National Exams Dec 2015

07-Mec-B8 Engineering Materials

3 Hours Duration

NOTES:

1. If doubts exist as to the interpretation of any question, the candidate is urged to submit with the answer paper, a clear statement of any assumptions made.

2. Any non-communicating calculator is permitted. This is an open book exam.

3. Any **five** of the **eight** problems given constitute a complete paper.

4. All problems are of equal value.

1- A composite made of a plastic reinforced with synthetic fibers is being used as a structural material. The modulus of elasticity of the synthetic fibers is 170 GPa and for the plastic material is 8 GPa. If the plastic constitutes 60% per volume of the composite, calculate:

a- the modulus of elasticity of the composite,
b- the percentage of stress carried by the synthetic fibers, and
c- assuming that the composite has a cross-sectional area of 150 mm^2 and is subjected to a longitudinal load of 15,000 N, calculate the resulting strain.

2- A barium-borate glass system ($BaO.4B_2O_3$) is converted into a glass-ceramic by remelting the glass and the addition of TiO_2 as a nucleating agent to the remelted batch. Referring to the periodic table of elements to obtain the molecular weights of each component element, calculate the composition of the new glass-ceramic in weight percent, if 11 mole% TiO2 is used for this conversion.

3- Floor beams of a transport airplane have been designed using an aluminum alloy containing 2.5 wt% Cu, 2.5 wt% Mg, 0.4 wt% Mn and 5 wt% Zn for a total weight of 7500 kg. A customer has ordered the airplane but requested that its total weight be reduced by 800 kg for fuel saving purposes. An engineer in the design and analysis department has suggested that at least 50% of that weight saving objective can be accomplished by replacing the aluminum alloy of the floor beams with an aluminum-lithium one containing 4.5 wt% Li and 1.25 wt % Cu. Is this possible? Answer the question by estimating the weight savings that will take place using the Al-Li alloy. Assume weighted averages of density and use the following densities for the mentioned materials:

Al = 2.70 g/cm^3 Cu = 8.92 g/cm^3 Mg = 1.74 g/cm^3 Zn = 7.14 g/cm^3 Mn = 7.47 g/cm^3
Li = 0.53 g/cm^3

4- Consider a homogeneous bar of length L and a rectangular cross section of width b and thickness t. When the bar is stretched by a small amount ΔL the cross sectional dimensions are reduced by the amounts Δb and Δt. If this corresponds to a case of perfect plasticity where the volume of the bar is the same before and after deformation, what is the Poisson's ratio for this material?

5- Describe the heat treatment scheme that would provide the following property changes to 1080 steel: (refer your treatments to the appropriate time-temperature-transformation curve)

a- Pearlite to bainite
b- Austenite to Martensite
c- Martensite to fine pearlite
d- Pearlite to martensite
e- 100% pearlite to a mixture of 50% pearlite and 50% martensite
f- Mixture of 75% pearlite and 25% martensite to 100% tempered martensite.

6- A ductile metal wire of uniform cross-section is loaded in tension until it just begins to neck. The curve of true stress σ vs. true strain ε for this wire approximates to:

$$\sigma = 470\ \varepsilon^{0.42}\ \text{MPa}$$

a- Assuming that the volume is conserved, derive a differential equation relating the true stress to the true strain at the point of necking.

b- Estimate the ultimate tensile strength of the metal and the work required to take 0.5 m^3 of the wire to necking.

7- The following data points have been obtained from a series of material strain cycling tests:

Range of plastic strain $\Delta\varepsilon$	Number of cycles to failure N
0.0450	80
0.0220	400
0.0150	1100
0.0080	6000

a) Represent these results by an equation of the type: $\Delta\varepsilon = CN^{\alpha}$ where C and α are material constants.

b) A component made from this material is subjected to a range of plastic strain of 0.025 for the first 50 cycles and then to a range of plastic strain of 0.01 for the next 800 cycles. What is the allowable plastic strain range that the component can be subjected to in order for it to survive an additional 8000 cycles prior to fatigue failure? Assume the material obeys Miner's cumulative damage law.

8- Discuss the following two applications where corrosion is an issue:

a- A brass faucet is connected to an iron pipe. Discuss this coupling from a corrosion viewpoint and explain which metal is likely to corrode and why?

b- Steel screws used as fasteners on aluminum siding experienced severe corrosion. Would you have expected this, why or why not? Explain why this might have occurred.