National Exams May 2013

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 (5) questions constitute a complete exam paper. If more than five questions are attempted, only the first five as they appear in the answer book will be marked..

4. All problems are of equal value.

1- A new aircraft program has been launched to build a new generation 100-150 passengers jet aiming to substantially exceed the range of its closest competitor for the same cabin capacity while hoping to maintain a strong hold on the market in terms of environmental friendliness and innovative use of aircraft structural materials.

Conceptual and preliminary design stages having already been completed, choice of materials for the aircraft body (semi monocoque structures) is down to three candidates: an advanced carbon fiber-reinforced polymeric composite, an aircraft grade aluminum alloy or a new generation of lightweight advanced metallic alloys recently introduced to the market. Select your own set of five different selection criteria that you think would be of most relevance to this particular application and evaluate each of the three families of materials in terms of those criteria. In the end, what choice of materials would you recommend?

2- 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- 100% pearlite to a mixture of 50% pearlite and 50% martensite
b- Mixture of 75% pearlite and 25% martensite to 100% tempered martensite
c- Pearlite to bainite
d- Martensite to fine pearlite
e- Pearlite to martensite

3- A box is to be placed on a bracket attached to the engine in an automobile. Two polymeric materials have been short-listed as primary candidates for this application, namely ABS and phenolic.

a- Compare the two materials in terms of strength, impact resistance, manufacturing methods, chemical resistance, heat resistance and cost.
b- What material would you select and why?

4- 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.

5- 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 12 mole% TiO2 is used for this conversion.

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:

$$\sigma = 340\ \varepsilon^{0.45}\ \text{MPa}$$

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 1 m^3 of the wire to necking.

7- A composite made of hardened PVC plastic reinforced with E-glass fibers is being used as a structural material. Assume the modulus of elasticity of E-glass is 73 GPa and for PVC is 2.5 GPa. If the PVC constitutes 65% per volume of the composite, calculate:

a- the modulus of elasticity of the composite,
b- the percentage of stress carried by the glass fibers, and
c- assuming that the composite has a cross-sectional area of 300 mm^2 and is subjected to a longitudinal load of 50,000 N, calculate the corresponding strain.

8- Floor beams of a transport airplane have been designed using an aluminum alloy containing 5 wt% Cu and 1.5 wt% Mg for a total weight of 9800 kg. A customer has ordered the airplane but requested that its total weight be reduced by 2000 kg for fuel saving purposes. An engineer in the design and analysis department has suggested that about 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 wt% Li and 1 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 Li = 0.53 g/cm^3