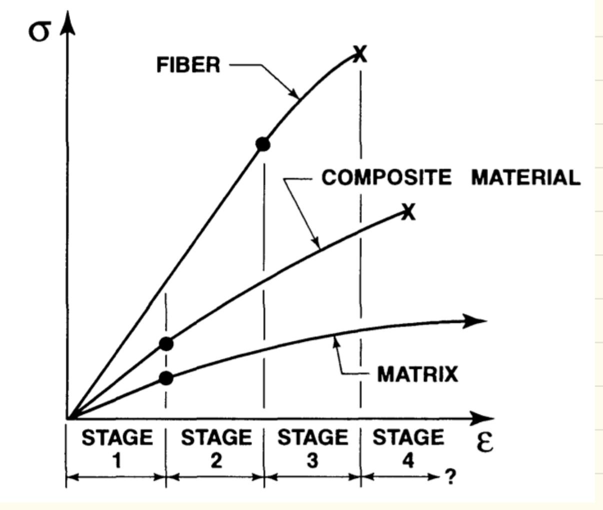
Composites   Lesson 5   بسم الله الرحمن الرحيم

Experimental methods to obtain the physical properties of the Composites will be studied in the next chapter.

2.5 - Tensile Strength in the Fiber Direction



1- Both fibers and matrix deform elastically

2- The fiber continue to deform elastically but the matrix deforms plastically

3- Both the fibers and the matrix deform plastically

4- The fibers fracture followed by fracture of the composite material

More than a certain minimum volume fraction of fibers (v_f) ultimate strength of composite is achieved when the fibers are strained to correspond to their maximum (ultimate) stress.

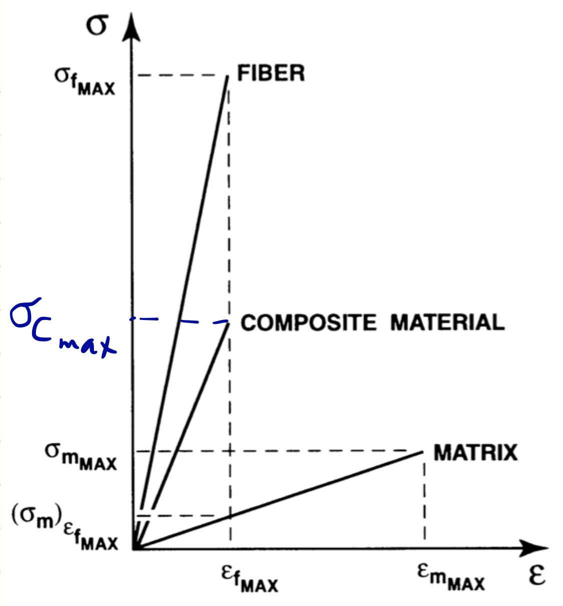
$$\varepsilon_{c_{max}} = \varepsilon_{f_{max}} \qquad (2.5\text{-}1)$$

and we had that

$$\sigma_{c_{max}} = \sigma_{f_{max}} v_f + (\sigma_m)_{\varepsilon_{f_{max}}} (1 - v_f) \qquad (2.5\text{-}2)$$

$\sigma_{f_{max}}$ = maximum fiber tensile stress

$(\sigma_m)_{\varepsilon_{f_{max}}}$ = matrix stress at a matrix strain equal to the maximum tensile strain in the fibers.



we use fiber reinforcement to lead to a greater strength than can be obtained wit the matrix alone.

$$\sigma_{c_{max}} > \sigma_{m_{max}} \quad (2.5\text{-}3)$$

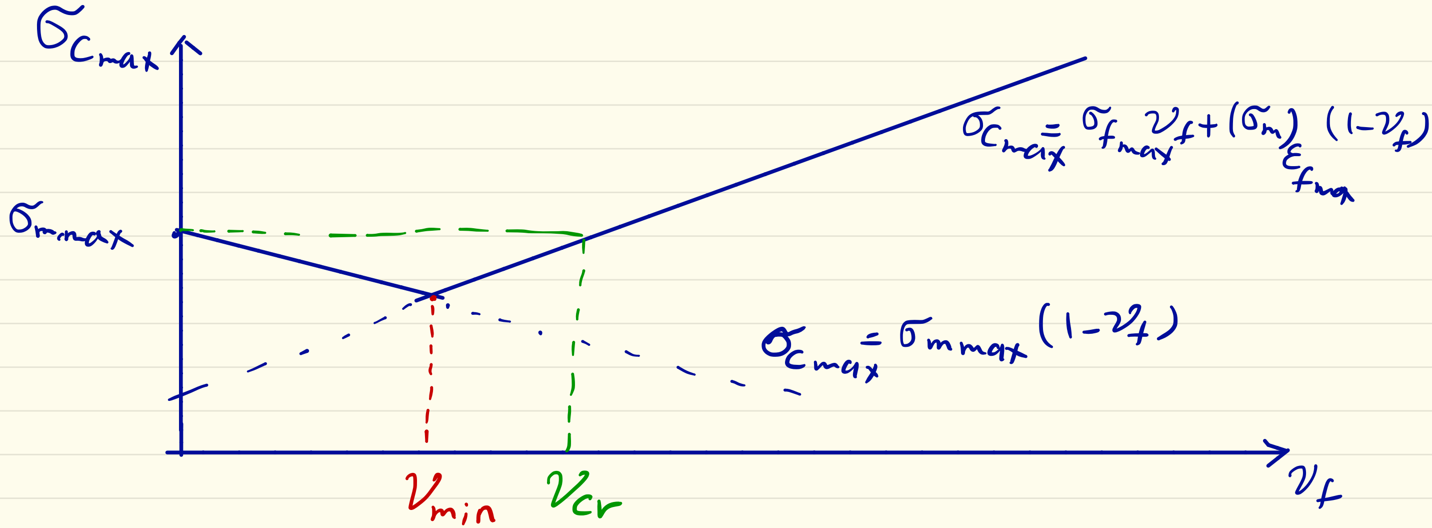
(2.5-2) & (2.5-3) $\longrightarrow$

$$v_{cr} = \frac{\sigma_{m\,max} - (\sigma_m)_{\varepsilon_{f\,max}}}{\sigma_{f\,max} - (\sigma_m)_{\varepsilon_{f\,max}}} \qquad (2.5\text{-}4)$$

$$\therefore \quad v_f \geqslant v_{cr} \longrightarrow \sigma_{c\,max} \geqslant \sigma_{m\,max}$$

For very small values of v_f, the behaivior of the composite material might not follow Eq. (2.5-2) because there might not be enough fibers to control the matrix elonglation. Therefore all fibers break at the first moment and the matrix dominates the composite material.

$$\sigma_{c\,max} = \sigma_{m\,max}(1 - v_f) \qquad (2.5\text{-}5)$$



$$\sigma_{m\,max}(1-V_f) = \sigma_{f\,max} V_f + (\sigma_m)_{\varepsilon_{f\,max}} (1-V_f)$$

$$\boxed{V_{min} = \frac{\sigma_{m\,max} - (\sigma_m)_{\varepsilon_{f\,max}}}{\sigma_{f\,max} + \sigma_{m\,max} - (\sigma_m)_{\varepsilon_{f\,max}}}}$$

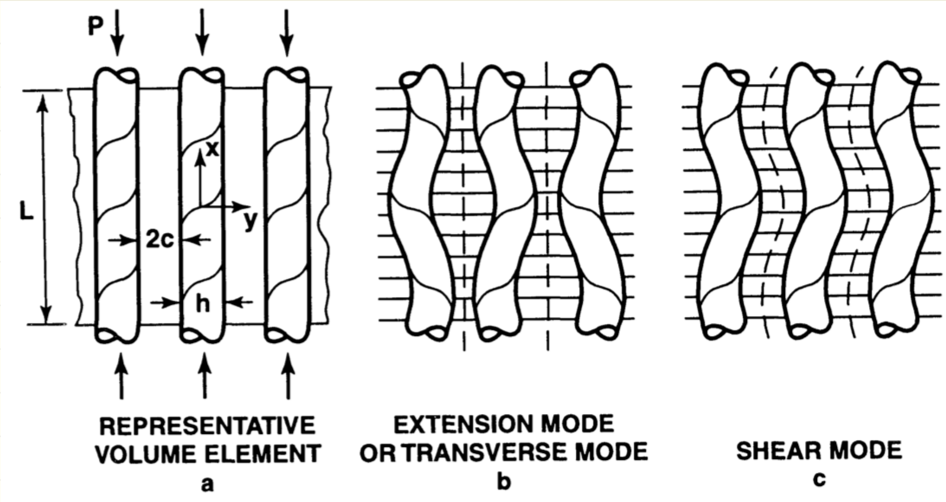
$v_f \leq v_{min} \Rightarrow$ The Composite Strength is controlled by the matrix deformation

$v_{min} < v_f \leq v_{cr} \Rightarrow$ The Composite Strength is controlled by the fiber deformation but the purpose of producing Composites has not satisfied

$v_{cr} < v_f \Rightarrow$ Only for this case the composite material gain strength from having fiber reinforcement.

2.6 Compresive Strength in the Fiber Direction

when fiber-reinforced composites are loaded in compression, the mode of failure appears to be fiber buckling within the restraint of the matrix.



b: Symmetric. Horizontal lines of original length 2c extend or contract. Thus, the matrix extends or contracts in y-direction transverse to the X-direction.

c: Antisymmetric. The matrix is subjected to shearing deformation. Horizontal lines do not change orientation or length.

Transvers or Extension mode

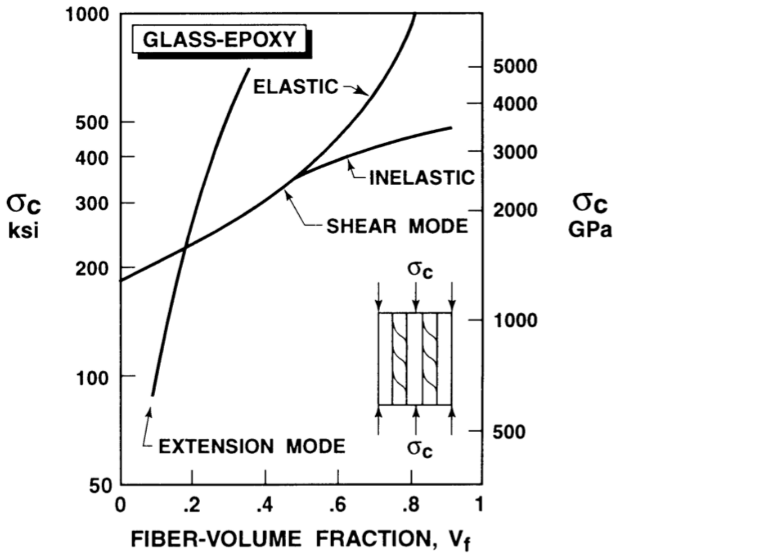
$$\sigma_{f_{cr}} = 2\sqrt{\frac{V_f E_m E_f}{3(1-V_f)}} \qquad \sigma_{c_{max}} = 2\left[V_f + (1-V_f)\frac{E_m}{E_f}\right]\sqrt{\frac{V_f E_m E_f}{3(1-V_f)}}$$

(2.6-1)

Shear mode

$$\sigma_{f_{cr}} = \frac{G_m}{V_f(1-V_f)} \qquad \sigma_{c_{max}} = \frac{G_m}{1-V_f}$$

(2.6-2)



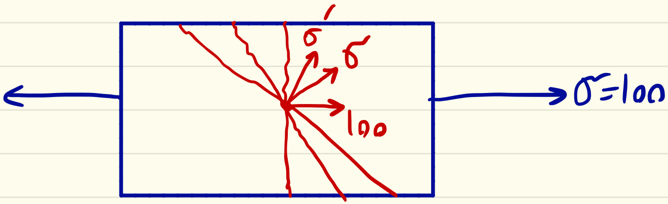
Compressive Strength of Glass-Epoxy Composite Materials

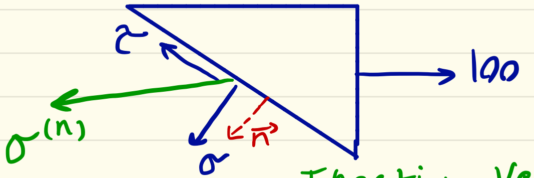
Extension mode is more probable for small values of V_f (for Glass-Epoxy it is less than 0.2) and for large values of V_f, shear mode is predicted.

Chapter 3- Macromecanical Behaivior of a Lamina

3.1- Stress and Strain

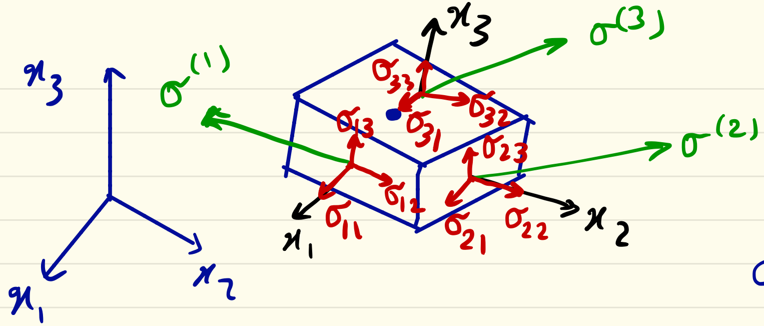
Stress





Traction Vector

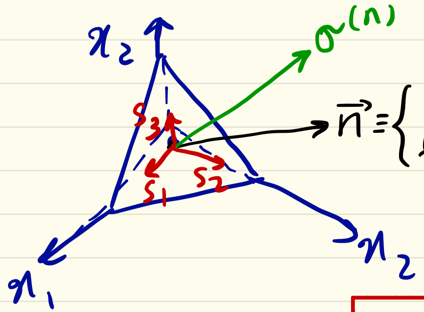
Stress Vector



$$\sigma \equiv \sigma_{ij} \equiv \begin{bmatrix} \sigma_{11} & \sigma_{12} & \sigma_{13} \\ \sigma_{21} & \sigma_{22} & \sigma_{23} \\ \sigma_{31} & \sigma_{32} & \sigma_{33} \end{bmatrix} \rightsquigarrow \begin{Bmatrix} \sigma_{11} \\ \sigma_{22} \\ \sigma_{33} \\ \sigma_{12} \\ \sigma_{23} \\ \sigma_{13} \end{Bmatrix}$$

Quadratic tensor

Cauchy's stress thearem



$$\vec{n} = \begin{Bmatrix} m \\ n \\ l \end{Bmatrix}$$

$$\sigma^{(n)} = \begin{Bmatrix} s_1 \\ s_2 \\ s_3 \end{Bmatrix} = \begin{bmatrix} \sigma_{11} & \sigma_{12} & \sigma_{13} \\ \vdots & \vdots & \vdots \\ \vdots & \vdots & \vdots \end{bmatrix} \cdot \begin{Bmatrix} m \\ n \\ l \end{Bmatrix}$$

$$\boxed{\sigma_i^{(n)} = \sigma_{ij} n_j}$$