ENGINEERING TRIPOS   PART IIB

Friday 4 May 2012   2.30 to 4

Module 4C2

DESIGNING WITH COMPOSITES

Answer not more than **three** *questions.*

All questions carry the same number of marks.

The **approximate** *percentage of marks allocated to each part of a question is indicated in the right margin.*

Attachments:
4C2 datasheet (6 pages).

STATIONERY REQUIREMENTS
Single-sided script paper

SPECIAL REQUIREMENTS
Engineering Data Book
CUED approved calculator allowed

You may not start to read the questions printed on the subsequent pages of this question paper until instructed that you may do so by the Invigilator

1 (a) Give the physical basis for the wide range of Poisson's ratio as seen in a composite lamina. [15%]

(b) A [0/90/0] epoxy-glass laminate is made of two outer 0° laminae, each of thickness 2 mm, and a central 90° lamina of thickness 4 mm. Elastic constants for unidirectional material are: $E_1 = 40$ GPa, $E_2 = 8$ GPa, $G_{12} = 3$ GPa, and $\nu_{12} = 0.3$. Determine the stresses in the 0° laminae when the laminate is subjected to a stress of 50 MPa parallel to the 0° laminae. [60%]

(c) The epoxy-glass material of part (b) is now laid up as a $[0_2/90]$ laminate. Explain qualitatively the effect of this change in lay-up upon the elastic response of the plate to in-plane tension. Outline the sequence of calculations needed to predict the response. [25%]

2 Explain the following observations.

(a) Pultruded CFRP is used in some large wind turbine blades. [15%]

(b) Design of composite joints is heavily reliant on testing. [25%]

(c) Factors other than mechanical performance often play a significant role in determining that composite material is used for a given application. [25%]

(d) Commercial aerospace companies are investing significantly in 'out-of-autoclave' manufacturing technologies. [20%]

(e) Chemical treatment of fibres can significantly increase the transverse tensile strength of composites. [15%]

3 (a) What leads to splitting failure in long-fibre composites? How can this failure mechanism be avoided? [15%]

(b) What tests are used to characterise toughness associated with splitting? [10%]

(c) Figure 1 illustrates a sharp notch of length $2a$ = 10 mm parallel to the fibre direction in a unidirectional laminate made from Scotchply/1002 (elastic properties given on the datasheet). The laminate is loaded remotely by a uniform tensile stress Σ at an angle θ to the fibre direction. The toughness G_c = 10 kJ m^{-2} associated with crack initiation in the laminate is independent of mode mix. Assume that linear elastic fracture mechanics applies with stress intensity factors given by the solutions for a crack of length $2a$ in an infinite plate: $K_{\text{I}} = \sigma\sqrt{\pi a}$ and $K_{\text{II}} = \tau\sqrt{\pi a}$. Find the stress leading to crack initiation for the following cases:

(i) $\theta = 90°$;

(ii) $\theta = 0°$;

(iii) $\theta = 45°$. [60%]

(d) What are the limitations of the above analyses in part (c)? [15%]

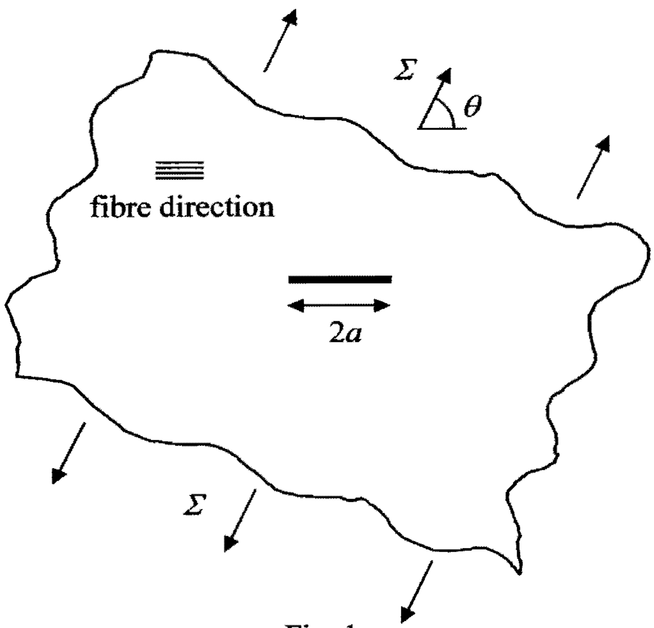

Fig. 1.

4 Figure 2 illustrates a composite tubular boom for use in a satellite application. The mass of the boom should be minimised. The boom has a fixed length $L = 10$ m and a circular cross-section, with fixed radius $R = 0.05$ m. The wall thickness t can be assumed to be small compared to R so that the second moment of area for bending of the cross section is given by $\pi t R^3$. The boom is free of gravitational loading, but is rigidly fixed to a support at one end and is subject to inertial loading due to manoeuvres of the support.

(a) The boom tip deflection δ should not exceed 50 mm due to a constant acceleration $a = 2$ ms^{-2} transverse to the boom. Use the data in Table 1 of the datasheet to identify appropriate composites for the application. Detail any assumptions you make in your analysis. [35%]

(b) It is proposed that the boom is made from a CFRP laminate made from a selection of 0°, 90° and ±45° plies, each ply of thickness 0.125 mm. In addition to the deflection constraint of part (a), the boom should not fail when the support is subject to a torsional moment $Q = 4$ kN m (but no transverse acceleration) applied at the end of the boom as illustrated in Fig. 2. Use the carpet plots of Fig. 3 and datasheet properties to identify an appropriate layup for the boom. [45%]

(c) What additional factors would you consider to finalise the design of the boom? [20%]

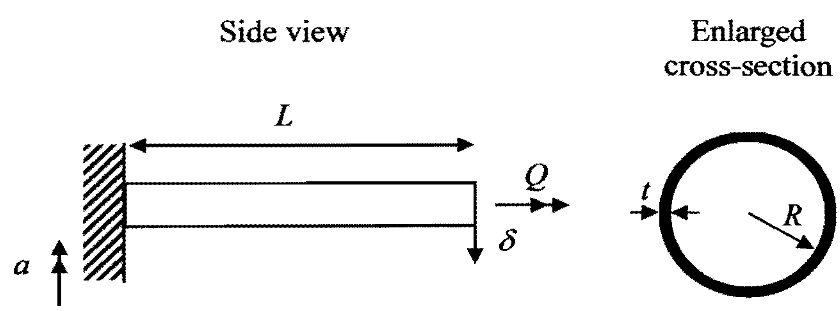

Fig. 2.

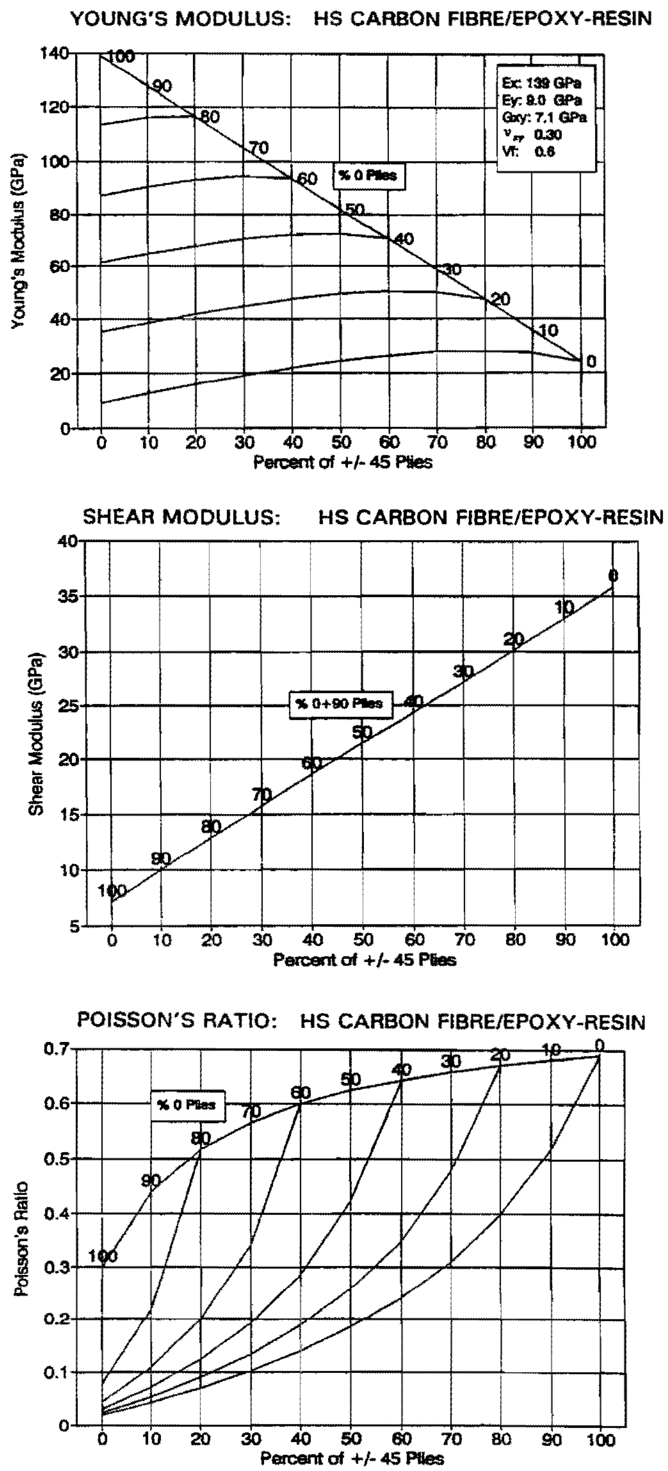

Fig. 3.

END OF PAPER

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Engineering Tripos Part IIB: Module 4C2
Designing with Composites

Numerical answers - 2011/12

1. (b) (i) 83.6, 3.37, 0 MPa

3. (b) (i) 79.2 MPa, (ii) infinite, theoretically, (iii) 131 MPa