

Materials and Manufacturing for
Niche Markets M6X04201 1pm
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- ① a) ▷ Primary / Matrix phase
▷ Secondary / Reinforcement phase

The primary phase can be used to classify composites into groups depending upon the its material type eg

- MMC - Metal matrix composite
- CMC - Ceramic matrix composite
- PMC - Polymer matrix composite

The Secondary phase can take different forms

- Fibres give opportunity for strength enhancement by taking a higher amount of the stress applied to the composite. Fibres can be woven into 1D, 2D or 3D fabrics or arranged randomly such as in Chopstrand mat. Chopstrand mat also provides example of discontinuous fibre reinforcement compared with woven fabrics

~~Carbon epoxy composites~~ are an example of fibre reinforcement

- Particulates are ~~are~~ randomly arranged within the matrix giving the composite isotropic material properties that are generally weaker than fibre reinforcement. The Particulates can be micro or macroscopic. Graphite is an example of ~~of~~ particulate reinforcement

① a) - flakes are in many ways similar to particles, other than they are 2 dimensional

b) $\Delta c = \Delta f + \Delta m$

$$\therefore t_c \epsilon_c = t_f \epsilon_f + t_m \epsilon_m$$

because $\epsilon = \frac{\sigma}{E}$ this can be written as

$$t_c \frac{\sigma_c}{E_c} = t_f \frac{\sigma_f}{E_f} + t_m \frac{\sigma_m}{E_m}$$

~~Because~~

$$\frac{t_c \sigma_c}{E_c} = \frac{t_f \sigma_f}{E_f} + \frac{t_m \sigma_m}{E_m}$$

$$\frac{t_c}{E_c} = \frac{t_f}{E_f} + \frac{t_m}{E_m}$$

$$\frac{1}{E_c} = \frac{1}{E_f} \frac{t_f}{t_c} + \frac{1}{E_m} \frac{t_m}{t_c}$$

$$\frac{1}{E_c} = \frac{1}{E_f} \frac{t_f h L_c}{t_c h L_c} + \frac{1}{E_m} \frac{t_m h L_c}{t_c h L_c}$$

$$\frac{1}{E_c} = \frac{1}{E_f} \frac{V_f}{V_c} + \frac{1}{E_m} \frac{V_m}{V_c}$$

$$\frac{1}{E_c} = \frac{1}{E_f} V_f + \frac{1}{E_m} V_m = \frac{V_f}{E_f} + \frac{V_m}{E_m}$$

① c)
$$\frac{1}{E_2} = \frac{0.7}{85 \times 10^9} + \frac{0.3}{2.5 \times 10^9}$$

$$\frac{1}{E_2} = 1.28235 \dots \times 10^{-10} \quad \boxed{A}$$

$$E_2 = 7.80 \text{ GPa}$$

② a)

$$\begin{bmatrix} \epsilon_1 \\ \epsilon_2 \\ \epsilon_3 \\ \gamma_{23} \\ \gamma_{31} \\ \gamma_{12} \end{bmatrix} = \begin{bmatrix} S_{11} & S_{12} & S_{13} & 0 & 0 & 0 \\ S_{12} & S_{22} & S_{23} & 0 & 0 & 0 \\ S_{13} & S_{23} & S_{33} & 0 & 0 & 0 \\ 0 & 0 & 0 & S_{44} & 0 & 0 \\ 0 & 0 & 0 & 0 & S_{55} & 0 \\ 0 & 0 & 0 & 0 & 0 & S_{66} \end{bmatrix} \begin{bmatrix} \sigma_1 \\ \sigma_2 \\ \sigma_3 \\ \tau_{23} \\ \tau_{31} \\ \tau_{12} \end{bmatrix}$$

if $\sigma_1 \neq 0$ & $\sigma_2 = \sigma_3 = \tau_{23} = \tau_{31} = \tau_{12} = 0$

$$\epsilon_1 = S_{11} \sigma_1$$

$$\therefore S_{11} = \frac{\epsilon_1}{\sigma_1} = \frac{1}{E_1}$$

$$\epsilon_2 = S_{12} \sigma_1$$

$$S_{12} = \frac{\epsilon_2}{\sigma_1} = -\nu_{12} \frac{\epsilon_1}{\sigma_1} = \frac{-\nu_{12}}{E_1}$$

also

$$\epsilon_3 = S_{13} \sigma_1$$

$$S_{13} = \frac{\epsilon_3}{\sigma_1} = -\nu_{13} \frac{\epsilon_1}{\sigma_1} = \frac{-\nu_{13}}{E_1}$$

if $\sigma_2 \neq 0$ & $\sigma_1 = \sigma_3 = \tau_{23} = \tau_{31} = \tau_{12} = 0$

$$\epsilon_2 = S_{22} \sigma_2$$

$$S_{22} = \frac{\epsilon_2}{\sigma_2} = \frac{1}{E_2}$$

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(2a) also

$$\epsilon_3 = S_{23} \sigma_2$$

$$S_{23} = \frac{\epsilon_3}{\sigma_2} = \frac{-\nu_{23} \epsilon_2}{\sigma_2} = \frac{-\nu_{23}}{E_2}$$

if $\sigma_3 \neq 0$ & $\sigma_1 = \sigma_2 = \tau_{23} = \tau_{31} = \tau_{12} = 0$

$$\epsilon_3 = S_{33} \sigma_3$$

$$S_{33} = \frac{\epsilon_3}{\sigma_3} = \frac{1}{E_3}$$

if $\tau_{23} \neq 0$ $\sigma_1 = \sigma_2 = \sigma_3 = \tau_{31} = \tau_{12} = 0$

$$\gamma_{23} = S_{44} \tau_{23}$$

$$S_{44} = \frac{\gamma_{23}}{\tau_{23}} = \frac{1}{G_{23}}$$

if $\tau_{31} \neq 0$ $\sigma_1 = \sigma_2 = \sigma_3 = \tau_{23} = \tau_{12} = 0$

$$\gamma_{31} = S_{55} \tau_{31}$$

$$S_{55} = \frac{\gamma_{31}}{\tau_{31}} = \frac{1}{G_{31}}$$

if $\tau_{12} \neq 0$ $\sigma_1 = \sigma_2 = \sigma_3 = \tau_{23} = \tau_{31} = 0$

$$\gamma_{12} = S_{66} \tau_{12}$$

$$S_{66} = \frac{\gamma_{12}}{\tau_{12}} = \frac{1}{G_{12}}$$

2a)

$$[S] = \begin{bmatrix} \frac{1}{E_1} & -\frac{\nu_{12}}{E_1} & -\frac{\nu_{13}}{E_1} & 0 & 0 & 0 \\ -\frac{\nu_{12}}{E_1} & \frac{1}{E_2} & -\frac{\nu_{23}}{E_2} & 0 & 0 & 0 \\ -\frac{\nu_{13}}{E_1} & -\frac{\nu_{23}}{E_2} & \frac{1}{E_3} & 0 & 0 & 0 \\ 0 & 0 & 0 & \frac{1}{G_{23}} & 0 & 0 \\ 0 & 0 & 0 & 0 & \frac{1}{G_{31}} & 0 \\ 0 & 0 & 0 & 0 & 0 & \frac{1}{G_{12}} \end{bmatrix}$$

2b)

$$S_{11} = \frac{1}{175 \times 10^9} = 5.714 \times 10^{-12}$$

$$S_{12} = \frac{-0.2}{175 \times 10^9} = -1.143 \times 10^{-12} \quad \times$$

$$S_{13} = \frac{-0.2}{175 \times 10^9} = -1.143 \times 10^{-12} \quad \times$$

$$S_{22} = \frac{1}{10 \times 10^9} = 1 \times 10^{-10}$$

$$S_{23} = \frac{-0.4}{10 \times 10^9} = -4 \times 10^{-11} \quad \times$$

$$S_{33} = \frac{1}{10 \times 10^9} = 1 \times 10^{-10}$$

$$S_{44} = \frac{1}{2 \times 10^9} = 5 \times 10^{-10}$$

$$S_{55} = \frac{1}{6 \times 10^9} = 1.6 \times 10^{-10}$$

$$S_{66} = \frac{1}{6 \times 10^9} = 1.6 \times 10^{-10}$$

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$$\begin{aligned} \Sigma_1 &= (5.714 \times 10^{-12} \times 6 \times 10^9) + (1.143 \times 10^{-12} \times 6 \times 10^9) + (1.143 \times 10^{-12} \times 5 \times 10^9) \\ \Sigma_1 &= 0.033141 \end{aligned}$$

$$C_1 = 0.033141$$

The diagrams illustrate the three basic types of simple machines:

- Inclined Plane:** A right-angled triangle with a vertical line on the left, a horizontal line on the bottom, and a diagonal line on the right representing the slope.
- Pulley:** A circle with a horizontal line passing through its center, representing the rope or belt.
- Lever:** A horizontal line with a vertical line intersecting it at its midpoint, representing the fulcrum.

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④ a) Several plies are combined to form a laminate because

- a single lamina is ~ 0.2 mm thick there fore to obt produce anything with a use ful strength several plies lamina must be combined into a laminate

- a single lamina in a single orient orientation is weak in the transverse direction therefore the addition of more laminae in differing orientations ~~shows up the weak~~ reduces the weaknesses of the first lamina

b) Hygrothermal stresses and strains are caused by the ~~very~~ different thermal expansion coefficients as the part cools from processing at a micro mechanical level. They may also be caused by different water absorption properties of the two phases resulting in one phase swelling at a different rate to the other phase.

The Consequences of Hygrothermal Stresses and strains can include warping ~~of~~ distortion of the part or delamination between the fibre reinforcement and matrix phases. These stresses and strains can be negated in the design process by ensuring that the ply ~~orient~~ orientations are symmetrical

④ c) - As with any material in bending the second moment of area must be taken into account therefore the outer most plies would see a greater stress from the same load as than the central ply

* Ply orientations must be considered due to the orthotropic nature of each of the laminae and the fact that the longitudinal fibres (in the direction of the stress) will take a higher portion of the stress than the laminae where the fibres are transverse to the direction of the stress. This does not need to be considered when dealing with isotropic materials because by nature they will have the same material properties in any direction

- Inter laminar shear forces may cause delamination between plies causing them to become separate parts which could cause a smaller/larger stress concentration in other plies. This would not be seen in isotropic materials as there are no plies to delaminate

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