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 we can calculate the stress in the composite when the matrix fials.

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

Note: The fibers and the composite have not yet failed. The fibers alone are supporting a stress. You can calculate the stress that the fibers alone can support. Fibers alone can carry up to 0.9 GPa, so the composite strength is 0.9 GPa. That is, the composite won't fail until that stress is applied.

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