# PRINCE OF SONGKLA UNIVERSITY

# FACULTY OF ENGINEERING

Final Examination : Semester I

Academic Year : 2006

Date : 10 October 2006

Time : 09.00 – 12.00

Subject : 230 - 463 Polymer Technology

Room : A400

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

Number of questions : 4

Time : 3 hours

Total marks : 120

Notes are not allowed.

Calculators are allowed.

Two graph papers are provided.

| Question | Full Marks | Marks Received |
|---|---|---|
| 1 | 30 | |
| 2 | 45 | |
| 3 | 25 | |
| 4 | 20 | |
| Total | 120 | |

ทุจริตในการสอบโทษขั้นต่ำคือ ปรับตกในรายวิชาที่ทุจริต และพักการเรียน 1 ภาคการศึกษา

1.  a) Describe production of homo-polypropylene and impact polypropylene by BASF process.

(5 marks)

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

b.1) $T_g$ for polypropylene and polyacrylonitrile

b.2) $T_m$ for high molecular weight polyethylene and poly (p-xylene) with structure $-(CH_2-\varnothing-CH_2)-$ where is a ring.

b.3) $T_g$ for cis-1,4-polybutadiene and trans-1,4-polybutadiene

1

b.4) $T_m$ for $-(CH_2CH_2CONH)-_n$ and $-(CH_2CH_2CH_2CONH)-_n$

b.5) $T_g$ for polymethyl methacrylate and poly n-butyl methacrylate

(10 marks)

c) What are the parameters used in determination of degree of crystallinity of a solid polymer? How can you estimate the values of these parameters?

(5 marks)

d) Discuss the effect of cooling rate in the experiment for determination of $T_g$.

(5 marks)

e) Explain the folded chain model for a single crystal of polyehtylene.

(5 marks)

Answers to Question 1

2.  a)  Describe the experimental steps used for determining viscosity-average

    molecular weight $\overline{M}_v$ of a polymer sample.

    Describe how $\overline{M}_v$ is determined.

    (10 marks)

    b)  A sample of a polypropylene analyzed by the gel permeation chromatography

    method provided the following data :

    | $M_i$ | $w_i$ |
    |---|---|
    | 3,000 | 0.04 |
    | 8,000 | 0.19 |
    | 18,000 | 0.43 |
    | 30,000 | 0.15 |
    | 45,000 | 0.08 |
    | 58,000 | 0.06 |
    | 75,000 | 0.05 |

    Calculate the weight-average molecular weight $\overline{M}_w$ and the number-average

    molecular weight $\overline{M}_n$. Sketch a distribution curve (weight fraction versus molecular

    weight) . Calculate the polydispersity index.

    $N_A$ = Avogadro number

    $$N_i = \left\{ \frac{w_i}{M_i} \right\} \times N_A$$

    $$N_i M_i = w_i N_A$$

    $$\overline{M}_n = \frac{\sum_i N_i M_i}{\sum_i N_i}$$

    $$\overline{M}_w = \frac{\sum_i C_i M_i}{\sum_i C_i} = \sum_i w_i M_i = \frac{\sum_i N_i M_i^2}{\sum_i N_i M_i}$$

    (15 marks)

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

c) Sketch and explain the time-temperature superposition principle on a plot of stress vs. temperature for a polymer which has $T_g$ of 273 K. Explain how the amount of shift can be estimated.

(5 marks)

d) Explain a mechanical model that can explain the stress relaxation behaviour of real polymer.

(5 marks)

e) Explain the experimental plot and the test method that can determine the optimum amount of plasticizer in polyvinylchloride.

(5 marks)

f) Sketch and explain the plot of shear stress vs. strain rate for a real polymer melt.

(5 marks)

Answers to Question 2

3. In the extrusion process for polymeric pipe, the extruder screw geometry is as follows. The axial flight land width is 2 mm, the channel depth is 10 mm, the screw diameter is 120 mm, flight helix angle is $17°$ and the screw length is 1800 mm. The screw speed is 100 rev/min, and the pressure varies linearly over the screw length from the hopper to the die. The leakage flow is negligible.

An annular die with dimensions $D_0 = 15$ mm, $L_0 = 30$ mm. and $\delta_0 = 4$ mm. is fixed to the end of the extruder. 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. Calculate the extruder output and die output at pressures 15 and 30 $MN/m^2$. Plot the characteristic curves for screw and die using Q and P in kg/h and $MN/m^2$ respectively. Read the operating point on the graph. (N is Newton, MN is mega Newton or $10^6$ N)

For annular die, the die output is given by

$$Q_d = \frac{\pi D_0 \, \delta_0^3}{12L_0} \bullet \frac{\Delta P_d}{\eta}$$
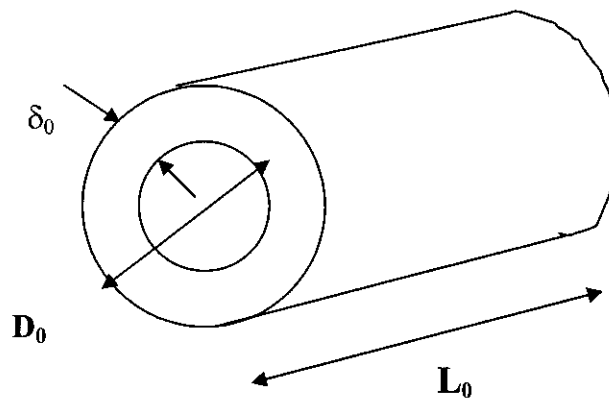
Output             = drag flow + pressure flow + leakage flow

output  Q                  $= Q_D + Q_P + Q_L$

( โดย  $Q_P$   และ $Q_L$ มีค่าเป็นลบ    มีทิศทางสวนทางกับ $Q_D$ )

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

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

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

N = screw speed, rpm

$\theta$ = มุมเกลียว, helix angle

$\delta$ 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

$\eta$ = viscosity ของ polymer melt

s = flight pitch, ระยะฟันเกลียว

(25 marks)

4. a) Describe the thermoforming process for thermoplastics. Comment on considerations and suggest for temperature settings for one type of thermoplastic.

(10 marks)

b) Give general specifications for an injection moulding machine.

(5 marks)

c) Moulding temperature for polystyrene in an injection moulding process is 177-260 $^{\circ}$C. Suggest temperature settings at the following zones: feed, middle, forward, nozzle and mould in $^{\circ}$C.

(5 marks)

_____ End of Question

Answers to Question 4