9.2 The reinforcing phase is the matrix within which the secondary phase is imbedded: (a) true or (b) false?

Answer. (b).

9.3 Which one of the following reinforcing geometries offers the greatest potential for strength and stiffness improvement in the resulting composite material: (a) fibers, (b) flakes, (c) particles, or (d) infiltrated phase?

Answer. (a).

9.4 Wood is which one of the following composite types: (a) CMC, (b) MMC, or (c) PMC?

Answer. (c).

9.5 Which of the following materials are used as fibers in fiber-reinforced plastics (four best answers): (a) aluminum oxide, (b) boron, (c) cast iron, (d) E-glass, (e) epoxy, (f) Kevlar 49, (g) polyester, and (h) silicon?

Answer. (a), (b), (d), and (f).

9.6 Which of the following metals are used as the matrix material in fiber-reinforced MMCs (two best answers): (a) aluminum, (b) copper, (c) iron, (d) magnesium, and (e) zinc?

Answer. (a) and (d).

9.7 Which of the following metals are used as the matrix metals in nearly all WC cemented carbides and TiC cermets (two correct answers): (a) aluminum, (b) chromium, (c) cobalt, (d) lead, (e) nickel, (f) tungsten, and (g) tungsten carbide?

Answer. (c) and (e).

9.8 Ceramic matrix composites are designed to overcome which of the following weaknesses of ceramics (two best answers): (a) compressive strength, (b) hardness, (c) hot hardness, (d) modulus of elasticity, (e) tensile strength, and (f) toughness?

Answer. (e) and (f).

9.9 Which one of the following polymer types are most commonly used in polymer matrix composites: (a) elastomers, (b) thermoplastics, or (c) thermosets?

Answer. (c).

9.10 Which of the following materials are not composites (two correct answers): (a) cemented carbide, (b) phenolic molding compound, (c) plywood, (d) Portland cement, (e) rubber in automobile tires, (f) wood, and (g) 1020 steel?

Answer. (d) and (g).

In the Boeing 787 Dreamliner, what percentage of the aircraft consist of composite materials (two correct answers): (a) 12% be volume, (b) 20% by volume, (c) 50% by volume, (d) 80% by volume, (e) 12% by weight, (f) 20% by weight, (g) 50% by weight, and (h) 80% by weight?

Answer. (d) and (g).

Problems

9.1 A fiberglass composite is composed of a matrix of vinyl ester and reinforcing fibers of E-glass. The volume fraction of E-glass is 35%. The remainder is vinyl ester. The density of the vinyl ester is 0.882 g/cm^3, and its modulus of elasticity is 3.60 GPa. The density of E-glass is 2.60 g/cm^3, and its modulus of elasticity is 76.0 GPa. A section of composite 1.00 cm by 50.00 cm by 200.00 cm is fabricated with the E-glass fibers running longitudinal along the 200-cm direction. Assume there

are no voids in the composite. Determine the (a) mass of vinyl ester in the section, (b) mass of E-glass fibers in the section, and (c) the density of the composite.

Solution: Volume V = (1.00 cm)(50.00 cm)(200.00 cm) = 10,000 cm^3

(a) $V_m = f_m\,(V_c)$ = 0.650(10,000 cm^3) = 6,500 cm^3
m_m = 6500 cm^3 (0.882 g/cm^3) = 5733 g

(b) $V_r = f_r\,(V_c)$ = 0.350(10,000 cm^3) = 3,500 cm^3
m_r = 3500 cm^3 (2.60 g/cm^3) = 9100 g

(c) $\rho_c = = f_m\,\rho_m + f_r\,\rho_r$ = 0.650(0.882) + 0.350(2.60) = **1.48 g/cm^3**

9.2 For problem 9.1, determine the modulus of elasticity in (a) the longitudinal direction of the glass fibers and (b) the perpendicular direction to the glass fibers.

Solution: f_m = 0.650, f_r = 0.350, E_m = 3.60 GPa, and E_r = 76.0 GPa

(a) $E_c = f_m E_m + f_r E_r$
E_c = 0.650(3.60) + 0.350(76.0) = **28.9 GPa**

(b) $E_c' = E_m E_r/(f_m E_r + f_r E_m)$
E_c' = 3.60(76.0)/(0.650(76.0) + 0.350(3.60)) = **5.40 GPa**

9.3 A composite sample of carbon reinforced epoxy has dimensions of 12 in by 12 in by 0.25 in and mass of 1.8 lb. The carbon fibers have a modulus of elasticity of 50(10^6) lb/in^2 and a density of 0.069 lb/in^3. The epoxy matrix has modulus of elasticity of 0.61(10^6) lb/in^2 and a density of 0.042 lb/in^3. What is the volume fraction of (a) the carbon fibers and (b) the epoxy matrix in the sample? Assume there are no voids in the sample.

Solution: V_c = 12(12)(0.25) = 36 in^3
$\rho_c = m_c/V_c$ = 1.8/36 = 0.050 lb/in^3

(a) $f_m = 1 - f_r$
$\rho_c = f_m\rho_m + f_r\rho_r$
$\rho_c = (1\text{-}f_r)\rho_m + f_r\rho_r$
$\rho_c = \rho_m - f_r\rho_m + f_r\rho_r = \rho_m - f_r(\rho_m - \rho_r)$
$f_r = (\rho_m - \rho_c)/(\rho_m - \rho_r)$ = (0.042 – 0.050)/(0.042 – 0.069) = **0.30 = 30%**

(b) $f_m = 1 - f_r$ $\quad f_m$ = 1- 0.30 = **0.70 = 70%**

9.4 In problem 9.3, what is the predicted value for the modulus of elasticity (a) in the longitudinal direction and (b) the perpendicular to the carbon fibers?

Solution: f_m = 0.70, f_r = 0.30, E_m = 0.61x10^6 lb/in^2, and E_r = 50.0x10^6 lb/in^2

(a) $E_c = f_m E_m + f_r E_r$ $\quad E_c$ = 0.70(0.61x10^6) + 0.30(50.0x10^6) = **15 x 10^6 lb/in^2**

(b) $E_c' = E_m E_r/(f_m E_r + f_r E_m)$
E_c' = 0.61(10^6)(50.0(10^6)/(0.70(50.0x10^6) + 0.30(0.61x10^6)) = **0.87 x 10^6 lb/in^2**

9.5 A composite has a matrix of polyester with Kevlar-29 fibers. The volume fractions of polyester and Kevlar are 60% and 40%, respectively. The Kevlar fibers have a modulus of elasticity of 60 GPa in the longitudinal direction and 3 GPa in the transverse direction. The polyester matrix has a modulus of elasticity of 5.6 GPa in both directions. (a) Determine the modulus of elasticity for the composite in the longitudinal direction. (b) Determine the modulus of elasticity in the transverse direction.

Solution: f_m = 0.60, f_r = 0.40, E_m = 5.6 GPa, and E_r = 60 GPa

(a) $E_c = f_m E_m + f_r E_r$ $\quad E_c$ = 0.60(5.6) + 0.40(60) = **27.4 GPa**

(b) $E_c' = E_m E_r/(f_m E_r + f_r E_m)$ $E_c' = 5.6(60)/(0.60(60) + 0.40(5.6)) =$ **8.79 GPa**