Loughborough University

24MPC114
Composite Materials

Semester 2 2024/25 — In-Person Exam paper

This examination is to take place in-person at a central University venue under exam conditions. The standard length of time for this paper is **2 hours**.

You will not be able to leave the exam hall for the first 30 or final 15 minutes of your exam. Your invigilator will collect your exam paper when you have finished.

<u>Help during the exam</u>

Invigilators are not able to answer queries about the content of your exam paper. Instead, please make a note of your query in your answer script to be considered during the marking process.

If you feel unwell, please raise your hand so that an invigilator can assist you.

You may use a calculator for this exam. It must comply with the University's Calculator Policy for In-Person exams, in particular that it must not be able to transmit or receive information (e.g. mobile devices and smart watches are **not** allowed).

You are required to answer **ALL** three questions.

A formula sheet is provided at the end of the paper.

1. The polymer infiltration and pyrolysis (PIP) process is used to produce continuous silicon carbide (SiC) fibre-reinforced SiC composite.

    (a) Define the PIP process. [3 marks]

    (b) Discuss the advantages of this processing route. [6 marks]

    (c) Discuss the disadvantages of this processing route. [4 marks]

    (d) Describe toughening mechanisms for this composite. [7 marks]

2. (a) Pressure infiltration (also known as squeeze casting) is used to produce silicon carbide (SiC) fibre-reinforced aluminium (Al) composite.

   (i) Describe and illustrate the procedures of this process. [6 marks]

   (ii) Discuss the advantages of this process. [6 marks]

   (iii) Discuss the disadvantages of this process. [1 mark]

   (b) The continuous Al_2O_3 fibre-reinforced Ti composite will be produced using a solid-state process.

   (i) Define the appropriate technique and describe the relevant procedures for producing the composite. [3 marks]

   (ii) Discuss the advantages and disadvantages of this processing route. [4 marks]

3. (a) A unidirectional and continuous fibre reinforced polymer matrix composite (PMC) is made from materials with the following mechanical properties. The volume fraction (V_f) of fibres is 0.4. Assume that there is linear stress/strain (constant modulus) behaviour for both matrix and fibre.

	Fibres	**Matrix**
Young's (tensile) modulus	E_f = 80 GPa	E_m = 2 GPa
Failure stress (strength)	$\sigma_f{}^*$ = 1.60 GPa	$\sigma_m{}^*$ = 0.10 GPa

(i) Calculate both the longitudinal and transverse moduli of this composite. Give your answers to two significant figures [3 marks]

(ii) Calculate both the minimum fibre volume fraction (V_{min}) and the critical fibre volume fraction (V_{crit}). Give your answers to two significant figures. [5 marks]

(iii) Calculate the longitudinal tensile failure stress (strength) of the composites, $\sigma_c{}^*$. Give your answers to two significant figures. [2 marks]

(iv) State and explain the functions of the polymers used in PMCs. [3 marks]

(v) Explain why fibres are used as the reinforcement for PMC. [3 marks]

(b) Describe the functions of an interphase coating on ceramic fibres in the production of ceramic matrix composites. [4 marks]

END OF PAPER

Dr H Zhang

24MPC114 Examination – Formula Sheet

Unidirectional composites with continuous aligned fibres

- Tensile modulus in Longitudinal & Transverse directions

$$E_c = E_f V_f + E_m V_m \qquad 1/E_c = V_f / E_f + V_m / E_m$$

Brittle fibres in a ductile matrix: $\varepsilon_f^* < \varepsilon_m^*$

- Fibre-controlled and matrix-controlled

$$\sigma_c{}^* = \sigma_f{}^* V_f + \sigma_m{}'(1 - V_f) \qquad \sigma_c{}^* = \sigma_m{}^*(1 - V_f)$$

$$V_{min} = \frac{\sigma_m{}^* - \sigma_m{}'}{\sigma_f{}^* + \sigma_m{}^* - \sigma_m{}'}$$

$$V_{crit} = \frac{\sigma_m{}^* - \sigma_m{}'}{\sigma_f{}^* - \sigma_m{}'}$$

Ductile fibres in a brittle matrix

- Fibre-controlled and matrix-controlled in longitudinal direction

$$\sigma_c{}^* = \sigma_f{}^* V_f \qquad \sigma_c{}^* = \sigma_f{}' V_f + \sigma_m * (1 - V_f)$$

$$V_{min} = \frac{\sigma_m{}^*}{\sigma_f{}^* + \sigma_m{}^* - \sigma_f{}'}$$