PRINCE OF SONGKLA UNIVERSITY

FACULTY OF ENGINEERING

Final Examination : Semester I — Academic Year : 2004

Date : 8 October 2004 — Time : 09.00 – 12.00

Subject : 230 - 463 Polymer Technology — Room : R201

Student Name: ..... ID no. : .....

Number of questions : 4

Time : 3 hours

Total marks : 120

Notes are not allowed

Calculators are allowed

Question	Full Marks	Marks Received
1	30	
2	35	
3	30	
4	25	
Total	120	

ทุจริตในการสอบโทษขั้นต่ำคือ ปรับตกในรายวิชาที่ทุจริต และพักการเรียน 1 ภาคการศึกษา

1. a) Describe suspension polymerization process for production of polyvinyl chloride.

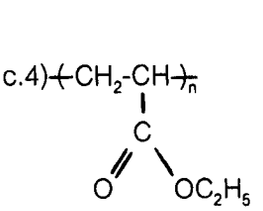
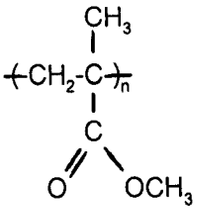
   b) Compare monomers and initiators used in suspension and emulsion polymerizations by free radical chain reactions.

   c) Give the reasons for the differences in transition temperatures for the following pairs of polymers.

   c.1) Polyvinylchloride T_g = 354 K Polyacrylonitrile T_g = 370 K

   c.2) PS ($\bar{M}_n$ = 10,000) T_g = 361 K PS ($\bar{M}_n$ = 55,000) T_g = 373 K

c.3) Syndiotactic PP T_m = 397 K Isotactic PP T_m = 435 K

c.4)  T_g = 249 K  T_g = 378 K

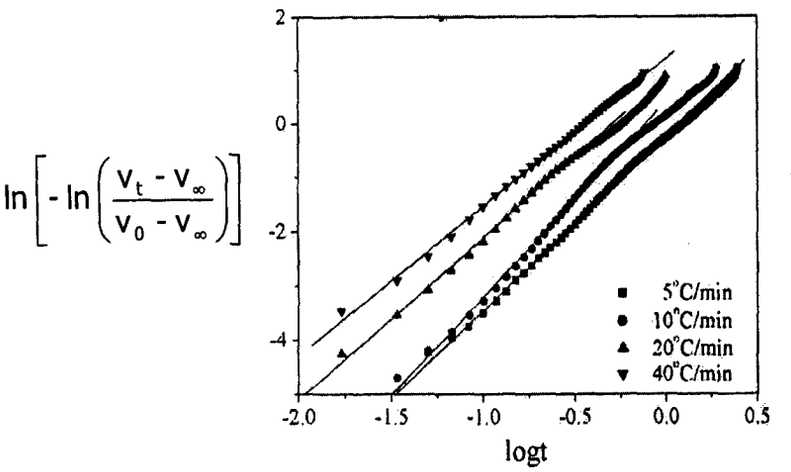
c.5) $-(CH_2CH_2)_n-$ T_m = 408 K $-(O(CH_2)_2OCO(CH_2)_6CO)_n-$ T_m = 318 K

d) Describe in details step by step the measurement for viscosity-average molecular weight of a polymer sample.

e) What are the necessary parameters for determination of degree of crystallinity of a solid polymer? How can you get the values of these parameters?

f) The figure shown below is obtained from an experiment on polyamide sample. What is the purpose of this experiment? What parameters can be obtained from this experiment?

Plot of $\ln\left[-\ln\left(\frac{v_t - v_\infty}{v_0 - v_\infty}\right)\right]$ vs log t



(30 marks)

Student Name: ..... ID no. : .....

Answers to Question 1

Student Name: ..... ID no. : .....

Answers to Question 1 (continued)

Student Name: ..... ID no. : .....

2. a) Layered-silicate-based polymer nanocomposites have received considerable interest over the past decade in research and development as an alternative to conventional filled composites. They have the potential of becoming a new class of high-performance engineering materials. The Toyota research group in Japan found that polyamide composites with silicate-clay loading as little as 4 wt% improved the tensile strength as much as 100% and heat distortion temperature was up by 87°C. Comment on the function of the silicate clay.

(5 marks)

b) Explain the Time-Temperature Superposition Principle and its benefits.

(5 marks)

c) From the relaxation modulus vs. time at different temperatures for polyisobutylene shown below if it is required to construct a master curve at 298 K, calculate log a_T for shifting of the curve at 223 K from the WLF equation. Calculate the new time and compare it with the value from the graph. Comment on the limitation of this principle.

$$\log a_T = \frac{-C_1 (T - T_0)}{C_2 + (T - T_0)} = \log \frac{t}{t_o}$$

where C_1 = 8.88 and C_2 = 180.7 K

T and T_o = original and reference temperatures respectively

t and t_o = original and reference times respectively

a_T = shift factor

(10 marks)

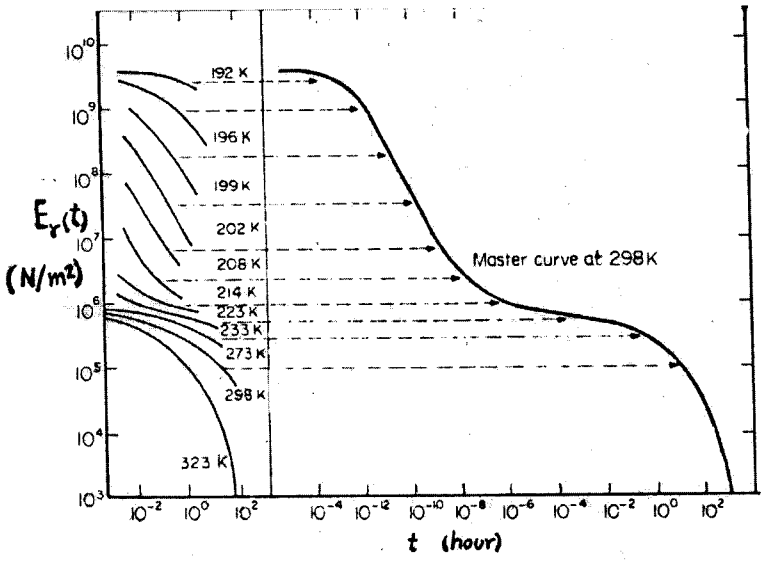


Figure : Relaxation modulus vs time for polyisobutylene

d) Sketch Maxwell model and show derivation for Maxwell equation. How does this model explain the viscoelastic behaviour of polymers.

$$\frac{d\epsilon}{dt} = \frac{1}{E} \cdot \frac{d\sigma}{dt} + \frac{\sigma}{\eta}$$

(10 marks)

e) Explain the setup of dynamic mechanical testing for determination of the optimum PVC/Plasticizer composition. Sketch a graph and explain the benefit of the test from this graph.

(5 marks)

Student Name: ..... ID no. : .....

Answers to Question 2

Student Name: ..... ID no. : .....

Answers to Question 2 (continued)

Student Name: ..... ID no. : .....

3. In the extrusion process for polyacetal pipe, the extruder screw geometry are as follows. The channel width is 7.0 mm, the channel depth is 5.0 mm, the screw diameter is 80 mm, flight helix angle is 17° and the screw length is 1600 mm. The screw speed is 90 rev/min, and the pressure varies linearly over the screw length from the hopper to the die. The leakage flow is negligible.

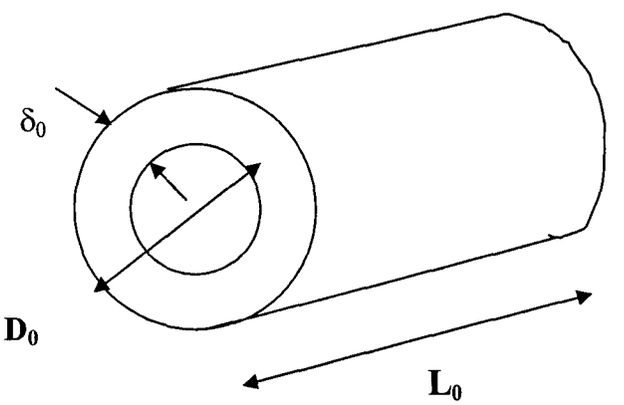
a) Show that the screw maximum pressure is $P_{max} = \frac{6\pi DLN\eta}{H^2 \tan\theta}$

b) An annular die with dimensions D_o = 8 mm, L_o = 35.0 mm. and δ_o = 1.5 mm. is fixed to the end of the extruder. If the screw metering zone and the annular die temperatures are at 220°C and the melt viscosity and density at this temperature are 218 Ns/m^2 and 1420 kg/m^3 respectively, plot the characteristic curves for screw and die using Q and P in m^3/s and MN/m^2 respectively. Show operating point on the graph.

c) If the die temperature in question (b) is reduced to 205°C, calculate the new die output in kg/hr. It can be assumed that the melt density remains the same as in (b) but the viscosity changes 17.43% from the value in (b). Find die output at both operating points in kg/hr and operating die pressure in MN/m^2.

For annular die, the die output is given by

$$Q_d = \frac{\pi D_0 \delta_0^3}{12 L_0} \bullet \frac{\Delta P_d}{\eta}$$



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Output = drag flow + pressure flow + leakage flow

output Q $= Q_D + Q_P + Q_L$

(โดย Q_P และ Q_L มีค่าเป็นลบ มีทิศทางสวนทางกับ Q_D)

drag flow $Q_D = \frac{1}{2} \pi^2 D^2 NH \sin\theta \cos\theta$

pressure flow $Q_P = -\frac{\pi DH^3 \sin^2\theta}{12\eta} \frac{dP}{dl}$

leakage flow $Q_L = -\frac{\pi^2 D^2 c^3}{12\eta e} \tan\theta \frac{dP}{dl}$

N = screw speed, rpm

θ = มุมเกลียว, helix angle

δ หรือ C = ช่องว่างระหว่าง screw กับ barrel ตามแนวรัศมี (radial screw clearance)

e = ความกว้างของ screw land ตามแนวแกน (axial flight land width)

H = ความลึกของฟันเกลียว (flight depth)

D = diameter ภายในของ barrel

η = viscosity ของ polymer melt

s = flight pitch, ระยะฟันเกลียว

(30 marks)

Student Name: ..... ID no. : .....

Answers to Question 3

Student Name: ..... ID no. : .....

Answers to Question 3(continued)

Student Name: ..... ID no. : .....

4. a) Suggest the type of polymer used for making 250-cc Coke and Pepsi plastic bottles. What are the properties required for the bottle? Suggest the polymer processing methods for making the bottle.

(6 marks)

b) Describe the process for making ice-cream plastic cup. What are the major factors in this type of polymer processing?

(6 marks)

c) Describe the dependence of melt viscosity on shear rate in polymer processing.

(6 marks)

d) Give specifications for an injection moulding machine for making rubber disks from an injection mould shown below. The rubber requires a moulding pressure of 4,000 psi. The combined sprue and runner length measured from the nozzle center is 3 inches. The disk diameters are approximately 1.5 inch. The total sprue and runner volume is 25 cc. Each disk volume is 3.5 cc.

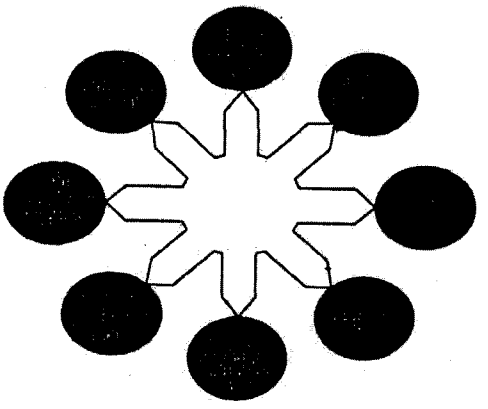

Figure : Rubber disks injection mould

(7 marks)

Student Name: ..... ID no. : .....

Answers to Question 4

Student Name: ..... ID no. : .....

Answers to Question 4 (continued)

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