National Exams May 2014

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- The casing of a jet engine's inlet air fan is proposed to be manufactured from two distinct materials, a high strength aluminum alloy and an advanced triaxially braided fiber-reinforced polymer capable of resisting temperatures up to 250 degrees C.

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

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- 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 8000 kg. A customer has ordered the airplane but requested that its total weight be reduced by 15 percent for fuel saving purposes. An engineer in the design and analysis department has suggested that more than 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

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- Advanced Composite Materials (ACM) are now commonly used in aircraft structures for both primary and secondary load bearing applications.
   a- List three different types of ACM that are now commonly used for primary load bearing aircraft structural applications and discuss the main reasons why they have become attractive replacement to other more conventional materials.
   b- Present the main manufacturing methods adopted in making these ACM for the aforementioned applications and discuss the advantages and disadvantages of each method in relationship to such considerations as mechanical properties, geometrical aspects, processing speeds, cost, size, etc.

6- A barium-borate glass system ($BaO.4B_2O_3$) is converted into a glass-ceramic by re-melting the glass and the addition of TiO_2 as a nucleating agent to the re-melted 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.

7- A 0.75 kg magnesium sacrificial anode in a hot water heater is used up in 10 years.

a- What is the anode reaction?
b- What is the average corrosion current supplied by the anode?
Use an electromechanical valence of 2 and an atomic mass of 24.3 amu for Mg.

8- A composite laminate is made from layers of unidirectional carbon fibre reinforced laminae oriented at 0 deg. from the x load direction. The longitudinal modulus of the laminate is 190 GPa, the transverse modulus is 15 GPa, the shear modulus is 10 GPa, and the longitudinal to transverse Poisson ratio is 0.3. If the laminate is subjected to strains $\varepsilon_x = 300 \times 10^{-6}$, $\varepsilon_y = 100 \times 10^{-6}$ and $\gamma_{xy} = 75 \times 10^{-6}$

a- Determine the resulting normal and shear stresses.
b- Answer the question in a) if the fibers were oriented at +45 degrees.