Properties of Polymers   Final Exam   12 June 2019

Total of 97 points. Answer the following questions in a concise manner.

1. [3 + 2 + 2 + 4 + 3 points] **A plate with the dimension of 100 x 100 x 5 mm^3 formed from a polymeric material with the Young's modulus of 2.0 GPa is subjected to a biaxial load of 25 kN along the two directions on the largest plane. Answer the following questions.**

(a) Express the stress state in a [3 x 3] matrix form. Don't forget the unit.

(b) To calculate the final dimension of the plate you need to assume that the polymer is isotropic. What other assumption do you need (about the behavior of the polymer)? Why?

(c) What additional information do you need to predict the final dimension of the plate? What would be the reasonable value for that?

(d) Estimate the final thickness of the plate using the value you gave in (c).

(e) Does the result of (d) justify the assumption you made in (b)? Explain.

2. [3 x 3 points] **There are two mechanical models for linear viscoelasticity; Maxwell and Voigt models. They are composed of one spring element with the modulus *E* and one dashpot element with the viscosity η.**

(a) Show the constitutive equation for a creep test of a Maxwell model with the given stress of σ_0.

(b) Show the constitutive equation for a stress relaxation test of a Voigt model with the given strain of e_0.

(c) One of the problems of the models results from the fact that they have single _________ ____ or _________ _____, which is unrealistic. Fill the both blanks.

3. [4 x 3 points] **For the construction of 'master curve' on modulus vs time plot using the time-temperature superposition principle, answer the following questions.**

(a) Vertical shift (in modulus) can be ignored. Why?

(b) For horizontal shift (in time), does the results at a temperature higher than the reference temperature shift to a shorter or longer time frame? Why?

(c) When the reference temperature is set to the ______ __________ temperature, the amount of horizontal shift is given by the ______ equation. Fill the both blanks. For the second one, no need to spell out.

(d) What is the two constants in the equation of (c) called? Why are they called so?

4. [5 + 3 x 3 points] **For a polymer that follows pressure-dependent Tresca yield criterion and critical-strain craze criterion, answer the following questions.**

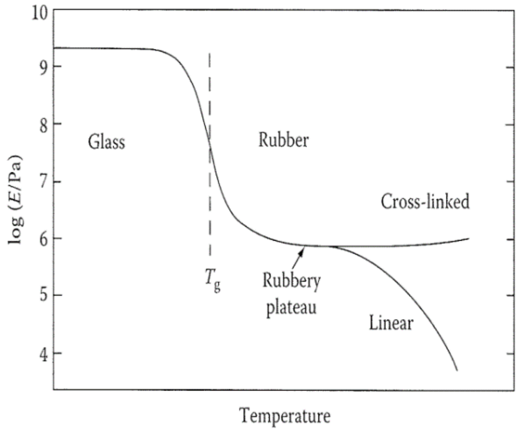
(a) It is observed that this polymer undergoes shear yielding at a stress of 60 MPa in uniaxial tension and at 70 MPa in uniaxial compression at the strain rate of 10 mm/min. It is also observed that the polymer undergoes crazing at a stress of 50 MPa in uniaxial tension and at 40 MPa in biaxial tension. Show the yield and craze locus on σ_1-σ_2 coordinate.

(b) Is this polymer ductile or brittle upon biaxial compression? Explain your answer using your drawing of (a).

(c) Show how the drawing changes when the strain rate increases to 100 mm/min.

(d) Show by drawing that a ductile-brittle transition can occur with the increase in testing temperature.

5. [4 x 3 points] **Referring to the figure on the right, answer the following questions.**



(a) As the average molar mass of an amorphous polymer increases, would the width (in temperature) of rubbery plateau increase, decrease, or remain the same? Why?

(b) As the average molar mass of an amorphous polymer increases, would the level (in modulus) of rubbery plateau increase, decrease, or remain the same? Why?

(c) As the crystallinity of a semi-crystalline polymer increases, would the level (in modulus) of rubbery plateau increase, decrease, or remain the same? Why?

(d) As the average molar mass between the crosslinks of a rubber increases, would the level (in modulus) of rubbery plateau increase, decrease, or remain the same? Why?

6. [9 x 2 points] **Fill the blanks in the description of the fracture stress [σ_f] of polymers.**

(a) The theoretical fracture stress of a material is one-tenth of its (a1)___________. However, the measured σ_f is much smaller than this due to the existence of flaw or crack, which results in (a2)________ _____________ and (a3)_________ __________.

(b) In front of a crack, exceedingly high stress resulted from (a2) is cut off by (b1)_________ ________ of the polymer, and the material undergoes (b2)_______ ____________. This is the reason why σ_f measured is much larger than that estimated based on the (b3)________ ________ that are created by crack propagation.

(c) Since both of the low σ_f of (a) and the high σ_f of (b) are due to the existence of crack, it is called (c)________ _______, following the name of the scientist who suggested the both.

(d) (a3) in front of a crack tip is due to the (d1)_________ stress state, which make the (b2) occur at a higher (b1). (a3) can explain the ductile-brittle transitions with the change in (d2)[temperature, strain-rate, surface crack, specimen thickness] (Choose two).

7. [6 x 3 points] **Answer the following questions in one sentence. No drawing or equation.**

(a) Why is a rubber called ‘entropy spring’?

(b) Why is a polymer melt ‘pseudo-plastic’, while some colloids or suspensions ‘dilatant’?

(c) Why is a PRP not as efficient in reinforcing [enhancing modulus] as an FRP with the same matrix and reinforcement materials?

(d) Why is the dielectric constant of a polymer related to its solubility parameter?

(e) How is the thermal stability different from the heat resistance?

(f) Why is the flame resistance of a polymer related to its thermal stability?