

One

a) Composite materials are composed from a combination of two or more ~~phases~~ materials, that fall into phases. The primary phase is the matrix, the classification of composites is based on the primary phase, as the matrix material change. Such as MMC (metal Matrix composite), CMC (ceramic matrix composite), PMC (polymeric matrix composite).

The second phase is a reinforcing material, and comes in the physical forms of fibres, particles and flakes. Fibres are filaments of reinforcement material, generally circular in diameter and can be different materials and are yarned, woven, roved or made into cloth or mat. Particles are second in commonality to fibres and are embedded within the primary phase and range in size, their distribution is random, often making material properties isotropic. Flakes are 2 dimensional particles and are cost less.

One

b)

$$\Delta_c = \Delta_f + \Delta_m$$

$$\epsilon = \frac{\Delta}{L}$$

$$\epsilon_c \epsilon_c = \epsilon_f \epsilon_f + \epsilon_m \epsilon_m$$

$$\epsilon = \frac{\sigma}{E}$$

$$\epsilon_c \frac{\sigma_c}{E_c} = \epsilon_f \frac{\sigma_f}{E_f} + \epsilon_m \frac{\sigma_m}{E_m}$$

$$\sigma_c = \sigma_f = \sigma_m$$

$$\frac{\epsilon_c}{E_c} = \frac{\epsilon_f}{E_f} + \frac{\epsilon_m}{E_m}$$

$$\times \epsilon_c$$

$$\frac{1}{E_c} = \frac{\epsilon_f}{E_f \epsilon_c} + \frac{\epsilon_m}{E_m \epsilon_c}$$

$$\frac{\epsilon_f}{\epsilon_c} = V_f \quad \frac{\epsilon_m}{\epsilon_c} = V_m$$

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

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

$$c) \quad \frac{1}{E_c} = \frac{V_f}{E_f} + \frac{V_m}{E_m} = \frac{0.75}{90 \times 10^9} + \frac{0.25}{2 \times 10^9} = 0.09166$$

$$E_c = ?$$

Two a)

ϵ_1	δ_{11}	δ_{12}	δ_{13}	0	0	0	σ_1
ϵ_2	δ_{12}	δ_{22}	δ_{23}	0	0	0	σ_2
ϵ_3	δ_{13}	δ_{23}	δ_{33}	0	0	0	σ_3
γ_{23}	0	0	0	δ_{44}	0	0	τ_{23}
γ_{31}	0	0	0	0	δ_{55}	0	τ_{31}
γ_{12}	0	0	0	0	0	δ_{66}	τ_{12}

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

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

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

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

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

$\epsilon_2 = \delta_{22} \sigma_2 \therefore \delta_{22} = \frac{\epsilon_2}{\sigma_2} = \frac{1}{E_2}$

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

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

$\epsilon_3 = \delta_{33} \sigma_3 \therefore \delta_{33} = \frac{\epsilon_3}{\sigma_3} = \frac{1}{E_3}$

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

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

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Two a) (continued)

$$\text{IF } \sigma_1 = \sigma_2 = \sigma_3 = \gamma_{23} = \gamma_{12} \quad \gamma_{31} \neq 0$$

$$\gamma_2 = \delta_{55} \gamma_{21} \quad \therefore \delta_{55} = \frac{\gamma_2}{\gamma_{21}} = \frac{1}{G_{31}}$$

$$\text{IF } \sigma_1 = \sigma_2 = \sigma_3 = \gamma_{23} = \gamma_{21} \quad \gamma_{12} \neq 0$$

$$\gamma_{12} = \delta_{66} \gamma_{12} \quad \therefore \delta_{66} = \frac{\gamma_{12}}{\gamma_{12}} = \frac{1}{G_{12}}$$

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

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Two

b)

$$S_{11} = \frac{1}{E_1} = \frac{1}{181 \times 10^9} = 5.525 \times 10^{-12} \text{ Pa}^{-1}$$

$$S_{12} = \frac{-\nu_{12}}{E_1} = \frac{-0.28}{181 \times 10^9} = -1.547 \times 10^{-12} \text{ Pa}^{-1}$$

$$S_{13} = \frac{-\nu_{13}}{E_1} = \frac{-0.27}{181 \times 10^9} = -1.492 \times 10^{-12} \text{ Pa}^{-1}$$

$$S_{22} = \frac{1}{E_2} = \frac{1}{10.3 \times 10^9} = 9.709 \times 10^{-11} \text{ Pa}^{-1}$$

$$S_{23} = \frac{-\nu_{23}}{E_2} = \frac{-0.6}{10.3 \times 10^9} = -5.825 \times 10^{-11} \text{ Pa}^{-1}$$

$$S_{33} = \frac{1}{E_3} = \frac{1}{10.3 \times 10^9} = 9.709 \times 10^{-11} \text{ Pa}^{-1}$$

$$S_{44} = \frac{1}{G_{23}} = \frac{1}{3 \times 10^9} = 3.333 \times 10^{-10} \text{ Pa}^{-1}$$

$$S_{55} = \frac{1}{G_{31}} = \frac{1}{7 \times 10^9} = 1.429 \times 10^{-10} \text{ Pa}^{-1}$$

$$S_{66} = \frac{1}{G_{12}} = \frac{1}{7.17 \times 10^9} = 1.395 \times 10^{-10} \text{ Pa}^{-1}$$

$$E_1 = 181 \text{ GPa}$$

$$E_2 = 10.3 \text{ GPa}$$

$$E_3 = 10.3 \text{ GPa}$$

$$\nu_{12} = 0.28$$

$$\nu_{23} = 0.60$$

$$\nu_{13} = 0.27$$

$$G_{12} = 7.17 \text{ GPa}$$

$$G_{23} = 3.00 \text{ GPa}$$

$$G_{31} = 7.0 \text{ GPa}$$

$$[S] = \begin{bmatrix} 5.525 \times 10^{-12} & -1.547 \times 10^{-12} & -1.492 \times 10^{-12} & 0 & 0 & 0 \\ -1.547 \times 10^{-12} & 9.709 \times 10^{-11} & -5.825 \times 10^{-11} & 0 & 0 & 0 \\ -1.492 \times 10^{-12} & -5.825 \times 10^{-11} & 9.709 \times 10^{-11} & 0 & 0 & 0 \\ 0 & 0 & 0 & 3.333 \times 10^{-10} & 0 & 0 \\ 0 & 0 & 0 & 0 & 1.429 \times 10^{-10} & 0 \\ 0 & 0 & 0 & 0 & 0 & 1.395 \times 10^{-10} \end{bmatrix} \text{ Pa}^{-1}$$

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Two

c) IF $\sigma_1 = 10 \text{ MPa}$

$\sigma_2 = -5 \text{ MPa}$

$\sigma_3 = 7 \text{ MPa}$

$$\therefore \epsilon_1 = S_{11} \sigma_1 + S_{12} \sigma_2 + S_{13} \sigma_3$$

$$= (5.525 \times 10^{-12} \times 10 \times 10^6) + (1.547 \times 10^{-12} \times -5 \times 10^6) - (1.492 \times 10^{-12} \times 7 \times 10^6)$$

$$= 5.25 \times 10^{-5} \text{ m}$$

Four

a) ~~For~~ A typical composite structure has several lamina stacked on top of each other to form a laminate. To create any meaningful strength, several lamina are combined to increase the thickness of the ~~overall~~ ~~the~~ laminate, as a single lamina is only 0.1-0.2mm thick.

The combination of lamina allows for ^{the} fibres ~~them~~ to be orientated and aligned ~~can~~ in the direction of stresses as a single lamina is weak in the transverse direction of the fibres.

B) Hydrothermal stresses and strains are caused by different thermal expansion coefficients of the matrix and reinforcement (first + second) phases. ^{on a microscopic level} These thermal coefficients are affected during thermal cycles of a composite most notably during the manufacturing process.

~~It is optimised for~~

The design process must consider this thermal effect and optimise to prevent warpage, shrinkage and other forms of deformation.

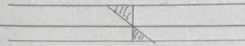
Hydrothermal stresses and strains also include the absorption of moisture as a result of the second phase which can lead to swelling of the phase at different rates to other phases.

B (continued)

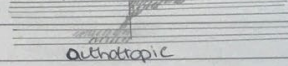
The design of the laminate must consider this as well ~~possibly~~ with an addition of Secondary finishing product application and requirements of component.

C)

monolithic isotropic



Composite laminate



Due to the anisotropic nature of a lamina, the stresses ~~are~~ distributed through the thickness of the laminate will differ based on the lamina's orientation as the vectors of the stresses change from lamina to lamina.

The ^{differing} Young's modulus ~~is~~ of ~~the diff~~ an anisotropic material means that the stresses change due to the vectors based on orientation. In comparison to an isotropic ~~and~~ material, properties do not differ, based on orientation or direction.

The stresses on each lamina differ due to their proximity to the neutral axis as a result of the second moment of inertia.