COMPOSITE MATERIALS

Composites

-Combination of two or more materials

-Usually a **reinforcing materials** and a **compatible binder**

Combination

1 own distinctive properties

2 Must be superior to either components

3 Properties attained must be an unattainable in the component constituents.

- NOTE: In a composite each material retains its separate chemical, physical, and mechanical properties.
- The two constituents being
  - a **reinforcement**
  - **a matrix.**
- When macroscopic examination is carried out the components can be identified by the naked eye.

Some of the properties that can be improved as a result of this combination are:

- strength
- fatigue life
- hardness
- creep resistance
- corrosion resistance
- thermal insulation properties
- wear resistance
- thermal conductivity
- attractiveness
- acoustical insulation (sound)

Forms of Composites

- Random particles in matrix
- Short discontinuous fibers all lined up in the same direction in a matrix
- Short discontinuous fibers randomly oriented
- Long continuous fibers all limned up in the same direction in a matrix .

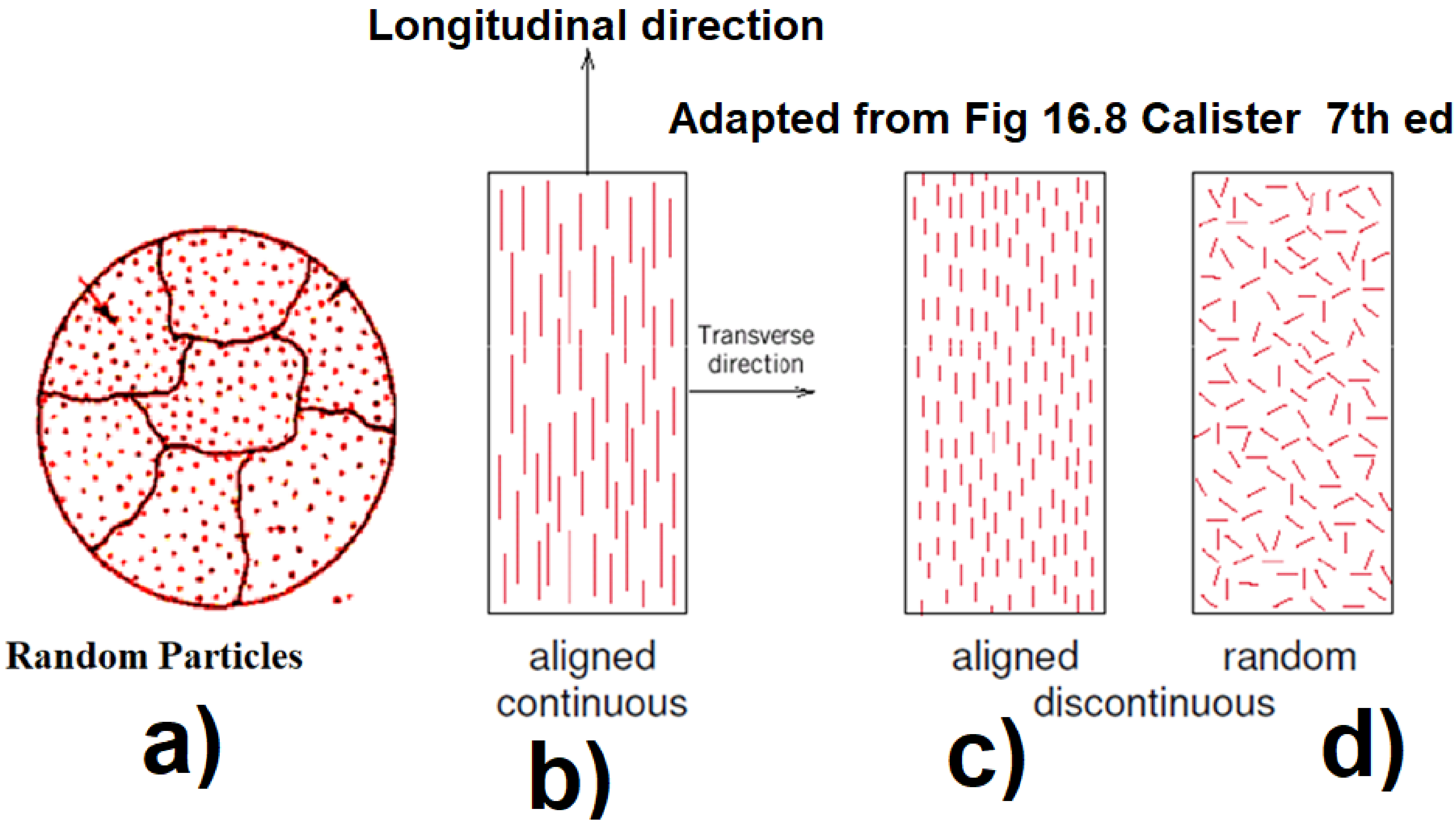
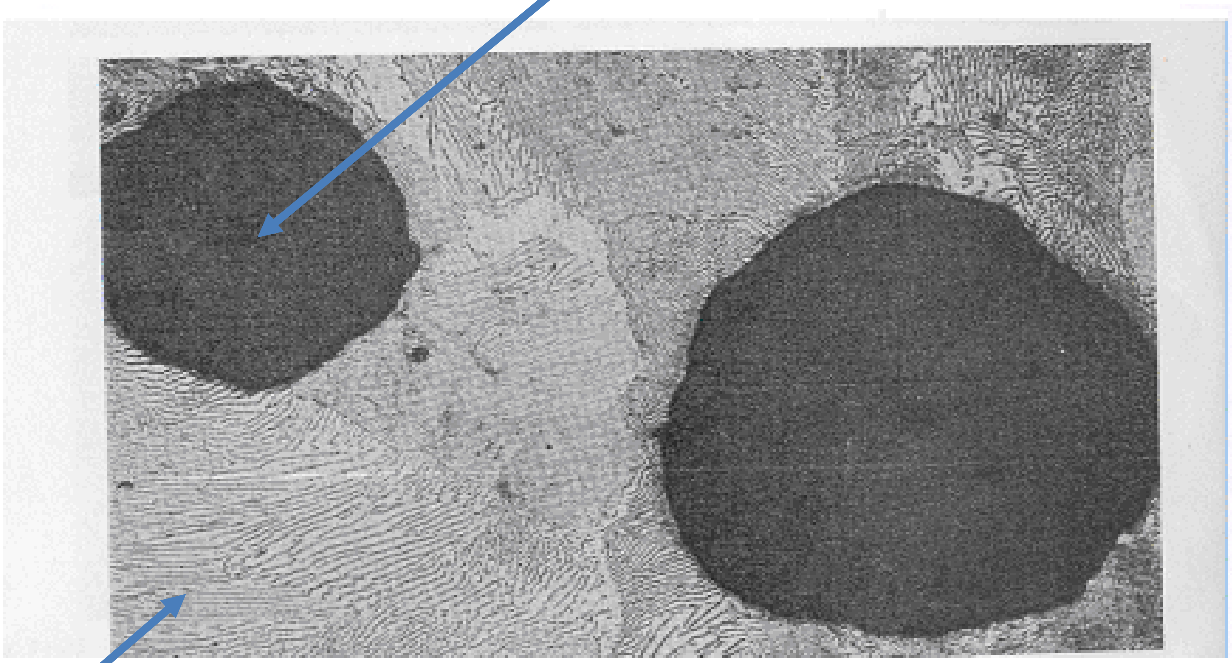


Fig 1 Types of fibers and their alignment

Graphite nodule



Pearlite matrix

Fig 2 Composite of Graphite nodules in a pearlite matrix

Matrix:

- Is the continuous phase

Purpose is to:

-Maintains fibers in proper orientation and spacing

-Protects fibers from abrasion and environment

-Transmits the load to the fibers through shear loading

Classification Composites:

MMC, CMC, PMC

M-metal

C –ceramic

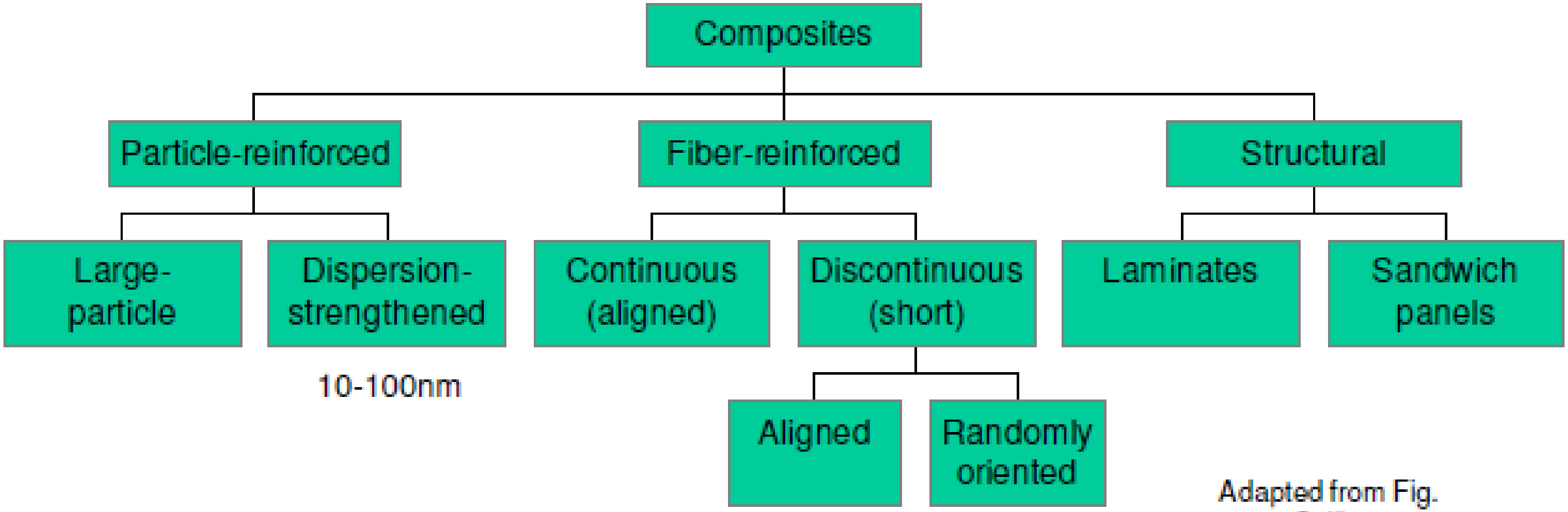
P- polymer

Dispersed phase: (Fiber or particulates)

Purpose: enhance matrix properties

General Classification of dispersed phase:

Particle, fiber, structural

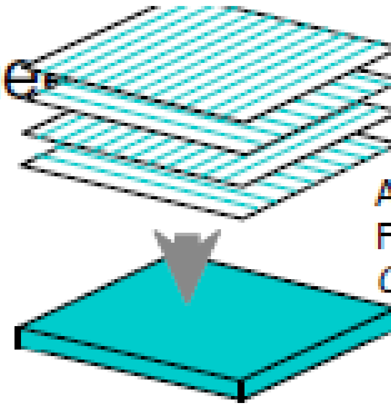


Adapted from Fig. 16.2, *Callister 7e.*

Stacked and bonded fiber-reinforced she[...]

-- stacking sequence: e.g., 0º/90º

-- benefit: balanced, in-plane stiffness

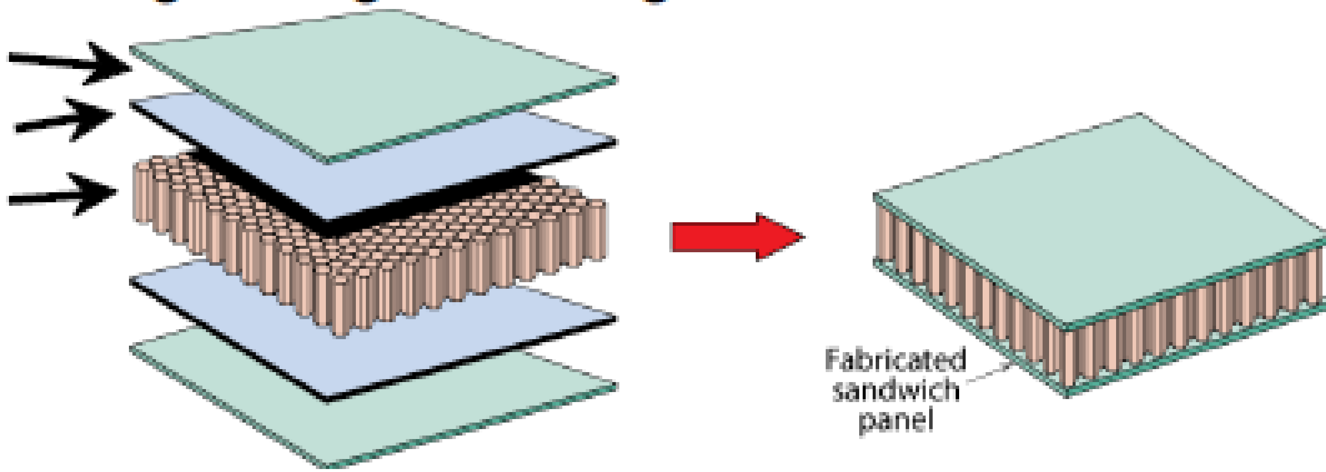


Adapted fr[...]
Fig. 16.16,
Callister 7e

Sandwich panels

-- low density, honeycomb core

-- benefit: small weight, large bending stiffness



Adapted from Fig. 16.18, *Callister 7e.* (Fig. 16.18 is from *Engineered Materials*

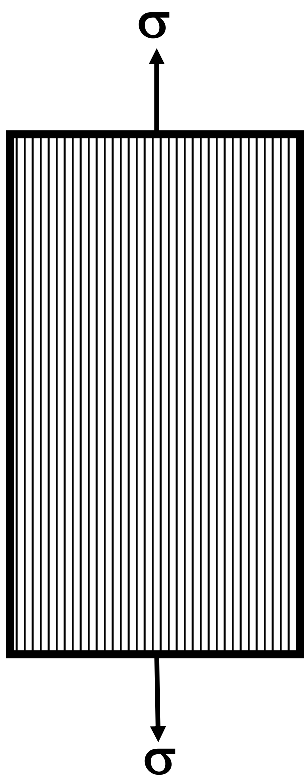
- Fiber Materials
  - Whiskers - Thin single crystals - large length to diameter ratio
    - graphite, SiN, SiC
    - high crystal perfection – extremely strong, strongest known
    - very expensive
  - Fibers
    - polycrystalline or amorphous
    - generally polymers or ceramics
    - Ex: Al_2O_3 , Aramid, E-glass, Boron, UHMWPE
  - Wires
    - Metal – steel, Mo, W

UHMWPE-Ultrahigh molecular weight polyethylene

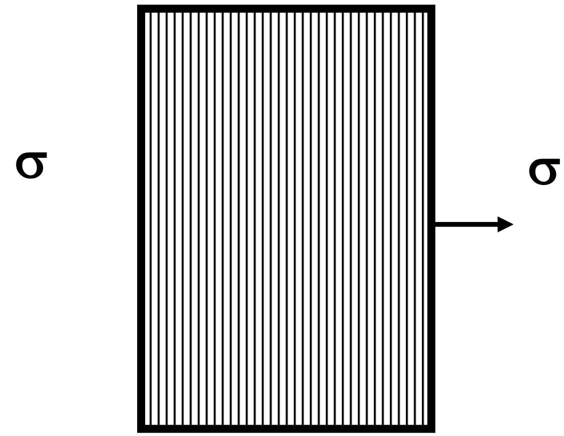
Loading of Composites

-Taking continuous fibers in a matrix as a basic structure of a composite,

-Loading can be in a direction which is parallel to the continuous fibers in a matrix or in a perpendicular direction



Iso-strain



Iso-stress

NOTE: Tensile stress and modulus of elasticity of composites are higher along the direction of the fibers than at right angles

Failures of composites will occur due to either one of the following

i) Composite fails when fibers fail

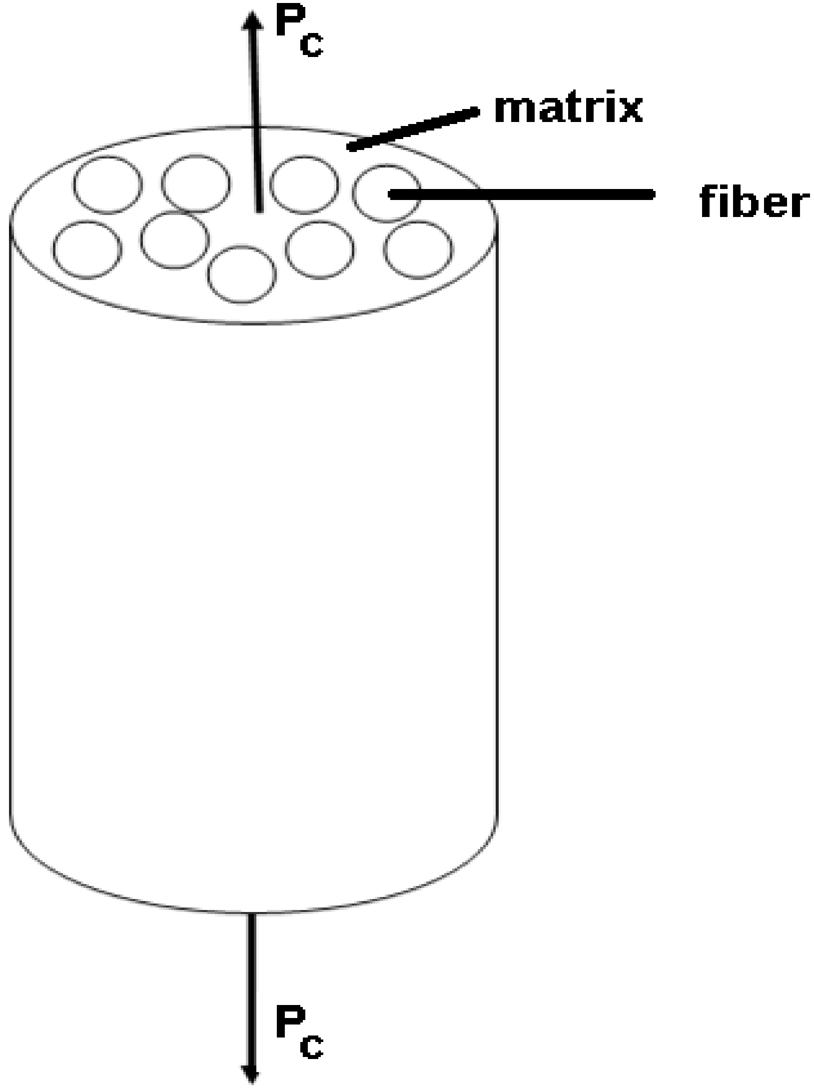
ii) Multiple fibers fracture prior to failure of composite

iii) Composite fails when matrix fails

iv) Multiple matrix fracture prior to failure of composite

- Randomly oriented fibers do not lead to directionality of properties and do not offer such high tensile strength or tensile modulus values e.g.

-A glass reinforced plastic (polyester) with long fibers might have a tensile strength of 1500MPa in the direction of the fibers and only 600Mpa at right angles to the fibers. With short fibers the strength in all directions might be 1200 Mpa .


P_c
matrix
fiber
P_c

Let
c be composite
f- fiber
m- matrix
P- Force
$P_c=P_f+P_m$
and S be stress

$$\text{stress} = \frac{P}{A}$$

$$P = \sigma A$$

$$P_f = \sigma_f A_f$$

$$P_m = \sigma_m A_m$$

$$P_c = \sigma_f A_f + \sigma_m A_m$$

$$\sigma A = \sigma_f A_f + \sigma_m A_m$$

$$\sigma = \sigma_f \frac{A_f}{A} + \sigma_m \frac{A_m}{A}$$

- Thus the stress on the composite is the stress on the fibers multiplied by the fraction of the area that is fibers plus the stress on the matrix multiplied by the area that is matrix.

$$\text{strin} = \frac{\sigma}{E}$$

$$\varepsilon_c = \frac{\sigma_c}{E_c} = \varepsilon_m = \frac{\sigma_m}{E_m} = \varepsilon_f = \frac{\sigma_f}{E_f}$$

$$\sigma_c = E_c \varepsilon_c$$

$$\sigma_m = E_m \varepsilon_m$$

$$\sigma_f = E_f \varepsilon_f$$

$$P_c = P_m + P_f$$

$$\therefore E_c \varepsilon_c A_c = E_m \varepsilon_m A_m + E_f \varepsilon_f A_f$$

for iso strain

$$E_c A_c = E_m A_m + E_f A_f$$

$$E_c = E_m \frac{A_m}{A_c} + E_f \frac{A_f}{A_c}$$

Because of geometry the area fraction is equivalent to the volume fraction or

$$E_c = E_m \upsilon_m + E_f \upsilon_f$$

where

υ_m and υ_f are volume fractions of matrix and fibers respectively

in this case $\upsilon_m + \upsilon_f = 1$

for most fiber glass composites

$$\frac{Pf}{Pm} > 0.96$$

i.e neartly the entire uniaxial load is carrieds by the high modulus fibers

Q1

A fiber glass composite contains 85% by volume % X glass in a Y epoxy matrix

a) Calculate the wt % of X in the Composite
b) Determine the density of the composite

Take the density of X as $3.5g/cm^3$ and that of $Y=1.3g/cm^3$

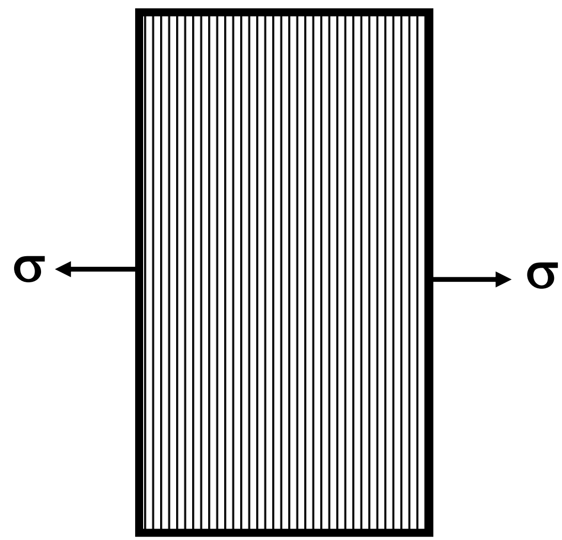
Q2

Suppose we have a glass fiber with a tensile strength of 1300Mpa in a matrix of polyester with strength 60Mpa.upy 60% of the cross sectional area of the composite. Find the stress the composite can withstand when both the fibers and matrix are stressed to the limits

Q3 A carbon fiber with a tensile modulus of 1400 GPa are used to reinforce aluminum with tensile modulus of 70GPa . If the fibers are long and parallel to the axis along which the load is applied. What is the tensile modulus of the composite when the fibers occupy 10% of the composite area.

Q4 A column of reinforced concrete has steel reinforcing rods running through the entire length of the column and parallel to the

Loading of composite perpendicular to reinforcing fibers (Isostress)



Iso-stress

- Isostress is defined by the equation

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

- *In this case* the total elongation of the composite in the direction of load application is ΔL_c (the sum of the elongation of matrix and the fiber components)

$$\Delta L_c = \Delta L_m = \Delta L_f$$

dividing by total component length L_c in the stress direction gives

$$\frac{\Delta L_c}{L_c} = \frac{\Delta L_m}{L_c} = \frac{\Delta L_f}{L_c}$$

because of geometry, the length of each componnet in the stress direction is proportional to the area fraction that is

$$L_m = A_m L_c$$

$$L_f = A_f L_c$$

$$\frac{\Delta L_c}{L_c} = \frac{A_m \Delta L_m}{L_m} = \frac{A_f \Delta L_f}{L_f}$$

$$\varepsilon_c = \upsilon_m \varepsilon_m + \upsilon_f \varepsilon_f$$

$$\frac{\sigma}{E_c} = \upsilon_m \frac{\sigma}{E_m} + \upsilon_f \frac{\sigma}{E_f}$$

$$\frac{1}{E_c} = \frac{\upsilon_m}{E_m} + \frac{\upsilon_f}{E_f}$$

$$E_c = \frac{E_m E_f}{\upsilon_f E_m + \upsilon_m E_f}$$

General equation

$$X_c = \frac{X_m X_f}{\upsilon_f X_m + \upsilon_m X_f}$$

X can be diffusivity, conductivity, emmisivity etc

Q1 Calculate the elastic modulus and thermal conductivity perpendicular to continuous fibers in E-glass (60% vol) polyester composite.

$E_{polyester}$=690Mpa. $E_{E\text{-}glass}$=72000Mpa.

$K_{polyester}$= 0.17w/m.K. $K_{E\text{-}glass}$=0.97w/m.K

Q2.A continuous and aligned glass fibers reinforced composite consists of 40 vol% of glass fibers having E of 69GPa and 60% of polyester resin that when hardened displays modulus of 3.4GPa.

a) Compute the E of the composite in the longitudinal direction

b) If cross sectional area is 250mm^2 and stress of 50Mpa .is applied in the longitudinal direction compute the magnitude of the load carried by each of the fibers and the matrix.

c) Determine the strain that is sustained by each phase when the stress in part (b) is applied