

ENGG2120 Fall 2011
Chapter 16 Assignment with Answers

1. What are composite materials?

Answer:

Composites are produced multiphase materials having desirable combinations of the best properties of the constituent phases. Usually there is one continuous phase called matrix and another dispersed phase called filler/reinforcement.

2. Categorize the fiber reinforced composites based on orientation and length of the fibers?

Answer:

There are four types namely

1. Aligned short fiber
2. Aligned long fiber
3. Random short fiber
4. Fiber in Fabric form

3. Cite an example for particle reinforced composites.

Answer:

Automobile tires (carbon reinforced rubber)

4. Write down the composition of concrete? What is the significance of sand in a concrete?

Answer:

Composition of concrete \longrightarrow (Gravel + sand + cement). Sand fills up the voids in the gravel.

5. If a matrix has elastic modulus E_m and reinforcement has the elastic modulus E_r , then write down the expression for calculating theoretical modulus of composites by rule of mixture. (V_m and V_r are the volume fraction of the matrix and the reinforcements, respectively)

Answer:

$$E_c = V_m E_m + V_r E_r,$$

Where E_c is the modulus of the composite.

6. Write down the expression for critical length of the fiber.

Answer:

$$l_c = \frac{\sigma_f d}{\tau_c}$$

σ_f - Fiber strength in tension

d - Fiber diameter

τ_c - Shear strength of fiber-matrix interface

7. Write down the advantages of sandwich panels?

Answer:

Low density and large bending stiffness

8. Give an example of composite where both the matrix and reinforcements are ceramics.

Answer: Glass reinforced with SiC fibers

9. A snow ski is an example of _____ composite.

Answer: structural

10. A *cermet* is a composite material composed of _____ & _____.

Answer:

Ceramic (cer) and metallic (met) materials

11. Write down the full forms for MMC, PMC and CMC

Answer:

MMC- Metal Matrix Composites

PMC- Polymer Matrix Composites

CMC- Ceramic Matrix Composites

12. Estimate the maximum and minimum thermal conductivity values for a cermet that contains 85 vol% titanium carbide (TiC) particles in a cobalt matrix (Co). Assume thermal conductivities of 27 and 69 W/m-K for TiC and Co respectively.

Answer:

This problem asks for the maximum and minimum thermal conductivity values for a TiC, Co cermet. Using equation $k_{\max} = k_m V_m + k_p V_p$ the maximum thermal conductivity

k_{\max} is calculated as

$$\begin{aligned} k_{\max} &= k_m V_m + k_p V_p = k_{\text{Co}} V_{\text{Co}} + k_{\text{TiC}} V_{\text{TiC}} \\ &= (69 \text{ W/m-K})(0.15) + (27 \text{ W/m-K})(0.85) = 33.3 \text{ W/m-K} \end{aligned}$$

Using equation $k_{\min} = \frac{k_p k_m}{V_p k_m + V_m k_p}$ the minimum thermal conductivity k_{\min} will be

$$\begin{aligned} k_{\min} &= \frac{k_{\text{Co}} k_{\text{TiC}}}{V_{\text{Co}} k_{\text{TiC}} + V_{\text{TiC}} k_{\text{Co}}} \\ &= \frac{(69 \text{ W/m-K})(27 \text{ W/m-K})}{(0.15)(27 \text{ W/m-K}) + (0.85)(69 \text{ W/m-K})} \\ &= 29.7 \text{ W/m-K} \end{aligned}$$

13. A continuous and aligned fiber-reinforced composite is to be produced consisting of 30 vol% of aramid fibers and 70 vol% of a polycarbonate matrix; mechanical characteristics of these two materials are as follows:

	Modulus of Elasticity [GPa]	Tensile Strength [MPa]
Aramid fiber	131	3600
Polycarbonate	2.4	65

Also, the stress on the polycarbonate matrix when the aramid fibers fail is 45 MPa.

For this composite, compute

The longitudinal tensile strength

The longitudinal modulus of elasticity

Answer:

This problem calls for us to compute the longitudinal tensile strength and elastic modulus of an aramid fiber-reinforced polycarbonate composite.

(a) The longitudinal tensile strength is determined using Equation

$$\begin{aligned}\sigma_{cl}^* &= \sigma_m^*(1-V_f) + \sigma_f^*V_f \\ \sigma_{cl}^* &= (45 \text{ MPa})(0.70) + (3600)(0.30) \\ &= 1100 \text{ MPa}\end{aligned}$$

(b) The longitudinal elastic modulus is computed using Equation

$$\begin{aligned}E_{cl} &= E_mV_m + E_fV_f \\ &= (2.4 \text{ GPa})(0.70) + (131 \text{ GPa})(0.30) \\ &= 41 \text{ GPa}\end{aligned}$$

14. Compute critical length of fiber in glass fiber-epoxy matrix composite in which the average fiber diameter and length are 0.010 mm and 2.5 mm, respectively. Assume that (1) the fiber-matrix bond strength is 75 MPa, (2) the fracture strength of the fibers is 3500 MPa.

Answer:

The of the critical fiber length is given by using equation $l_c = \frac{\sigma_f^* d}{2\tau_c}$

Given

Diameter of fiber = 0.010 mm

Fiber-matrix bond strength = 75 MPa

Fracture strength of the fibers = 3500 MPa.

Thus,

$$l_c = \frac{\sigma_f^* d}{2\tau_c} = \frac{(3500 \text{ MPa})(0.010 \text{ mm})}{2(75 \text{ MPa})} = 0.233 \text{ mm}$$

15. For a polymer-matrix fiber-reinforced composite,

- List three functions of the matrix phase.
- Compare the desired mechanical characteristics of matrix and fiber phases.
- Cite two reasons why there must be a strong bond between fiber and matrix at their interface.

Answer:

a) For polymer-matrix fiber-reinforced composites, three functions of the polymer-matrix phase are:

1. To bind the fibers together so that the applied stress is distributed among the fibers
2. To protect the surface of the fibers from being damaged
3. To separate the fibers and inhibit crack propagation.

b) The matrix phase must be ductile and is usually relatively soft, whereas the fiber phase must be stiff and strong.

c) There must be a strong interfacial bond between fiber and matrix in order to:

1. Maximize the stress transmittance between matrix and fiber phases
2. Minimize fiber pull-out, and the probability of failure.

16. a) Briefly describe sandwich panels.

b) What is the prime reason for fabricating structural composites?

c) What are the functions of the faces and the core?

Answer:

a. Sandwich panels consist of two outer face sheets of a high-strength material that are separated by a layer of a less-dense and lower-strength core material.

b. The prime reason for fabricating these composites is to produce structures having high in-plane strengths, high shear rigidities, and low densities.

c. The faces function so as to bear the majority of in-plane tensile and compressive stresses. On the other hand, the core separates and provides continuous support for the faces, and also resists shear deformations perpendicular to the faces.

17. For a continuous and oriented fiber-reinforced composite, the moduli of elasticity in the longitudinal and transverse directions are 19.7 and 3.66 GPa, respectively. If the volume fraction of fibers is 0.25, determine the moduli of elasticity of fiber and matrix phases.

Answer:

This problem asks for us to compute the elastic moduli of fiber and matrix phases for a continuous and oriented fiber-reinforced composite. We can write expressions for the longitudinal elastic modulus using Equations

$$E_{cl} = E_m(1 - V_f) + E_f V_f$$
$$19.7 \text{ GPa} = E_m(1 - 0.25) + E_f(0.25)$$

And transverse elastic modulus

$$E_{ct} = \frac{E_m E_f}{(1 - V_f)E_f + V_f E_m}$$
$$3.66 \text{ GPa} = \frac{E_m E_f}{(1 - 0.25)E_f + 0.25E_m}$$

Solving these two expressions simultaneously for E_m and E_f leads to

$$E_m = 2.79 \text{ GPa}$$

$$E_f = 70.4 \text{ GPa}$$