ENGINEERING TRIPOS PART IIB
ELECTRICAL AND INFORMATION SCIENCES TRIPOS PART II

Wednesday 23 April 2003 9 to 10.30

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.*

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) Explain briefly how splitting cracks can be prevented when designing with composite materials. [10%]

(b) (i) Figure 1 illustrates a bridged crack extending through a unidirectional composite with fibre diameter d and fibre volume fraction v_f Derive the following expression for the bridging stress σ_b associated with an embedded fibre of length h:

$$\sigma_b = \frac{4h\tau_f v_f}{d}$$

where τ_f is the shear strength of the interface between fibre and matrix. [25%]

(ii) Hence derive an expression for the bridging stress as a function of crack opening displacement δ, making the assumption that all fibres initially break a distance h_0 from the crack line. Sketch the shape of this function. Hence find an expression for the toughness G_{IC} of the composite associated with the crack bridging mechanism. [20%]

(iii) Estimate the toughness associated with crack bridging for a typical unidirectional carbon fibre-epoxy composite by assuming that $h_0/d = 10$. State clearly, with justification, any other assumptions that you need to make in reaching this estimate. [15%]

(iv) By reference to the bridging model above, and making use of sketches where relevant, comment in detail on factors which influence the toughness of composites associated with crack bridging. [30%]

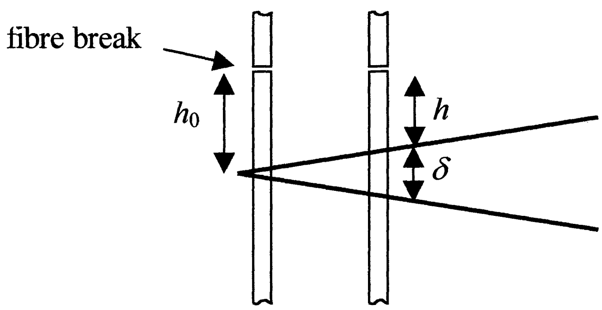

Fig. 1

2 (a) Explain briefly the principle of the conceptual, preliminary and detailed design approach for designing with engineering composites. [15%]

(b) A Scotchply/1002 glass fibre-epoxy laminate $(0_5,90_5)_s$, (material properties on the datasheet), has been chosen as a candidate material for the detailed design of a composite component. At a critical section, the laminate is subject to a biaxial stress state, with a tensile stress σ acting along the 0° fibres, and an equal and opposite compressive stress σ acting along the 90° fibres. The $[Q]$ matrix for the 0° composite may be taken as

$$Q = \begin{bmatrix} 40 & 2 & 0 \\ 2 & 8 & 0 \\ 0 & 0 & 4 \end{bmatrix} \text{GPa}$$

(i) Using the Tsai-Hill failure criterion, calculate the applied stress and corresponding strain along the 90° fibres at first ply failure. [60%]

(ii) Estimate the final failure stress of the laminate. Sketch the corresponding stress-strain response, marking any other salient points on the curve. [25%]

3 A $(0, 30)_s$ laminate has the following elastic constants for each layer of thickness 0.1mm: E_1=150 GPa, E_2=10 GPa, G_{12}=10 GPa and ν_{12}= 0.3.

(a) Determine the components of the laminate extensional matrix $[A]$ and the laminate coupling stiffness matrix $[B]$. [40%]

(b) A similar $(0, 30)_s$ laminate is made in tube form, with a radius a = 100mm and wall thickness h = 4mm, with the axis of the tube aligned with the 0° fibres of the laminate. The tube is then subjected to an axial load F = 1kN.

(i) Write down the stress resultants on the cross-sectional wall of the tube. [10%]

(ii) Determine the magnitude of the engineering shear strain on the tube wall. [30%]

(iii) Hence calculate the twist per unit length of the tube. [10%]

(iv) How might the laminate be re-designed to eliminate this twist? [10%]

4 (a) Define the following terms:

(i) pre-preg material, [10%]

(ii) sheet-moulding compound, [10%]

(iii) resin transfer moulding. [10%]

(b) For EITHER an aircraft composite vertical stabiliser OR an automotive composite body side panel:

(i) propose a suitable fabrication method, [10%]

(ii) give reasons for the suitability of the fabrication method for your selected component, comparing it with that suitable for the other component, [30%]

(iii) for the chosen component, propose a suitable composite material and discuss the reasons for your selection. [30%]

END OF PAPER