DEDAN KIMATHI UNIVERSITY OF TECHNOLOGY

UNIVERSITY EXAMINATIONS 2021/2022 ACADEMIC YEAR
FIRST YEAR FIRST SEMESTER EXAMINATION FOR THE DEGREE OF MASTER OF SCIENCE IN MACHINE TOOL DESIGN AND MANUFACTURING

EMM 6102 POLYMER TECHNOLOGY

DATE: 23RD AUGUST 2021 **TIME: 10:00AM-1:00PM**

INSTRUCTIONS

1. This paper contains **FOUR** questions. Question 1 is COMPULSORY.
2. Answer Question 1 and any other two questions.
3. All symbols have usual meaning unless otherwise stated.

QUESTION 1 - 40 MARKS (COMPULSORY)

(a) In polymerization process, differentiate between;
- (i) Addition and condensation polymers (2 Marks)
- (ii) Inhibitors and retarders (2 Marks)
- (iii) Fillers and plasticizers (2 Marks)

(b) (i) Differentiate between monofunctional and a bifunctional polymerization. (1 Mark)

(ii) Using appropriate examples show that a monofunctional group cannot lead to the propagation of a polymer chain as a bifunctional group will do. (5 Marks)

(c) Explain in detail how the following factors affect the glass transition temperature (T_g) of polymers.
- (i) Chain flexibility (3 Marks)
- (ii) Geometric factors (3 Marks)

(d) Dynamic mechanical experiments are often carried out to gain insight into some mechanical properties of plastics.
- (i) Define the term dynamic mechanical experiments. (1 Mark)
- (ii) With the aid of a sketch, describe how the torsion pendulum experiment is carried out on a plastic specimen. (4 Marks)
- (iii) Explain some useful information about the plastic that can be derived from such experiment. (3 Marks)

(e) (i) Polypropylene has an elastic modulus of 1.378 GPa and Poisson's ratio of 0.32. For a strain of 0.05, calculate the shear stress and the percentage change in volume. (5 Marks)

(ii) The mechanical properties of nylon 66 vary with its moisture content. A nylon specimen with moisture content (MC) of 2.5% has an elastic modulus of 1.2 GN/m^2, while that for a sample of moisture content of 0.2% is 2.8 GN/m^2. Calculate the elastic energy or work per unit volume in each sample subjected to a tensile strain of 10%. The formulae to be used should first be derived.

(5 Marks)

(f) Explain the following observations.

(i) LDPE is used mainly as thin film for packaging and sheets while HDPE is used predominantly in injection molding of crates, pails, tubs, and automobile gas tanks.

(2 Marks)

(ii) PVC has an advantage over other thermoplastic polyolefins in applications such as insulation for electrical circuitry in household electronic appliances.

(2 Marks)

QUESTION 2 - 30 MARKS

(a) In contrast to materials like metals and ceramics, the modulus of polymers shows strong dependence on temperature.

(i) With the aid of a schematic modulus-temperature curve for a linear amorphous polymer illustrating this dependence, explain the different regions of viscoelastic behavior.

(6 Marks)

(ii) Explain in detail how such modulus-temperature curve will change with molecular weight of specific polymers.

(4 Marks)

(b) (i) The effect of crystallinity on modulus becomes readily understandable on the basis of two concepts. Define crystallinity and briefly explain the concepts.

(3 Marks)

(ii) With the aid of a schematic modulus-temperature curve for various degrees of crystallinity, explain the effect of crystallinity on modulus of polymers as temperature increases.

(5 Marks)

(c) Briefly describe the following types of polymer degradation and their effects. Give two examples of common materials that are usually affected in each case.

(i) Photo Induced (3 Marks)

(ii) Thermal (3 Marks)

(ii) Chlorine Induced (3 Marks)

(d) The theoretical fracture strength of a material can be deduced from the cohesive forces between the component atoms in the plane under consideration from a simple energy balance between the work to fracture and the energy require to create two new surfaces.

(i) Give the formula for theoretical cohesive strength of a material and explain the terms.

(2 Marks)

(ii) Explain why engineering materials, including polymers, generally have low fracture strengths relative to their theoretical capacity.

(1 Mark)

QUESTION 3 - 30 MARKS

(a) Briefly explain the following tests carried out on plastic specimens. In addition, state and define the parameter of interest in each case.

(i) Creep (2.5 Marks)

(ii) Stress relaxation (2.5 Marks)

(b) Consider both the Maxwell and Voigt models for linear viscoelastic response. In each case;

(i) Sketch the arrangement of the spring-dashpot system representing the model.

(2 Marks)

(ii) Derive the general expression for the relevant rheological equation.

(5 Marks)

(iii) Derive the expression for the relevant equation in a creep.

(6 Marks)

(c) A polystyrene sample of 0.02 m^2 cross-sectional area is subjected to a creep load of 10^5 N. The load is removed after 30 s. Assuming that the Maxwell element accurately describes the behavior of polystyrene and that viscosity is $5X10^9$ $N.s/m^2$, while Young's modulus is 3.45 GPa, calculate:

(i) The compliance (2 Marks)

(ii) The deformation recovered on the removal of the dead load (2 Marks)

(iii) The permanent set (2 Marks)

(d) (i) Briefly explain the three types of internal stresses that occur in amorphous polymers. (4.5 Marks)

(ii) Name three properties that lead to buildup of cooling stresses in plastic parts during their manufacture.

(1.5 Marks)

QUESTION 4 - 30 MARKS

(a) Briefly describe the following fiber materials used as reinforcement materials in composites. Mention some of their desirable and/or undesirable properties and specific applications.

(i) Glass (3 Marks)

(ii) Carbon (3 Marks)

(b) (i) Differentiate between multi-end rovings and prepreg forms of reinforcements in fiber reinforced composites. Mention two other commonly used forms of reinforcements.

(3 Marks)

(ii) Shear failure may be considered as a characteristic mode of failure in fiber reinforced composites under longitudinal compression. List any other three characteristic modes of failure in the case.

(3 Marks)

(c) (i) After the separation of petroleum by fractional distillation, further refinement of certain fractions to form petrochemicals is required. Explain the three most common sources from which petrochemicals are derived.

(4.5 Marks)

(ii) With the aid of a simplified flow diagram, show the main polymers produced from ethylene as a basic petrochemical.

(4.5 Marks)

(d) When it comes to industrial production of polymers, some issues may arise that are not really associated with laboratory polymerization process.

(i) Briefly explain the process of homogeneous bulk polymerization.

(3 Marks)

(ii) Explain three common drawbacks of homogeneous bulk polymerization making clear their root causes.

(6 Marks)

END!!