Total No. of Questions : 12]

SEAT No. :

P1204

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[4659]-318

B.E. (Polymer)

b-MECHANICS OF COMPOSITES

(Semester-I) (409364)(2008 Course)(Elective-I)

Time : 3 Hours] *[Max. Marks : 100*

Instructions to the candidates:

1) *Answers to the two sections should be written in separate answer books.*
2) *Neat diagrams must be drawn, wherever necessary.*
3) *Figures to the right side indicate full marks.*
4) *Use of calculator is allowed.*
5) *Assume suitable data if necessary.*

SECTION-I

Q1) a) Explain the term coefficient of mutual influence. Prove that apparent engineering constant $\eta_{xy,y}$ for an orthotropic lamina stressed in non-principal material direction in terms of engineering constants in given by- **[7]**

$$\eta_{xy,y} = E_y\left[\left[\frac{2}{E_1}+\frac{2v_{12}}{E_1}-\frac{1}{G_{12}}\right]\sin^3\theta\cos\theta-\left[\frac{2}{E_2}+\frac{2v_{12}}{E_1}-\frac{1}{G_{12}}\right]\sin\theta\cos^3\theta\right]$$

b) An unidirectional lamina oriented at 45° has following properties: **[7]**

$E_1 = 135\text{GPa},\ E_2 = 7\text{GPa},\ G_{12} = 5\text{GPa}, v_{12} = 0.28.$

If a stress of 9 MPa is applied in the x-direction and 6 MPa in the y-direction, Determine the strains in local directions and global directions.

c) Write down the stiffness matrix and compliance matrix in terms of engineering constants for an orthotropic lamina for plane stress condition. **[4]**

OR

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Q2) a) Prove the condition of symmetry for stiffness matrix for orthotropic material $C_{ij} = C_{ji}$. **[5]**

b) A unidirectional lamina has fibers at +45° to the coordinate axis. The lamina properties in the principal material directions are given below. Determine the invariants of the lamina. **[9]**

$E_1 = 120GPa,\ E_2 = 10GPa,\ G_{12} = 5GPa,\ \nu_{12} = 0.28$

c) Write stiffness matrix and compliance matrix in terms of engineering constants for anisotropic (21 constants) and isotropic lamina (2 constants). **[4]**

Q3) a) A lamina has following engineering properties: **[8]**

$E_{11} = 207GPa$,

$E_{22} = 19GPa$,

$\nu_{12} = 0.21$,

$G_{12} = 6.4GPa$

Failure strengths are:

Tensile Failure strength in direction 1=1500MPa

Tensile Failure strength in direction 2=50MPa

Compressive failure strength in direction 1=500MPa

Compressive Failure strength in direction 2=400MPa

Shear failure strength =5GPa

Fibers are oriented at 45 degrees and following loads in non-principal directions are applied

$\sigma_x = 5MPa$

$\sigma_y = 2MPa$

$\tau_{xy} = -2MPa$

Check failure by any two failure criteria.

b) Determine the coefficients of thermal expansion α_1 and α_2 of a uniaxial lamina with. **[8]**

E_{fiber}=80GPa, E_{matrix}=5GPa, $\nu_{Fiber} = 0.25, \nu_{matrix} = 0.38,$

α_{fiber} =5×10^{-6}/^{o}C, α_{matrix} =85×10^{-6}/^{o}C

Volume fraction of fiber = 0.5.

OR

Q4) a) Show that uniaxial off-axis Tsai-Hill criteria reduces to **[8]**

$$\frac{Cos^4\theta}{X^2} + \left[\frac{1}{S^2} - \frac{1}{X^2}\right] Cos^2\theta\, Sin^2\theta + \frac{Sin^4\theta}{Y^2} = \frac{1}{6X^2}$$ where X and Y are tensile or compressive strengths in direction 1or 2 and s is shear strength in 1-2 plane.

b) Write a detailed note on Tsai-Wu failure criteria. Explain the significance of the fourth order tensor used. **[8]**

Q5) a) Write in short about significance of parameters ξ and η in Halpin -Tsai equations which are dependent on the fiber geometry and fiber packing geometry. Show also that Halpin-Tsai equations reduce to upper bound and lower bound of the composite modulus in extreme situations. **[9]**

b) For a lamina following things are know- **[7]**

$E_1 = 2E_2 and\ G_{12} = E_2\ \nu_{12} = 0.3$

Find $\nu_{xy} at\ 45^o$

OR

Q6) a) Following data about a lamina with 50% fibers is known- $E_{fibers} = 20GPa$, $E_m = 2GPa$, $\nu_m = 0.2$ Estimate composite modulus E_2 by Mechanics of Materials approach and by Halpin-Tsai equations assuming factor $\xi = 1$ **[7]**

b) Derive an equation for prediction of E_1, modulus in fiber direction, using mechanics of materials approach. **[9]**

SECTION-II

Q7) a) A single layer Specially Orthotropic laminate having 1 mm thickness has following engineering constants **[6]**

$E_{11} = 207GPa$
$E_{12} = 19GPa$
$\nu_{12} = 0.21$
$G_{12} = 6.4GPa$

Calculate [A], [B] and [D] matrix for the laminate

b) Write in short about laminate design procedure with a neat flow chart for the design procedure. **[5]**

c) Give example of symmetric laminate with multiple specially orthotropic layers and write force and moment relationship for the same. Explain also regular symmetric cross ply laminates and comment on elements- A_{16}, A_{26}, D_{16} *and* D_{26} **[7]**

OR

Q8) a) A quasi- isotropic laminate having configuration [-60/0/+60] with each lamina having thickness of 0.2 mm has[A], [B] and [D] matrix element as follows: **[7]**

$$[A] = \begin{bmatrix} 36.22 & 10.88 & 0 \\ 10.88 & 36.22 & 0 \\ 0 & 0 & 12.67 \end{bmatrix} \text{GPa} - mm$$

$$[B] = \begin{bmatrix} 0 & 0 & -1.22 \\ 0 & 0 & -3.32 \\ -1.22 & -3.22 & 0 \end{bmatrix} \text{GPa} - mm^2$$

$$[D] = \begin{bmatrix} 0.442 & 0.447 & 0 \\ 0.447 & 1.482 & 0 \\ 0 & 0 & 0.497 \end{bmatrix} \text{GPa} - mm^3$$

Calculate midplane strains and curvatures if $N_{xx} = 100\text{KN} / meter$ is applied to the laminate.

b) Discuss the assumptions of classical lamination theory and obtain expressions for force per unit width and moment per unit width in terms of [A],[B] and [D] matrix. **[7]**

c) Calculate the elements of [A], [B] and [D] matrix for a single layer isotropic laminate having thickness "t" in terms of engineering constants. **[4]**

Q9) a) A hybrid laminated beam is to be designed having carbon-epoxy layer with each ply having 0.1mm thickness and boron-epoxy layer with each ply having 0.2 mm thickness. The arrangement of layers each having thickness t_0 in the hybrid laminate is as shown in fig below. Assume that fibers in the laminate are parallel to beam axis and this is to replace a steel beam having bending stiffness equal to 30KN-m^2. Assume width of beam to be 25.4 mm. Given that E_{carbon} =200 GPa and E_{baron} =150GPa

i) Calculate thickness of hybrid laminated beam.

ii) Calculate the number of plies in carbon layers and number of plies in boron layers.

Carbon-epoxy
Boron-Epoxy
Carbon-epoxy
Boron-Epoxy
Carbon-epoxy

[10]

b) Write basic restrictions assumptions and consequences of these restrictions and assumptions in deriving the governing equations for bending, buckling and vibrations of laminated plates. **[6]**

OR

Q10) a) A pressure vessel is to be designed having 500 mm as diameter with E-glass-epoxy laminate. The internal design pressure for the vessel is 2 bar.It is proposed to have symmetric laminate structure with $[+45/-45]_s$ configuration with each lamina 6 mm thick. Calculate the strain in the laminate Given- **[9]**

$$[A] = \begin{bmatrix} 962.6 & 806.6 & 0 \\ 806.6 & 962.6 & 0 \\ 0 & 0 & 829.6 \end{bmatrix} \times 10^6 \text{ N}/m$$

$$[D] = \begin{bmatrix} 46.2 & 38.7 & 27 \\ 38.7 & 46.2 & 27 \\ 27 & 27 & 39.8 \end{bmatrix} \times 10^3 \text{ N}/m$$

b) With neat figures, explain in details adhesive joints and bolted joints for laminated composites. Also explain failure modes in bolted joints. **[7]**

Q11) a) Explain Celanese compression test and Sandwich edgewise compression testing of composites. **[8]**

b) Explain Laser shearography and X-radiography as non destructive test methods for fiber reinforced composites. **[8]**

OR

Q12) a) Write in short about two fatigue test methods for fiber reinforced composite materials. **[6]**

b) Write in short about shear-out, bearing, net tension and cleavage failure modes in fiber reinforced composites. **[5]**

c) Explain test configuration for a two rail and three rail shear test and explain test strain gauge arrangement for determining the shear modulus. **[5]**

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