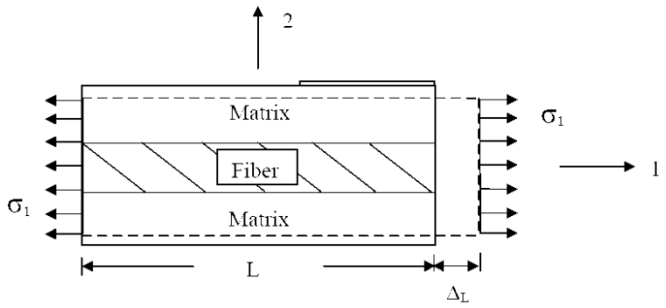
Composite Materials

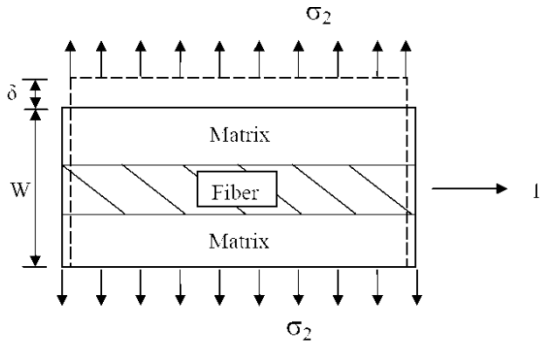
Exercise Questions

The mechanical properties of a continuous fiber reinforced composite are related to those of the matrix and fiber phases and their volume ratio. The upper limit is obtained by considering the case when the stress is applied longitudinally in the continuous fiber axis, producing equal strains in the phases and the stresses are additive. The lower limit is obtained by considering the case of transverse stress application perpendicular to the fiber axis, where stresses supported by the phases are equal and the strains are additive. The two limiting cases are represented in the figure below.



$$E_{C1}\varepsilon_{C1} = E_{F1}\,\varepsilon_{F1}V_F + E_{M1}\,\varepsilon_{M1}V_M$$

$$E_{C1} = E_{F1}\,V_F - E_{M1}\,V_M = E_{F1}\,V_F + E_{M1}\,(1\text{-}V_F)$$



$$\frac{\sigma_{C2}}{E_{C2}} = \frac{\sigma_{F2}}{E_{F2}}V_F + \frac{\sigma_{M2}}{E_{M2}}V_M$$

$$\frac{1}{E_{C2}} = \frac{1}{E_{F2}}V_F + \frac{1}{E_{M2}}(1-V_F)$$

or

$$E_{C2} = \frac{E_{F2}E_{M2}}{E_{F2}V_M + E_{M2}V_F}$$

1. A unidirectional pre-preg composite laminate for aerospace vehicles is designed from various matrices and carbon fibers to support high stress due to environmental effects without crack formation. The stiffness of the material should be <u>at least</u> 100 GPa, and the coefficient of thermal expansion should be <u>at most</u> $15*10^{-6}$/°C. Based on the micromechanics approximation mentioned above and for a fiber volume ratio of 0.6, evaluate the following matrices and carbon fiber reinforcements in terms of their suitability for the application:

Matrix	E (GPa)	σ_f (MPa)	α (10^{-6}/°C)
2024 aluminum	73.11	190	23.22
Borosilicate glass	62.76	20	3.24
930 epoxy	4.35	11	43.92
Fiber			
P100	796.63	1700	6.84
C6000	233.13	2760	10.08

2. C6000 fiber is commonly used to strengthen the composite. Calculate the fiber volume ratio required to obtain an epoxy/C6000 carbon fiber composite with a strength of 500 MPa. Compare the result with the volume ratio of P100 fiber.
3. Do the calculations of question 2 for a combination of aluminum/carbon fiber
4. What is the critical fiber aspect ratio for a C6000 fiber in aluminum matrix?
5. Calculate the effective fiber strength for a batch of C6000 fibers with mean aspect ratio of 30.