

Influence of Fiber Orientation and Concentration

16.D2 In order to solve this problem, we want to make longitudinal elastic modulus and tensile strength computations assuming 40 vol% fibers for all three fiber materials, in order to see which meet the stipulated criteria [i.e., a minimum elastic modulus of 55 GPa (8×10^6 psi), and a minimum tensile strength of 1200 MPa (175,000 psi)]. Thus, it becomes necessary to use Equations 16.10b and 16.17 with $V_m = 0.6$ and $V_f = 0.4$, $E_m = 3.1$ GPa, and $\sigma_m^* = 69$ MPa.

For glass, $E_f = 72.5$ GPa and $\sigma_f^* = 3450$ MPa. Therefore,

$$\begin{aligned} E_{cl} &= E_m(1 - V_f) + E_f V_f \\ &= (3.1 \text{ GPa})(1 - 0.4) + (72.5 \text{ GPa})(0.4) = 30.9 \text{ GPa} \quad (4.48 \times 10^6 \text{ psi}) \end{aligned}$$

Since this is less than the specified minimum (i.e., 55 GPa), glass is not an acceptable candidate.

For carbon (PAN standard-modulus), $E_f = 230$ GPa and $\sigma_f^* = 4000$ MPa (the average of the range of values in Table B.4), thus, from Equation 16.10b

$$E_{cl} = (3.1 \text{ GPa})(0.6) + (230 \text{ GPa})(0.4) = 93.9 \text{ GPa} \quad (13.6 \times 10^6 \text{ psi})$$

which is greater than the specified minimum. In addition, from Equation 16.17

$$\begin{aligned} \sigma_{cl}^* &= \sigma_m^*(1 - V_f) + \sigma_f^* V_f \\ &= (30 \text{ MPa})(0.6) + (4000 \text{ MPa})(0.4) = 1620 \text{ MPa} \quad (234,600 \text{ psi}) \end{aligned}$$

which is also greater than the minimum (1200 MPa). Thus, carbon (PAN standard-modulus) is a candidate.

For aramid, $E_f = 131$ GPa and $\sigma_f^* = 3850$ MPa (the average of the range of values in Table B.4), thus (Equation 16.10b)

$$E_{cl} = (3.1 \text{ GPa})(0.6) + (131 \text{ GPa})(0.4) = 54.3 \text{ GPa} \quad (7.87 \times 10^6 \text{ psi})$$