UNIVERSITY OF TORONTO

FACULTY OF APPLIED SCIENCE AND ENGINEERING

FINAL EXAMINATION - APRIL 2001

Third Year - Program: III – AEMECBASCF, AEMMSBASC, AEESCBASCM

MMS330H1 S — Introduction to Polymer Engineering

Examiner: S. Doroudiani

No aids are allowed (type A), other than a non-programmable calculator (type 2). **Answer all seven questions** in your examination booklet. Please read each question thoroughly and if required, make assumptions and state them clearly. You will find formulae on a separate sheet. TOTAL = 100

(MARKS)

1. Name five factors that must be considered in selecting polymeric materials for product design. *(10)*

2. Outline a suitable method of manufacture (forming process) for

a) 100,000 meters of garden hose from plasticised poly (vinyl chloride); *(2)*

b) 50,000 pocket combs from polystyrene; *(2)*

c) two boat hulls, each 5 meters long, from glass cloth and a solution of an unsaturated polyester in styrene monomer; *(2)*

d) 1,000,000 bottle of 1-liter size for milk from linear polyethylene. *(2)*

3. It is desired to produce an aligned and continuous fiber-reinforced epoxy composite having a maximum of 50 vol% fibres. In addition, a minimum longitudinal modulus of elasticity of 50 GPa is required, as well as a minimum tensile strength of 1300 MPa. Of E-glass, carbon, and aramid fibre materials, which are possible candidates and why? The epoxy has a modulus of elasticity of 3.1 GPa and a tensile strength of 75 MPa. In addition, assume the following stress levels on the epoxy matrix at fibre failure: E-glass 70 MPa; carbon 30 MPa; and aramid 50 MPa. Tensile strengths of E-glass, carbon and aramid are 3450 MPa; 4000 MPa; and 3850 MPa, respectively.

(15)

4. Following is a typical formulation of a poly (vinyl chloride) compound for electric wire coating. Name the suitable process for wire coating and explain briefly the role of each additive used in this formulation:

Suspension PVC (ISO No. 125)	100	parts
DIOP (plasticiser)	40	parts
Trixylyl phosphate (flame retardant plasticiser)	20	parts
China clay	20	parts
Tribasic lead sulfate (stabiliser)	7.0	parts
Stearic acid (lubricant)	0.5	parts
Pigment	2	parts

(15)

5. A panel is to be made having the following proportions of constituents by weight: 20% glass fibres (density 2540 kg/m^3), 55% polyester resin (density 1280 kg/m^3) and 25% calcium carbonate filler (density 2700 kg/m^3). What is the volume fraction of fibres in the panel?

(7)

6. a) A rod of unstressed length 0.720 m is needed to support a tensile load in an environment where the temperature is 17°C. With a load of 200 N, the rod must elongate by 15.0 mm. The rod has diameter 0.83 mm and is made of a thermoset polyester matrix reinforced with continuous Kevlar fibres aligned along its length. The density, tensile modulus and tensile strength of the matrix are respectively 1280 kg m^{-3}, 3.00 GPa and 55.0 MPa; the same properties of the fibres are 1450 kg m^{-3}, 124 GPa and 2800 MPa. What parameter can you specify to characterise the structure of the reinforced polymer, and what is its numerical value?

(10)

b) If the load were doubled, to 400 N, what change would occur? Do appropriate numerical calculations to give a quantitative answer.

(10)

7. Branched polyethylene (BPE) is produced by polymerisation of ethylene at high pressure. while low-pressure polymerisation of ethylene leads to linear polyethylene (LPE).

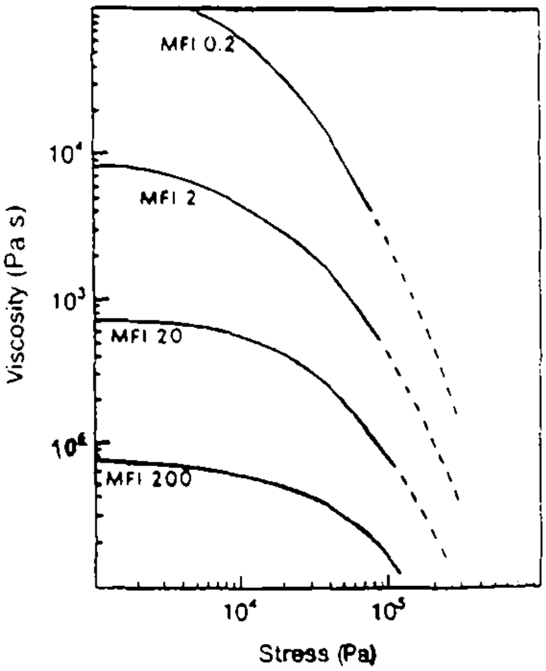
a) Sketch the structure of BPE and LPE. *(3)*

b) Compare the behaviour of molten BPE and LPE under tensile stress. Plot elongational viscosity versus tensile stress for BPE and LPE. *(5)*

c) Describe how BPE tends to be degraded during melt processing and ways to prevent this degradation. *(5)*

d) A tube of BPE with a melt flow index (MFI) of 2 is extruded at 170°C through an annular die of diameter 50 mm and die gap 2mm. Within the die the average linear velocity of the melt is 2 m/min. Assuming Newtonian behaviour, calculate the pressure gradient in the die, using data given in the plot of viscosity versus stress. Treat thin-walled tube as a flat sheet (slit die) and assume Newtonian behaviour (constant viscosity). *(7)*

e) Describe briefly and sketch the various parts of the extruder for production of BPE tube. *(5)*



Formulae:

$$\overline{M_n} = \frac{\sum n_i M_i}{\sum n_i} = \frac{\sum W_i}{\sum n_i} = \frac{W}{\sum n_i}$$

$$\overline{Mw} = \frac{\sum w_i M_i}{\sum w_i} = \frac{\sum w_i M_i}{W}$$

$$x = \frac{v_a - v}{v_a - v_c} = \frac{\rho_c}{\rho_s}\phi$$

$$\sigma = \frac{F}{A}$$

$$\sigma = G\left[\lambda - \frac{1}{\lambda^2}\right]$$

$$S = k \times Ln\Omega$$

$$J(t) = \frac{\gamma(t)}{\sigma}$$

$$G(t) = \frac{\sigma(t)}{\gamma}$$

$$G^* = G' + iG''$$

$$J^* = J' - iJ''$$

$$\tan\delta = \frac{J''}{J'} = \frac{G''}{G'}$$

$$\frac{d\sigma}{d\varepsilon} = \frac{d\sigma}{d\lambda} = 0 \text{ (at yield)}$$

$$\frac{A}{V} = \left(\frac{2\pi}{V}\right)^{\frac{1}{3}}\left(a^{-\frac{1}{3}} + 2a^{\frac{1}{3}}\right)$$

$$\rho = \phi_f \rho_f + (1 - \phi_f)\rho_m$$

$$\sigma_1 = \phi_f \sigma_f + (1 - \phi_f)\sigma_m$$

$$E_1 = \phi_f E_f + (1 - \phi_f)E_m$$

$$E_2 = \frac{E_f E_m}{(1-\phi_f)E_f + \phi_f E_m}$$

$$Q = \bar{v}wh$$

$$G_{12} = \frac{G_f G_m}{(1-\phi_f)G_f + \phi_f G_m}$$

$$\sigma_1^* = (1 - \phi_f)\sigma_m^*$$

$$\sigma_1^* = \phi_f \sigma_f^* + (1 - \phi_f)\sigma_m$$

$$E_1 = E_2 = \frac{3}{8}E_{max}$$

$$E_1 = E_2 = E_3 = \frac{1}{5}E_{max}$$

$$\dot{\gamma}_w = \frac{2(2n+1)}{n}\frac{Q}{wh^2}$$

$$Q = \frac{wh^3}{12\mu}\left(\frac{\Delta P}{\Delta L}\right)$$

$$\tau = K\dot{\gamma}^n$$

$$\frac{\Delta l}{l_0} = \alpha_l \Delta T$$

$$\frac{\Delta v}{v_0} = \alpha_v \Delta T$$

$$\sigma = E\varepsilon$$