UNIVERSITI SAINS MALAYSIA

First Semester Examination
2014/2015 Academic Session

December 2014 / January 2015

EBP 306/3 – Properties of Polymer Materials Engineering
[Sifat-sifat Kejuruteraan Bahan Polimer]

Duration : 3 hours
[Masa : 3 jam]

Please ensure that this examination paper contains NINE printed pages before you begin the examination.
[Sila pastikan bahawa kertas peperiksaan ini mengandungi SEMBILAN muka surat yang bercetak sebelum anda memulakan peperiksaan ini.]

This paper consists of SEVEN questions. THREE questions in PART A and FOUR questions in PART B.
[Kertas soalan ini mengandungi TUJUH soalan. TIGA soalan di BAHAGIAN A dan EMPAT soalan di BAHAGIAN B.]

Instruction: Answer **FIVE** questions. Answer **ALL** questions from PART A and **TWO** questions from PART B. If a candidate answers more than five questions only the first five questions answered in the answer script would be examined.
*[**Arahan**: Jawab **LIMA** soalan. Jawab **SEMUA** soalan dari BAHAGIAN A dan **DUA** soalan dari BAHAGIAN B. Jika calon menjawab lebih daripada lima soalan hanya lima soalan pertama mengikut susunan dalam skrip jawapan akan diberi markah.]*

The answers to all questions must start on a new page.
[Mulakan jawapan anda untuk semua soalan pada muka surat yang baru.]

You may answer a question either in Bahasa Malaysia or in English.
[Anda dibenarkan menjawab soalan sama ada dalam Bahasa Malaysia atau Bahasa Inggeris.]

In the event of any discrepancies in the examination questions, the English version shall be used.
[Sekiranya terdapat sebarang percanggahan pada soalan peperiksaan, versi Bahasa Inggeris hendaklah digunapakai.]

...2/-

PART A / *BAHAGIAN A*

1. In your opinion which model is the best to describe the response of a viscoelastic material in a stress relaxation test, Maxwell or Voight-Kelvin model? Compare these 2 models and provide justifications for your choice of model.

Pada pendapat anda model manakah yang terbaik bagi menerangkan kelakuan suatu bahan viskoelastik semasa ujian pengenduran tegasan, model Maxwell atau model Voight-Kelvin? Bandingkan kedua-dua model ini dan beri justifikasi bagi model pilihan anda.

(100 marks/*markah*)

2. [a] A plastic which can have its creep behavior described by a Maxwell model is to be subjected to the stress history shown in Figure 1. If the spring and dashpot constants for this model are 20 GNm^{-2} and 1000 GNm^{-2} respectively then predict the strains in the material after 150, 350 and 450 seconds.

Suatu bahan plastik di mana sifat kripnya diterangkan oleh model Maxwell, dikenakan sejarah tegasan seperti di Rajah 1. Jika pemalar bagi spring dan daspot masing-masing ialah 20 GNm^{-2} dan 1000 GNm^{-2}, ramalkan terikan yang dialami oleh bahan selepas 150, 350 dan 450 saat.

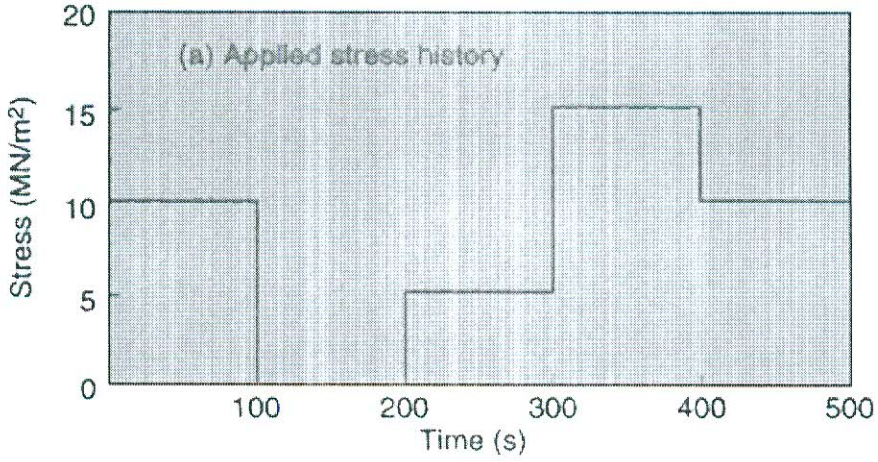

Figure 1 - Applied stress history for a plastic subjected to creep test

Rajah 1 - Sejarah tegasan suatu bahan plastik yang dikenakan ujian krip

(30 marks/*markah*)

[b] A viscoelastic polymer that follows the Boltzmann superposition principle had the following loading history. At t = 0, a stress of 10 MNm^{-2} was applied for 100 s. The stress then was removed immediately. Given: J_o = 2 m^2 GN^{-1} and τ_o = 200 s

$$J(t) = J_o\left(1 - \exp\left(-\frac{t}{\tau_o}\right)\right)$$

Calculate the total strain after 100 and 200 s.

Suatu polimer viskoelastik yang mematuhi prinsip superposisi Boltzmann telah dikenakan sejarah tegasan yang berikut. Pada t = 0, tegasan sebanyak 10 MNm^{-2} telah dikenakan selama 100 s. Tegasan tersebut kemudiannya dilepaskan serta merta. Diberi J_o = 2 m^2 GN^{-1} dan τ_o = 200 s

$$J(t) = J_o\left(1 - \exp\left(-\frac{t}{\tau_o}\right)\right)$$

Kirakan jumlah terikan selepas 100 dan 200 s.

(20 marks/*markah*)

[c] A master curve for polyisobutylene indicates that stress relaxes to a modulus of 10 dyn/cm^2 in about 10 h at 25°C. Using the WLF equation,

(i) Calculate the glass transition temperature (T_g) for polyisobutylene. It is given that at T_g, the modulus is observed at 2.0 x 10^{12} h.

(ii) Estimate the time it will take to reach the same modulus at temperature of – 20°C.

Keluk induk bagi poliisobutilena menunjukkan tegasan mengendur ke suatu modulus 10 dyn/cm^2 dalam tempoh 10 jam pada 25°C. Dengan menggunakan persamaan WLF,

(i) Kirakan suhu peralihan kaca (T_g) bagi poliisobutilena. Pada T_g, modulus tersebut diperhatikan pada 2.0 x 10^{12} jam.

(ii) Anggarkan masa yang diperlukan bagi mencapai modulus yang sama pada suhu – 20 °C.

(20 marks/*markah*)

[d] Briefly explains the THREE conditions under which a polymer displays rubbery behavior.

Terangkan secara ringkas TIGA keadaan yang mana polimer menunjukkan tingkah laku bergetah.

(30 marks/*markah*)

3. [a] With the aid of schematic curves, give your critical comments on Considêre construction.

Dengan bantuan lengkung skematik, berikan komen kritikal anda berkenaan dengan "Considêre construction".

(50 marks/*markah*)

[b] You are given a rectangular bar of PMMA in the form of a Single-End-Notch-Bending (SENB) specimen with a central edge crack of length. Calculate the force F required to fracture the bar in SENB with given span length. For this geometry, with S/W = 80/10 = 8.0 and specimen geometrical correction factor, Y is given by;

$$Y = 1.11 - 1.55(a/W) + 7.71(a/W)^2 - 13.5(a/w)^3 + 14.2(a/w)^4$$

Detail information of geometry given as;

Thickness B = 6 mm

Width W = 10 mm

Central edge crack length a = 1 mm

Span length S = 80 mm

Critical stress intensity factor K_{IC} = 1.60 MPa

Anda diberikan blok segiempat PMMA dalam bentuk spesimen "Single-End-Notch-Bending (SENB)" dengan panjang retak di bahagian tengah hujung. Kirakan tenaga yang diperlukan untuk merekahkan blok tersebut dalam bentuk SENB dengan panjang span yang diberikan. Untuk geometri ini, dengan S/W = 80/10 = 8.0 dan faktor pembetulan geometri spesimen, Y diberikan sebagai;

$$Y = 1.11 - 1.55(a/W) + 7.71(a/W)^2 - 13.5(a/w)^3 + 14.2(a/w)^4$$

Maklumat terperinci berkenaan geometri diberikan sebagai;

Ketebalan B = 6 mm

Lebar W = 10 mm

Panjang retak di bahagian tengah hujung a = 1 mm

Panjang span S = 80 mm

Faktor keamatan tegasan kritikal K_{IC} = 1.60 MPa

(50 marks/*markah*)

PART B / *BAHAGIAN B*

4. [a] The quantity n, the number of active network chain segments per unit volume, was shown to be equal to the density over the molecular weight between cross-link, ρ/M_c. Suppose an amorphous polymer of Tg = -10°C, and of density ρ = 1.10g/cm^3, was chemically cross-linked, such that a cross-link point was placed every 10,000 g/mol of chain. Calculate the Young's modulus at 25°C. (Note that since Tg is well below 25°C and the polymer is cross-linked, the polymer is in the rubbery plateau region). In this case, Mc is given as 1 x 10^4 g/mol.

Kuantiti n, bilangan aktif segmen rantaian rangkaian per unit isipadu, telah ditunjukkan bersamaan ketumpatan dibahagikan dengan berat molekul antara jaringan silang, ρ/M_c. Katakan polimer amorfus dengan Tg = -10°C, dan ketumpatan ρ = 1.10g/cm^3, telah disambung silang secara kimia supaya titik sambung silang diletakkan pada setiap 10,000 g/mol rantai. Kira modulus Young pada 25°C. (Ambil kira Tg adalah jauh di bawah 25°C dan polimer bersambung silang, polimer berada dalam kawasan bergetah yang mendatar). Dalam kes ini, Mc diberikan sebagai 1 x 10^4 g/mol.

(30 marks/*markah*)

[b] Explain the Phantom Network.

Terangkan Jaringan "Phantom".

(40 marks/*markah*)

[c] Write a short essay on Mooney-Rivlin theory and its application in rubber elasticity.

Tuliskan nota ringkas tentang teori Mooney-Rivlin dan kegunaannya dalam kekenyalan getah.

(30 marks/*markah*)

5. Write short notes on THREE of the following topics:

(i) Factors affecting yield behaviours of polymers

(ii) Brittle-ductile transition

(iii) Modification to Griffith's Fracture Theory

(iv) The application of Eyring model in the understanding of yield behavior of polymers

Tulis nota ringkas tentang TIGA daripada topik berikut:

(i) Faktor yang mempengaruhi kelakuan alah polimer

(ii) Peralihan rapuh-mulur

(iii) Pengubahsuaian pada Teori Rekahan Griffith's

(iv) Penggunaan model Eyring dalam memahami sifat-sifat alah polimer

(100 marks/*markah*)

6. [a] A thick, wide plate of polystyrene contains a central, sharp crack and the crack is found to propagate at maximum stress. Calculate:

(i) K_{IC}

(ii) G_{IC}

(iii) K_I in plane strain condition under stress σ = 10 MPa, if a crack of length 2 mm. Give your comment with respect to K_{IC}.

Sekeping polistirena yang tebal dan lebar mengandungi rekahan yang tajam di tengah dan rekahan tersebut telah tersebar pada tekanan maksima. Kirakan:

(i) K_{IC}

(ii) G_{IC}

(iii) K_I *dalam keadaan terikan di bawah tegasan* σ = *10 MPa, jika panjang retak ialah 2 mm. Berikan komen anda berlandaskan* K_{IC}.

Given: / *Diberikan:*

Fracture stress σ_f = 4.20 MPa / *Tegasan rekahan* σ_f = *4.20 MPa*

Young's modulus E = 3.0 GPa / *Modulus Young's E = 3.0 GPa*

Poisson ratio υ = 0.40 / *Nisbah Poisson,* υ = *0.40*

(70 marks/*markah*)

[b] Discuss the shortcoming of conventional impact test in characterizing the toughness property of polymeric materials.

Bincangkan kelemahan ujian hentaman konvensional dalam mencirikan sifat keliatan bahan polimer.

(30 marks/*markah*)

7. [a] Calculate the activation energy volume V* and activation enthalphy ΔH for the yielding of polycarbonate, using the data shown in Figure 2.

Kirakan jumlah tenaga pengaktifan V dan entalpi pengaktifan ΔH untuk kelakuan alah polikarbonat, dengan menggunakan data yang ditunjukkan dalam Rajah 2.*

(70 marks/*markah*)

Given; / *Diberikan*;

$$\left(\frac{\sigma_y}{T}\right) = \left(\frac{2}{V^*}\right)\left[\left(\frac{\Delta H}{T}\right) + 2.303R \quad \log\left(\frac{\varepsilon_y}{\varepsilon_o}\right)\right]$$

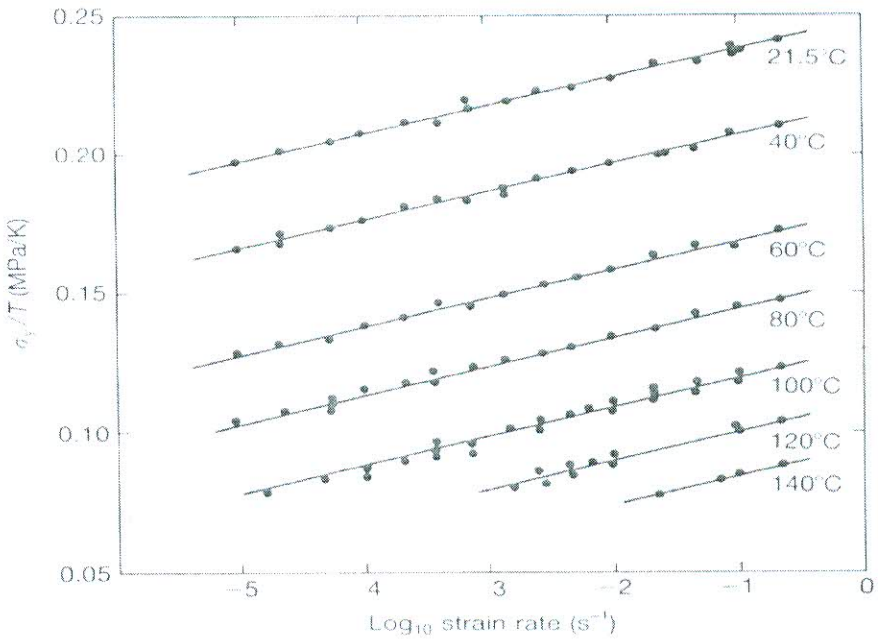

Figure 2 - Eyring plot σ_y/T against log $\bar{\varepsilon}$ for polycarbonate

Rajah 2 - Plot Eyring σ_y/T melawan log $\bar{\varepsilon}$ untuk polikarbonat

[b] Estimate the yield stress of polycarbonate at 25°C in an impact test which shows fracture occuring in approximately 1 ms.

Anggarkan tegasan alah polikarbonat pada 25°C dalam ujian hentaman yang menunjukkan rekahan yang berlaku kira-kira 1 ms.

(30 marks/*markah*)

- oooOooo -