GX659

OLLSCOIL NA hÉIREANN
The National University of Ireland

National University of Ireland, Galway

Trinity Examinations, 2000/01

Fourth Year Mechanical and Biomedical Engineering Examination

POLYMERS, CERAMICS & COMPOSITES

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Attempt *Five* Questions (Four Questions from Section A and One Question from Section B)
Time Allowed: *3 Hrs.*

Additional Information is available on the back page of the examination paper.

SECTION A

1. A compact tension specimen shown in Figure 1(a) with the following dimensions is to be used to test the fracture toughness of a steel

   W= 200mm, H= 100mm, t= 20mm

   A notch of depth a= 60mm is machined, as shown in Figure 1(a), into the specimen.

   It is necessary, before static fracture testing to pre-start the crack with cyclic loading.

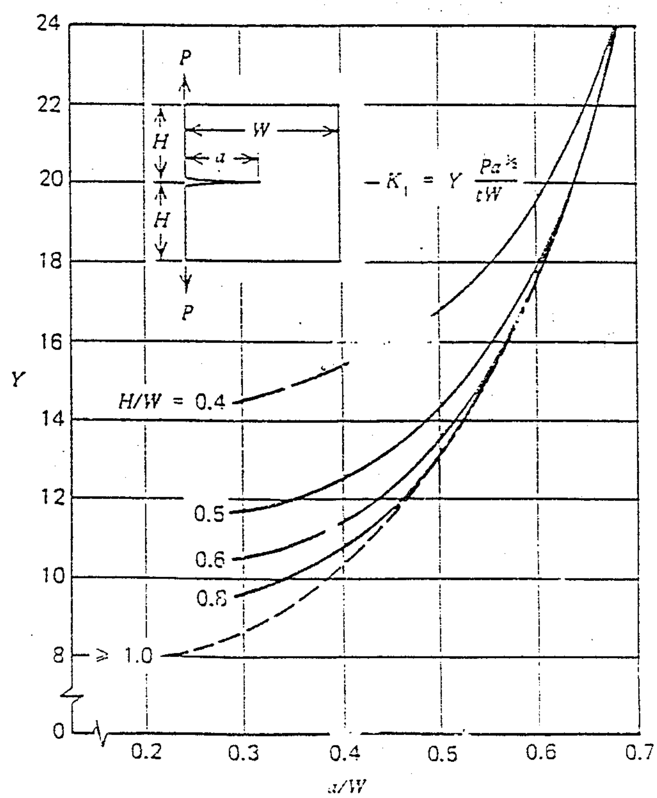

FIGURE 1(a)

(i) Recommend a force amplitude and number of cycles to extend the crack by 5mm, given the experimental crack growth data in Figure 1(b) *(15)*

(ii) What value of Mode I fracture toughness, K_{IC}, is indicated by a static fracture load of 192 kN? *(5)*

HINT: Assume $\frac{a}{w} = 0.3$ throughout.

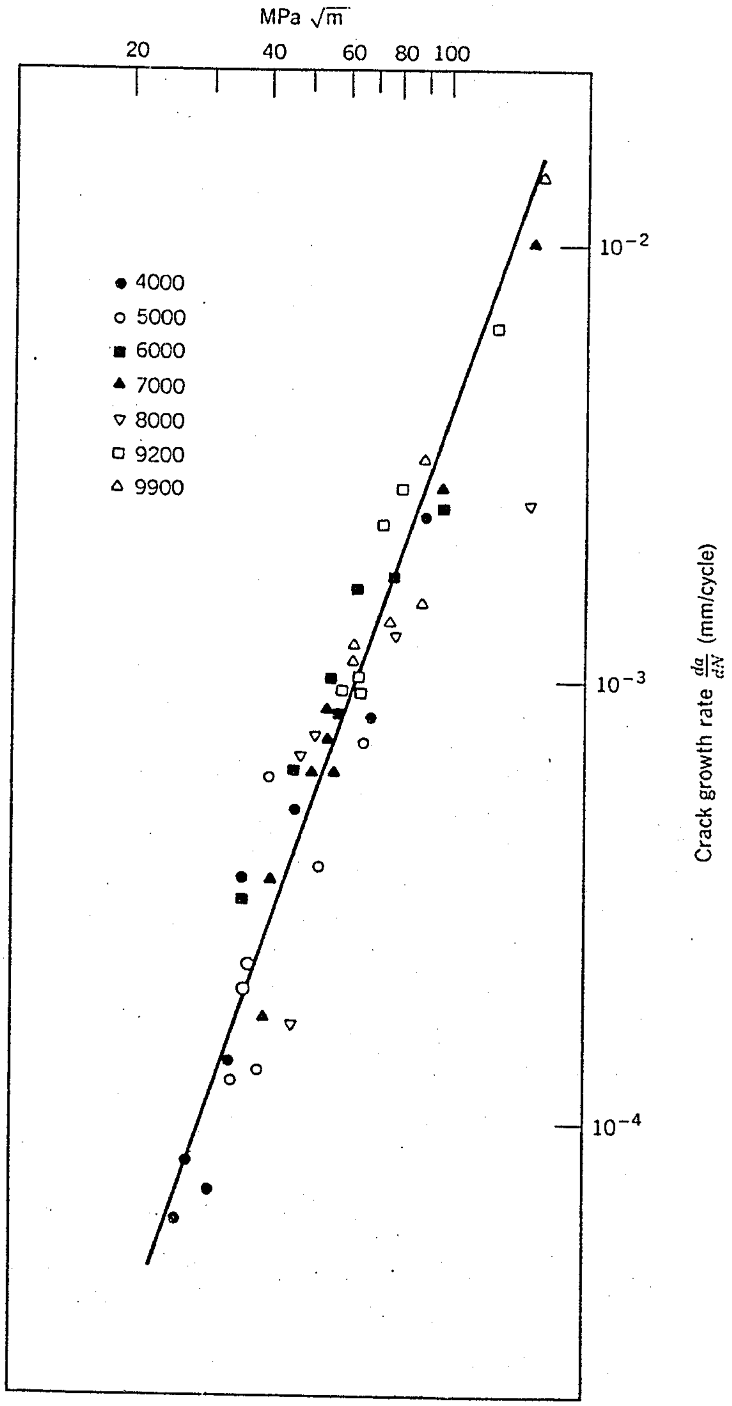

FIGURE 1(b)

2(a) Derive the stress-relaxation modulus for the Maxwell model shown in Figure 2. *(8)*

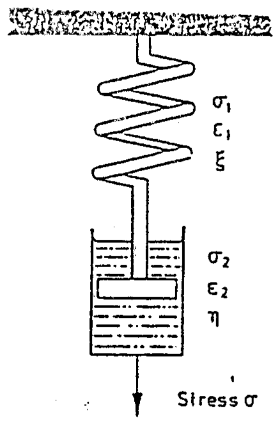

FIGURE 2

(b) A polymer whose mechanical properties are represented by a Maxwell Model, with constants $\zeta_1 = 0.25$ GPa, $\eta_2 = 2.6 \times 10^{15}$ Pa.sec is produced in the form of a tube of inner diameter 47mm, and outer diameter 50mm.

A 150mm length of the tube is pushed over a rigid metal pipe of outer diameter 47.5mm.

If the coefficient of friction between the two materials is $\mu = 0.2$, calculate the axial force needed to separate the two tubes.

(i) immediately after connection, and
(ii) 1 month (30 days) after connection.

Given: Poisson's Ratio, $\nu = 0.34$

HINT: Find hoop stress and radial pressure *(12)*

$$\sigma_\theta(t) = \frac{E(t)}{(1-\gamma^2)}\varepsilon_\theta$$

3(a) Derive and sketch the creep compliance of the 4-element viscoelastic model shown in Figure 3. *(8)*

(Note: Solutions to Ordinary Differential Equations at back of paper)

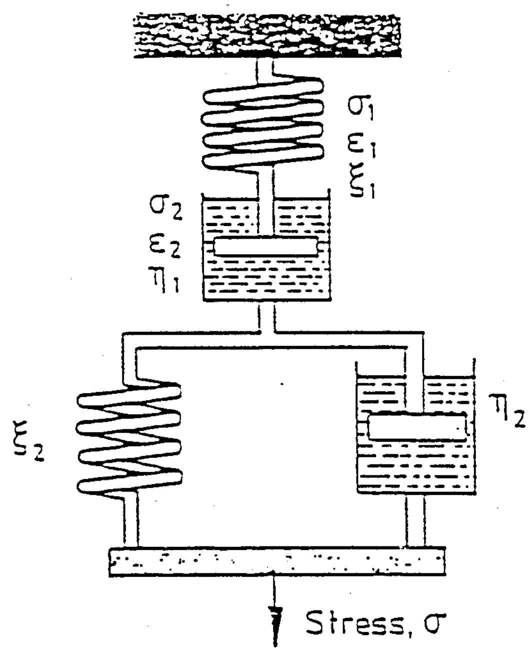

FIGURE 3

(b) A polymer represented by the 4-element model is subjected to a creep stress of 24MPa. After 10^5 sec, the stress is abruptly removed. Calculate the time it would take the polymer to recover 20% of the strain caused by the creep stress.

Given: Material Properties

$\zeta_1 = 3.5\text{x}10^9$ Pa

$\zeta_2 = 9.8\text{x}10^8$ Pa

$\eta_1 = 4.6\text{ x}10^{13}$ Pa.secs

$\eta_2 = 2.5\text{ x}10^{14}$ Pa.secs

(12)

4(a) For an imcompressible, Newtonian polymer, show that the Trouton (tensile) viscosity is equal to three time the shear viscosity:

$\lambda = 3\eta$

(see constitutive equation for Newtonian fluid attached) *(8)*

(b) A cone and plate viscometer is used to measure the viscosity of a polymeric power-law fluid, as shown in Figure 4(b)

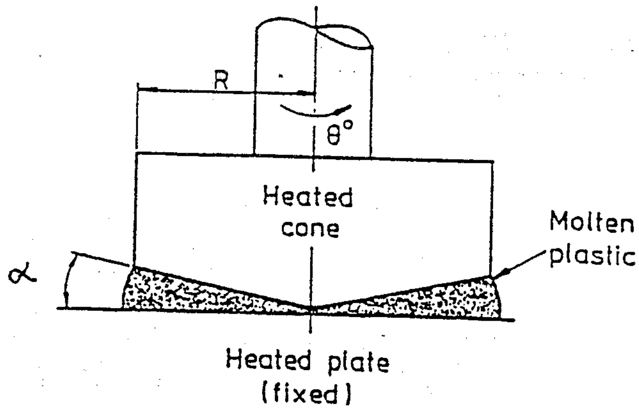

FIGURE 4(b)

(i) Derive the expression relating viscosity to the applied torque and rotational speed of the apparatus. *(6)*

(ii) A cone of 100mm radius and included angle of 170^0 yields the following measurements: *(6)*

θ (deg/sec)	1	4	12	17	28	39	52
Torque (N.m)	0.142	0.216	0.299	0.332	0.386	0.426	0.465

Plot the viscosity against shear rate and determine the power-law constants, C and n.

5(a) Discuss the advantages, disadvantages and typical applications of the following fibre reinforcements:

E = Glass, Kevlar, Carbon

Briefly describe the pultrusion, filament-winding and resin-transfer moulding processes for manufacturing composite materials. What type of materials may be processed in each case? *(10)*

(b) Explain how the table at electrode potentials of metals is constructed and the significance of position on this table. Give three examples of practical use of this table in corrosion prevention. *(10)*

Section A

6(a) Classify the different types of crystallographic ceramic materials under the following headings: bond type, basic compound type and examples of materials. Sketch the crystallographic unit cell for three different ceramic materials. *(7)*

(b) Describe the deformation and fracture characteristics of a typical ceramic, commenting on the materials ability to support tensile and compressive loads and the materials machinability. Name the quantity typically used to quantify ceramic strength. Describe the test used to evaluate it and establish the relevant formula for a ceramic sample with a rectangular cross section. *(7)*

(c) Compare a typical ceramic with a typical metal in terms of values for a range of the most significant material properties and comment on the industrial implications of the comparison. *(6)*

7(a) Draw a diagram that describes the main ceramic material groupings and relates them to applications. Draw a diagram that describes the main ceramic material processing techniques. *(6)*

(b) Discuss clay products in terms of typical applications, compositions and forming processes. Illustrate the slip casting process with a sketch. *(4)*

(c) Discuss, with the aid of sketches, the pressing and sintering of silicon nitride powder under the following headings:

- particle sizes, typical pressing densities and pressing methods
- densification mechanisms in sintering
- typical sintering histories
- form of final microstructure, implications for material strength and methods of improvement
- effects of non-uniform pressing density on shape of final part. *(10)*