BIRLA INSTITUTE OF TECHNOLOGY AND SCIENCE, PILANI
FIRST SEMESTER 2023-2024
DE G631 Material Technology and Testing
Comprehensive Examination (Regular) (Open Book)

Duration:2 hrs **PART- B** Total marks: 30

Q1. A composite beam of dimension 2m long, 100mm wide (b), and 200mm thick (h) is to be designed (selection of best material). The important consideration in selecting the material is to be given to bending stiffness in terms of longitudinal modulus of elasticity. Stiffness is to be specified as maximum allowable deflection in bending. A three-point bend test is performed on the beam, which is resting on two supports. The design requires that load of 6kN/m distributed uniformly till a distance of 1m from left hand side should not produce elastic deflection more than 1mm.

Continuous fibers that are oriented parallel to the beam axis will be used, possible fiber materials are glass and C (in standard and high modulus grades). The matrix material to be used is an epoxy resin, and the maximum allowable fiber volume fraction is 0.60. The properties of the fibers and matrix are given below in the table **[10M]**

a) Decide which of the three fiber materials, when embedded in the epoxy matrix, meet the stipulated criterion.

b) Of these possible fibers, select the fiber material that will yield the lowest cost composite material (assume the fabrication cost is same for all fibers)

Material	E(GPa)	Density g/cm^3	Cost(4/kg)
Glass Fibers	70	2.5	25
C-fiber(Std. Modulus)	200	1.5	30
C-fiber(Std. Modulus)	400	1.5	100
Epoxy Resin Matrix	2.5	1.1	10

Q2. A shear stress τ_{xy} = -15 MPa is applied on a unidirectional angle-ply lamina. The fibers are at 45° to the x-axis. Calculate the stresses in the principal material directions. **[3M]**

Q3. . For some metal alloy, a true stress of 345 MPa produces a plastic true strain of 0.02. How much will a specimen of this material elongate when a true stress of 415 MPa is applied if the original length is 500 mm ? Assume a value of 0.22 for the strain-hardening exponent, *n* **[3M]**

Q4. A stress of 7MPa is applied to an elastomer at 27ºC, and after 25 days the stress is reduced to 5MPa by stress relaxation. When the temperature is raised to 50ºC, the stress is reduced from 8MPa to 3MPa in 30 days. Calculate the activation energy for this relaxation process. **[3M]**

Q5. A continuous and aligned fiber-reinforced composite is to be produced consisting of 45 vol% aramid fibers and 55 vol% of a polycarbonate matrix; mechanical characteristics of these two materials are as follows: **[7M]**

	MODULUS OF ELASTICITY(GPa)	Tensile strength (MPa)
Aramid fiber	131	3600
Polycarbonate	2.4	65

Also, the stress on the polycarbonate matrix when the aramid fibers fail is 35 MPa. For this composite, compute

a) The longitudinal tensile strength, and the longitudinal modulus of elasticity
b) Assume that the composite has a cross-sectional area of 480 mm2 and is subjected to a longitudinal load of 53,400 N
   i. Calculate the fiber–matrix load ratio
   ii. Calculate the actual loads carried by both fiber and matrix phases
   iii. Compute the magnitude of the stress on each of the fiber and matrix phases.
   iv. What strain is experienced by the composite?

Q6. The design stress of the tail section of a prototype military aircraft is such that it never exceeds a stress corresponding to one-third of the yield strength, and the cyclic service loading is expected to vary from a minimum stress σ_{min} of one-twelfth of the yield strength to a maximum stress σ_{max} of one-third of the yield strength. The tail section is inspected with an ultrasonic non- destructive testing method, with a resolution limit of 0.254 mm. Assuming that the stress intensity factor for any defects present in the tail section is given by: $K_I = \sigma_{max}\sqrt{\pi a}$ where, "a" is the crack length and the growth of fatigue cracks is governed by $\frac{da}{dN} = C\Delta K^m$, where $\frac{da}{dN}$ is the fatigue crack growth rate per cycle, ΔK is the stress intensity factor 'range, and C and m are material constants. Derive expressions for

(i) the critical crack length in the tail section and
(ii) the lifetime (N_f) of the tail section for m = 2 in terms of the material properties (i.e. the yield strength, plane strain fracture toughness, C, K_{IC} etc.) **[4M]**

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Duration:1 hr **PART- A** Total marks: 15

Q1. For a tensile test, it can be demonstrated that necking begins when,

$$d\sigma_T/d\varepsilon_T = \sigma_T.$$

Determine the value of true strain at this onset of necking **[2M]**

Q2. Find the toughness (or energy to cause fracture) for a metal that experiences both elastic and plastic deformation. Assume for elastic deformation, that the modulus of elasticity is 172 GPa, and that elastic deformation terminates at a strain of 0.01. For plastic deformation, assume that the relationship between stress and strain is described by $\sigma = K\varepsilon^n$, in which the values for *K* and *n* are 6900 MPa and 0.30, respectively. Furthermore, plastic deformation occurs between strain values of 0.01 and 0.75, at which point fracture occurs. **[2M]**

Q3. A polymeric material has a relaxation time of 50 days at 30 ^{0}C when a stress of 10MPa is applied.

i) How many days will be required to decrease the stress to 5 MPa
ii) What is the relaxation time at 40^{0}C if the activation energy for this process is 30kJ/mol. **[2M]**

Q4. Answer the following with proper justifications

a) Two specimens of different materials and cross-section are subjected to tensile test. Based on the given data, comment on the stiffness of the two specimens. **[1M]**

Material A: E_A=200GPa, A_A=200mm^2, L_A=50mm^2 ,

Material B: E_A=75GPa, A_A=100mm^2, L_A=100mm^2

b) A tensile specimen is elongated to twice its original length. Determine the engineering strain and true strain for this test. If the metal has been strained in compression, determine the final compressed length of specimen such that: **[2M]**

i. Engineering strain is equal to same value in tension.
ii. True strain would be equal to same value as in tension.

c) Describe acousto ultrasonic technique? In what aspect is it better than acoustic emission technique? **[2M]**

d) Explain the phenomenon of acoustic emission. Define counts, events and lock out time. Also, explain Kaiser effect and Felicity ratio. Would a higher Felicity ration mean a better quality specimen or worse quality specimen? Explain why? **[2M]**

Q5. The tensile strength and number-average molecular weight for two polyethylene materials are as follows: **[2M]**

Tensile strength (MPa)	***Number-Average Molecular Weight (g/mol)***
90	20,000
180	40,000

Estimate the number-average molecular weight that is required to give a tensile strength of 140 MPa.