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Question Paper Code : 40530

B.E./B.Tech. DEGREE EXAMINATION, APRIL/MAY 2018
Sixth Semester
Aeronautical Engineering
AE 6603 – COMPOSITE MATERIALS AND STRUCTURES
(Regulations 2013)

Time : Three Hours | Maximum : 100 Marks

Answer ALL questions

PART – A (10×2=20 Marks)

1. Define specific modulus and specific strength of a composite material.
2. Express the density ρ_c of a composite material in terms of constituent material densities and volume fractions.
3. Mention a few drawbacks and limitations on the use of composite materials.
4. What is the number of independent elastic constants required to characterize the following class of materials: orthotropic, transversely isotropic, isotropic.
5. A 0.010 in. thick laminate is subjected to in-plane loads. The mid-plane strains and curvatures are given as follows: $\epsilon_x^0 = 2751\ \mu$ in/in, $\epsilon_y^0 = -1331\ \mu$ in/in, $\gamma_{xy}^0 = -1125\ \mu$ in/in, curvatures $K_x = 1.965$ in/in, $K_y = 0.2385$ in/in, $K_{xy} = -1.773$ in/in. Determine the strains ϵ_x, ϵ_y and γ_{xy} at the laminate top surface.
6. Define quasi-isotropic laminate.
7. List the factors which govern the selection of a fabrication process for a composite part.
8. Summarize the production of glass fibers and name the raw materials used.
9. Consider two facesheets each of thickness t/2 separated by honeycomb core of height h. Approximately how many times will the transverse stiffness, strength and panel weight increase if the core height h is increased 3 times, facesheet thickness being the same ?
10. What are the core parameters in sandwich type construction which control structural efficiency ?

PART – B (5×13=65 Marks)

11. a) i) Derive and obtain an expression for the transverse modulus of a unidirectional composite lamina using the mechanics of materials approach. State the assumption used. (5)

ii) Dimensions of a graphite-epoxy composite test specimen weighing 2.98 g are 2.54 cm ×2.54 cm × 0.3 cm. After resin-digestion in an acid solution, the remaining fibers weigh 1.863 g. From independent tests, densities of graphite and epoxy are 1.9 g/cm^3 and 1.2 g/cm^3 respectively. Some of the mechanical properties of constituent materials graphite and epoxy are as follows : E_{f1} = 220 GPa, E_{f2} = 13.79 GPa, E_m = 3.45 GPa. Determine the volume fractions of the constituent materials, and the longitudinal and transverse moduli of the given composite. Are the elastic constants E_1, G_{12} and v_{12} of a unidirectional composite lamina fiber dominated or matrix dominated ? (8)

(OR)

b) i) Classify composite materials according to reinforcement type and write short notes in each category. (5)

ii) Compare the mechanical properties of glass fibers, carbon fibers and epoxy resin with conventional metals. Write down the density of each material. (8)

12. a) i) Find the compliance matrix [S] for a graphite/epoxy lamina whose material properties are given as E_1 = 181 GPa, E_2 = 10.3 GPa, E_3 = 10.3 GPa, v_{12} = 0.28, v_{23} = 0 60, v_{13} = 0.27 and G_{12} = 7.17 GPa, G_{23} = 3.0 GPa, G_{31} = 7.0 GPa. How can the stiffness matrix for the same lamina be determined ? (5)

ii) A unidirectional lamina with continuous fibers at $\theta = 60°$ to the x-axis has the following properties : E_1 = 14 GPa, E_2 = 3.5 GPa, v_{12} = 0.4 and G_{12} = 4.2 GPa. The lamina is subject to the following stresses : $\sigma_x = -3.5$ MPa, σ_y = 7.0 MPa and $T_{xy} = -1.4$ GPa. Compute the stresses and strains with respect to the principal material directions. (8)

(OR)

b) i) A filament wound cylindrical pressure vessel of mean diameter 1 m and wall thickness 2 cm is subject to internal pressure P. Filament winding angle = 53.1° to the cylinder longitudinal axis. If the normal strain in the fibre direction = 0.001, determine the internal pressure P. The cylinder is made of composite material with the following properties :

E_1 = 40 GPa, E_2= 10 GPa, v_{12} = 0.25, and G_{12} = 3.5 GPa. (8)

ii) Differentiate between the study of micromechanics and macromechanics of a unidirectional composite lamina. What are the different methods (either micromechanics or macromechanics) using which the elastic constants of a unidirectional lamina can be determined ? (5)

13. a) i) What are the objectives and assumptions of the classical lamination theory ? (5)

ii) Consider a 3-layer symmetric laminate with middle layer thickness 6 mm while top and bottom layers have 3 mm thickness. Fibers are at 0° for the middle layer and 45° for the top and bottom layers. The laminate is subject to the following in-plane loads : $N_x = 1000$ N/mm, $N_y = 200$ N/mm, while $N_{xy} = 0$. Determine the strains in each layer. The stiffness matrix for each laminate ply is as follows :

$$[Q]_0^\circ = \begin{bmatrix} 20 & 0.7 & 0 \\ 0.7 & 2.0 & 0 \\ 0 & 0 & 0.7 \end{bmatrix} \text{GPa}$$

While $[Q]_{45}^\circ = \begin{bmatrix} 6.55 & 5.15 & 4.50 \\ 5.15 & 6.55 & 4.50 \\ 4.50 & 4.50 & 5.15 \end{bmatrix} \text{GPa}$. (8)

(OR)

b) i) Discuss the various factors which contribute to the mechanical performance of a composite laminate. (5)

ii) Consider a 2-layer laminate with 3 mm thick top layer with fibers at 45° and 5 mm thick bottom layer with fibers at 0°. The stiffness matrix for the layers are given in Question 13. (a) (ii). Determine the [A] and [Dl matrices for the given laminate. (8)

14. a) i) Explain the steps involved in laminate stress analysis with a neat flowchart. List the inputs. (8)

ii) Compare the advantages and state the application of the following fabrication methods – resin transfer moulding, autoclave molding. (5)

(OR)

b) Describe the following fabrication processes : (i) Hand lay-up method, and (ii) Vacuum bagging technique. What are the equipment and tools required for each ?

15. a) Explain the production of graphite fibers from PAN precursor. Are carbon and graphite the same ? Discuss the advantages and characteristics of graphite fibers.

(OR)

b) With neat sketches, show the following failure modes in sandwich panels and explain when each failure mode is likely to occur : skin compression failure, panel buckling, shear crimping, skin wrinkling, intra-cell buckling, local failure due to applied compressive load on sandwich panel surface.

PART – C (1×15=15 Marks)

16. a) An orthotropic lamina has the following properties : Longitudinal modulus = 138 GPa, transverse modulus = 9 GPa, shear modulus G_{12} = 6.9 GPa, major Poisson ratio v_{12} = 0.3. Fiber orientation angle θ = 30°. How much of uniaxial compressive stress σ_x can the lamina withstand (i) to avoid transverse failure using the maximum strain failure criterion, and (ii) using the maximum work failure criterion? Longitudinal tensile and compressive strengths are 1448 MPa and 1172 MPa respectively while transverse tensile and compressive strengths are 48.3 MPa and 248 MPa respectively. Lamina shear strength = 62.1 MPa.

(OR)

(b) How are the strain-stress relations for a generally orthotropic lamina written in terms of cross-coefficients m_x and m_y ? Derive an expression for the cross-coefficient m_y and sketch its variation with fiber orientation angle θ.
