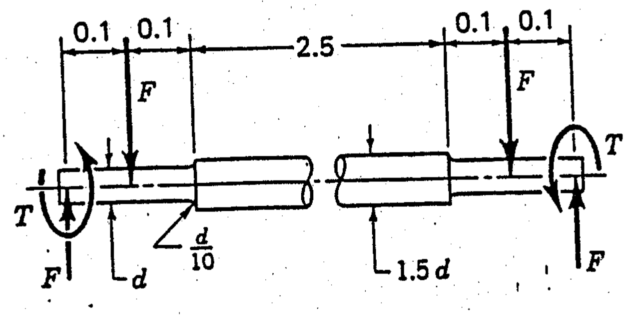

FIGURE 2

3. Figure 3 shows a hydraulic cylinder in which D = 100mm, t = 10mm, L =300mm and w = 20mm. Both end brackets as well as the cylinder are made of steel. The cylinder has been designed for a working pressure of 4MPa. Five M12 x 1.75 metric grade 5.8 bolts are used, tightened to 75 per cent of the proof load

(a) Find the stiffness of the bolts and members assuming that the entire cylinder is compressed uniformly and that the end brackets are perfectly rigid.

(4)

(b) Find the mean and alternating stresses in the bolts.

(4)

(c) Find the endurance limits of the bolts based on 50% reliability

(4)

(d) What factor of safety gurads against:

(i) static failure *(4)*

(ii) fatigue failure *(4)*

Assume Young's modulus for the bolt and cylinder steel is 207GPa.

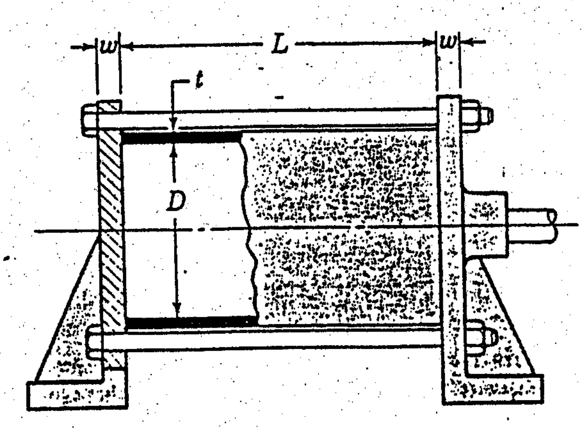

FIGURE 3

4. An unpeened extension spring is made of 0.60 mm music wire and has an outside diameter of 4.8 mm. The spring is wound with a pretension of 1.10 N and the load fluctuates between this value and 6.8 N.

   Since the spring might fail statically or in fatigue, find the factor of safety for both types of failure.

5. A centrifugal pump is driven through a speed reducing gearset. The 20 tooth hobbed pinion with 20° full depth teeth rotates at 1450 rpm and meshes with a 50 tooth hobbed gear. Both gears are manufactured from steel with a Brinell hardness of 200 and an ultimate tensile strength of 600 MPa. The gears have a face width of 50 mm and module of 8 mm.

   Determine the maximum power that can be safely transmitted, based on both bending and contact strengths i.e. fatigue and wear.

   Use a factor of safety n = 2.5, a reliability of 95%, and an elastic coefficient, C_p, of 190×10^3 N/m. Also, assume direction of gear rotation as one-way only.

6. An internal expanding-rim-type brake is shown in Figure 6. The drum diameter is 250 mm, R is 100 mm and the shoe face width is 50 mm. The material used has a coefficient of friction of .24 and permits a maximum pressure of 1.2 MPa.

   i) Calculate the actuating force. *(8)*
   ii) Calculate the braking capacity. *(6)*
   iii) Calculate the hinge pin reactions. *(6)*

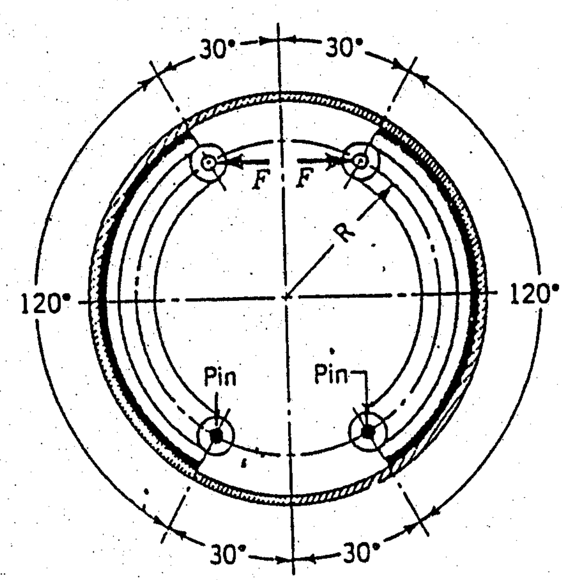

FIGURE 6

7(a) Discuss the difference between boundary lubrication and hydrodynamic lubrication in terms of stability

(5)

(b) Sketch a general assembly layout of a single impression mould for a plastic container which is spruegated and uses stripper plate ejection. Show cooling arrangements for the cavity and core. Name all mould parts.

(10)

(c) Explain, using an example, the function of the Gannt chart in project management.

(5)

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METALS and METAL PROCESSING

Professor J.J. O'Connor
Professor J.F. McNamara
Dr. M. Bruzzi

Attempt Three Questions
Time Allowed: 2 hours

1 (a) For a Face Centre Cubic (FCC) crystal structure, sketch and identify in terms of the Miller indices, one of the most closely packed planes in the unit cell.
What is the total number of slip systems in such a crystal structure?
What is the relevance of the most closely packed planes? Explain.

(3)

(b) Discuss the large difference between the theoretical strength based on the atomic bond strength and the experimentally measured critical resolved shear stress in a single crystal.

(2)

(c) Discuss crystal imperfections under the following headings:
- Point Defects
- Line Defects
- Planar Defects

(6)

(d) Calculate the Burgers vector **b** for (i) α-Fe
(ii) Al
where the atomic radius of α-Fe = 0.124nm and that of Al = 0.143nm.

(4)

(e) Sketch a resolved shear stress – shear strain curve for a single crystal of a metal and explain it in the context of dislocation motion.
Sketch a typical stress-strain curve for a polycrystal and explain why its shape differs from that of the single crystal.

(4)

(f) Discuss the effects and stages of annealing a polycrystalline metal component following cold working.

(6)

2 (a) Define and comment on the following terms used in alloying:

- Solid Solution
- Intermediate Compound
- Intermetallic

(3)

(b) Discuss Interstitial and Substitutional solid solutions in terms of solubility and diffusion.

(4)

(c) For the case of Carbon interstitially dissolved in BBC α-Fe, how much oversize is the Carbon atom. Atom Radius of α-Fe = 0.124nm. Atomic Radius of C = 0.077nm. Comment on the solubility of Carbon in α-Fe.

(5)

(d) Discuss, with the aid of sketches, coring of a Cu / Ni alloy. How is the coring removed?

(8)

(e) For a steel alloy, a carburizing heat treatment of 15h duration will raise the carbon concentration to 0.35 wt% at a point 2.0mm from the surface. Estimate the time necessary to achieve the same concentration at a 6.0mm position for an identical steel and at the same carburizing temperature.

(5)

3 (a) Discuss the restrictions in using a phase equilibrium diagram for representing the state of an alloy.

(3)

(b) Explain the terms in the modified version of Gibb's Phase Rule for a metallic alloy. Why was it modified? Discuss its use in explaining a Eutectic point of a Binary alloy.

(3)

(c) Figure 3 shows a phase equilibirium diagram for Magnesium / Tin alloys. Briefly discuss the Mg_2Sn phase in terms of:

- Material type and composition in wt%
- Representation on phase diagram
- Melting temperature

(4)

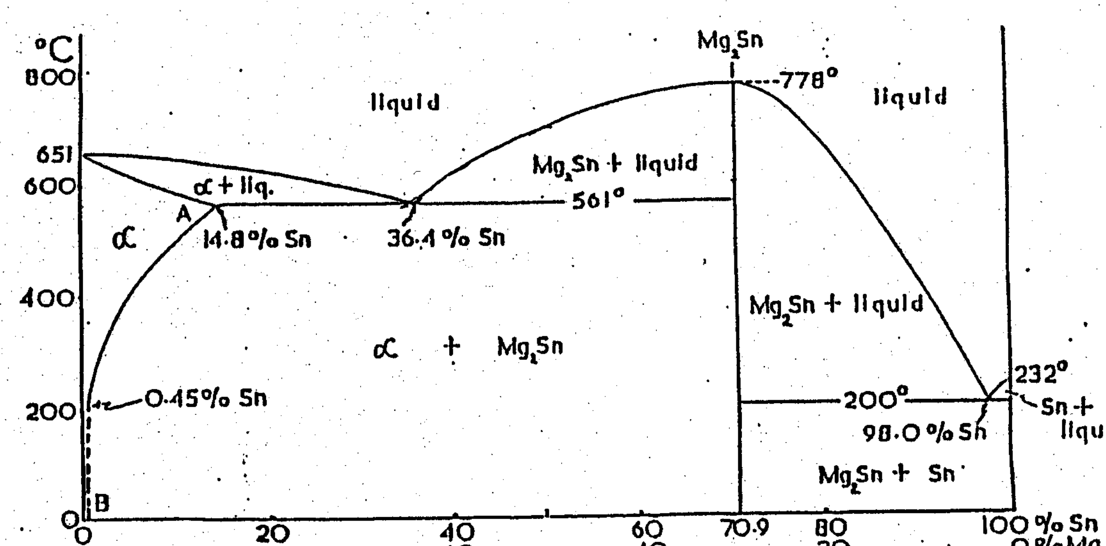

Figure 3: Phase Equilibrium Diagram for Magnesium / Tin

(d) Specify temperature - composition points at which all eutectic phase transformations occur. Discuss the formation of a Eutectic structure.

(5)

(e) Describe the slow cooling from liquid to room temperature of an alloy with 50 wt% Mg, 50wt% Sn. Sketch the equilibrium microstructures at a number of stages during the cooling process.
Estimate the compositions and relative amounts in weight percentages of the various phases at 400°C.

(10)

4(a) Discuss the microstructure of Pearlite and comment on its material properties.

(2)

(b) Discuss the following heat treatments in terms of heating, cooling and their effect on the microstructure of plain carbon steels:

- Process anneal
- Spherodizing anneal
- Normalising
- Full anneal

Sketch the temperature-composition regions of each on a phase equilibrium diagram.

(8)

(c) Draw and clearly label a Time Temperature Transformation (TTT) diagram for a 0.8wt% Carbon steel.
Draw continuous cooling curves for the transformation of Austenite to:

- Pearlite
- Martensite
- Bainite + Martensite

Comment on their microstructure and associated mechanical behaviour.

(6)

(d) Sketch on a TTT diagram the mass effect associated with the continuous cooling of components with different thicknesses.
Discuss the problems and appropriate solutions of quenching a large component to produce uniform Martensite.

(4)

(e) How may the material properties of Martensite be made less brittle? Discuss.

(2)

(f) Discuss the isothermal treatments of Martempering and Austempering.
Indicate these processes on a TTT diagram.

(3)