



NATIONAL UNIVERSITY OF SCIENCE AND TECHNOLOGY

FACULTY OF ENGINEERING

DEPARTMENT OF FIBRE AND POLYMER MATERIALS ENGINEERING

POLYMER MATERIALS ANALYSIS I

TFE 3106

First Semester Examination Paper

December 2024

This examination paper consists of 4 pages

Time Allowed: 3 hours
Total Marks: 100
Special Requirements: N/A
Examiner's Name: Dr. M. MOYO

INSTRUCTIONS

1. Answer **QUESTION 1** and **ANY OTHER THREE** Questions.
2. The first fifteen minutes should be spent reading the question paper and making notes.
3. **Do not** open your answer sheet until told to do so.
4. Marks will be awarded for skill in appreciating the scope of questions, clarity of argument and conciseness of presentation as well as for the knowledge displayed by a candidate.

MARK ALLOCATION

QUESTION	MARKS
1.	25
2.	25
3.	25
4.	25
5.	25

QUESTION 1

- a) A polymer composite material was tested for its behaviour to impact loading conditions using a Charpy impact testing machine. The results of the tested specimens are shown in Table Q1a).

Table Q1a) Charpy impact testing results

Test Number	Specimen thickness (mm)	Specimen width (mm)	Width after notch (mm)	Impact Energy absorbed (J)
Test 1	3.4	11.5	9.0	1.2204
Test 2	3.4	10.8	8.1	1.2204
Test 3	3.4	8.9	7.1	1.0848
Test 4	3.4	10.6	8.1	1.2204

Showing all your workings, determine the impact strength (including the associated standard deviation) of the polymer composite material according to the:

- ASTM standard. [3 Marks]
 - ISO standard. [4 Marks]
- b) Explain the importance of the following properties in any **one** specific real-life application:
- barrier and permeation properties of materials. [3 Marks]
 - resistance to accelerated weathering. [3 Marks]
 - tribology properties. [3 Marks]
- c) Discuss the macroscopic fracture profiles A, B and C shown in Figure Q1c) and cite any two specific materials that follow those fracture profiles.

[9 Marks]

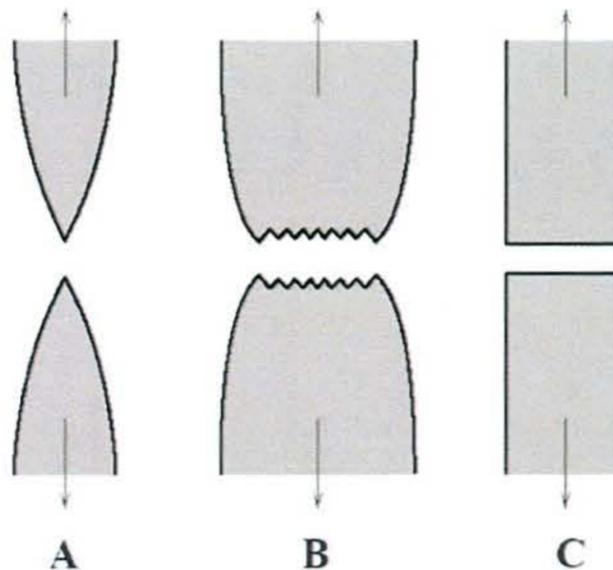


Figure Q1c) Macroscopic fracture profiles

QUESTION 2

- a) Define Thermogravimetric Analysis (TGA) and explain its significance in polymer material analysis. **[4 Marks]**
- b) A Dynamic Mechanical Analysis (DMA) test on a fibre-reinforced polymer composite reveals that the storage modulus drops significantly at 150°C, loss modulus peaks at 160°C and tan delta (δ) peak is broad and occurs at 170°C. Interpret the material's thermal behaviour and potential applications. **[5 Marks]**
- c) Elucidate any **three** reasons for the importance of knowing the thermal stability of polymers in industrial applications. **[6 Marks]**
- d) With the help of well-labelled sketches of typical curves for loss modulus and tandelta, discuss the importance of the information gathered from analysing loss modulus and tandelta of a material. **[10 Marks]**

QUESTION 3

- a) With the help of a diagram, describe the stress-strain curve of a typical thermoplastic polymer and explain its **four** key regions. **[6 Marks]**
- b) A polymer sample shows different mechanical properties in two directions. Explain what causes this and how it can be analysed. **[4 Marks]**
- c) During a tensile strength test, a polymer sample broke at a stress of 50 MPa and strain of 200%. Evaluate this polymer's mechanical properties and explain its potential applications. **[4 Marks]**
- d) Tensile strength of a composite material was tested on a Universal Testing Machine. Table Q3d) shows an extract of the results obtained.

Table Q3d) Extract of the tensile strength results

Crosshead displacement (mm)	Load (kN)	Time (s)
0.121	0.063	3.624

The dimensions of the specimen were as follows:

Specimen length (mm)	250
Gauge length (mm)	150
Width (mm)	25
Thickness (mm)	3.6

Calculate:

- i. the crosshead speed. **[3 Marks]**
- ii. strain rate. **[3 Marks]**
- iii. Young's modulus of the biocomposite (in GPa). **[5 Marks]**

QUESTION 4

- a) Using any **two** real life applications, explain the importance of a material's resistance to high velocity impact loading. **[4 Marks]**
- b) High velocity impact testing was performed on a biopolymer composite material using a laboratory high speed gas gun. A hemispherical shaped mild steel projectile of mass 7.34 g, diameter of 9.6 mm and length of 15.5 mm was used during the test. Figure Q4b) shows a plot of the biopolymer composite material's residual energy against impact energy.

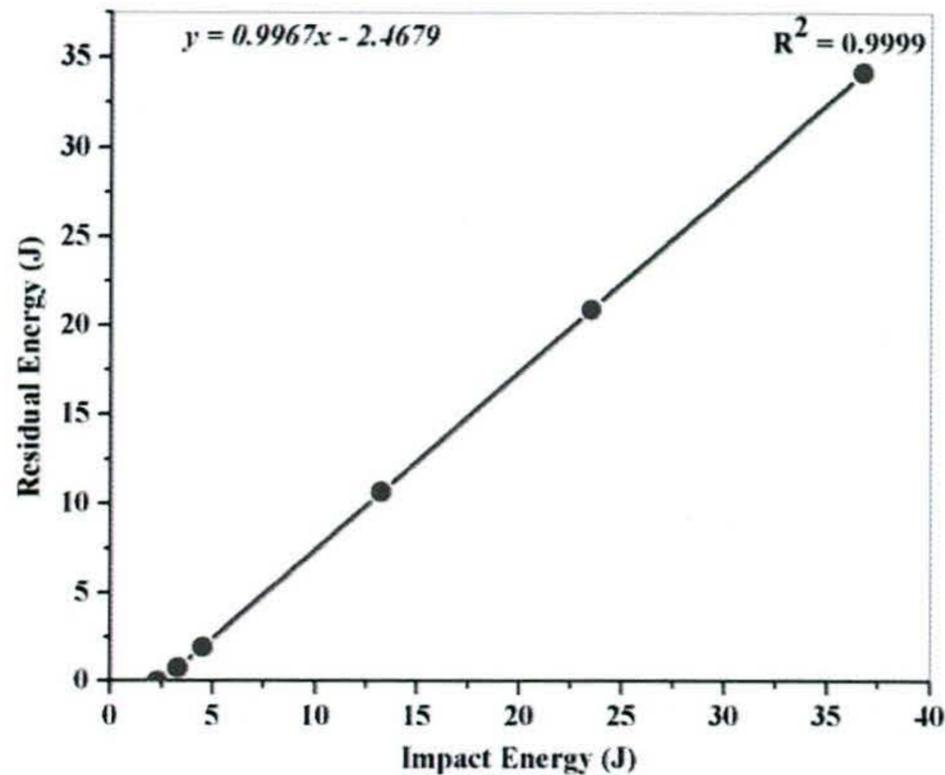


Figure Q4b) Plot of residual energy against impact energy

Using information from Figure Q4b) and showing all your calculations:

- Deduce the ballistic limit of the material tested. **[5 Marks]**
- Determine the impact energy, residual energy and energy absorbed by the biopolymer composite material, given that the impact velocities of the projectile were 30 m/s, 35 m/s, 60 m/s, 80 m/s and 100 m/s. Present your final answers in form of a table. **[12 Marks]**
- Explain the general energy absorption behaviour of the biopolymer composite material. **[4 Marks]**

QUESTION 5

- a) Describe the distinct stages of fatigue failure. **[5 Marks]**
- b) Discuss the principle of operation of the following instruments in fibre analysis:
- Advanced fibre information system (AFIS). **[5 Marks]**
 - High volume instrument (HVI). **[5 Marks]**

- c) Evaluate the occurrence and effects of cyclic loading in any **two** real life applications of polymeric materials and proffer any **two** possible solutions to alleviate the mentioned effects. **[10 Marks]**

END OF EXAMINATION QUESTION PAPER

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