In-Class Exercise
Tensile Strength in Composites
SOLUTIONS

A composite material consists of 50% (by volume) continuous, uniaxially aligned, E-glass fibers in a matrix of a thermoset polyester. Predict the tensile strength parallel to the fibers. The tensile strength of E-glass fibers is 1800 MPa and modulus is 76 GPa. The tensile strength of the thermoset polyester is 55 MPa and the modulus is 3 GPa.

First decide which fails first:

$$\varepsilon_F^* = \frac{1800\text{x}10^6\,\text{Pa}}{76\text{x}10^9\,\text{Pa}} = 2.37\text{x}10^{-2}$$

$$\varepsilon_M^* = \frac{55\text{x}10^6\,\text{Pa}}{3.0\text{x}10^9\,\text{Pa}} = 1.83\text{x}10^{-2}$$

Note that to do this calculation we assume perfectly elastic behavior (no yield point). Matrix fails first.

When matrix fails, stress in fibers is:

$$\sigma'_F = E_F\varepsilon_M^* = (76\,\text{GPa})(1.83\text{x}10^{-2}) = 1.39\,\text{GPa}$$

Now compare the maximum stress that can be carried by the composite when the matrix fails to the maximum stress that can be carried by the fibers alone, and see which is higher.

$$\sigma_1^*(\text{composite}) = V_F\sigma'_F + V_M\sigma_M^* = (0.5)(1.39\,\text{GPa}) + (0.5)(0.055\,\text{GPa}) = 0.723\,\text{GPa}$$

$$\sigma_1^*(\text{fiber}) = V_F\sigma_F^* = (0.5)(1.8\,\text{GPa}) = 0.9\,\text{GPa}$$

Fibers can carry up to 0.9 GPa by themselves, so the composite strength is 0.9 GPa.