Engineering Composite Materials

Macromechanics of Composites

Dawit Gemechu (Ph. D.)

E-mail: dawit.gemechu@aait.edu.et

Macromechanics of composites

Laminate

Laminated fibrous composites

- are made by bonding together two or more laminae
- frequently referred to as laminates,
- are different from sheet laminates made by bonding flat sheets of materials
- the individual unidirectional laminae or plies are oriented in a manner that the resulting structural component has the desired mechanical and/or physical characteristics in different directions

Micromechanics of fibrous composites,

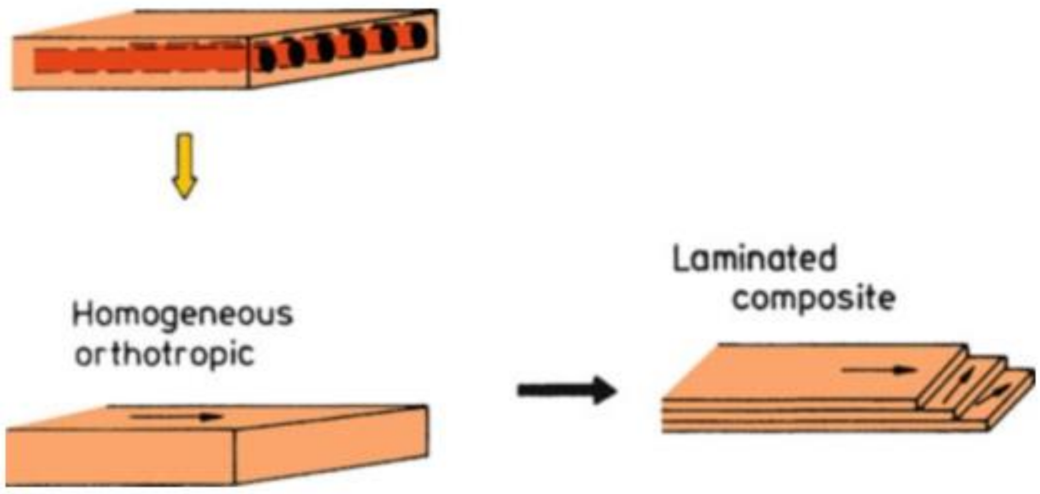
- *It is how to obtain the composite properties when the properties of the matrix and fiber and their geometric arrangements are known (refer previous slides/lecture)*
- *useful in analyzing the composite behavior*

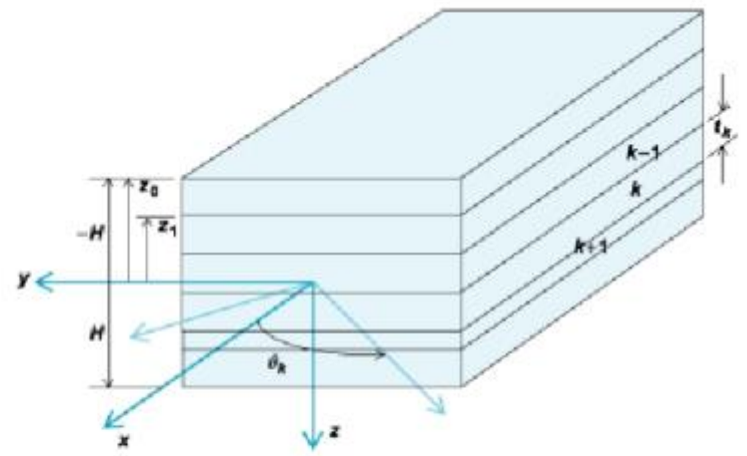
We use the information obtained from a micromechanical analysis of a thin unidirectional lamina (or in the case of a lack of such analytical information, we must determine experimentally the properties of a lamina) as input for a ***macromechanical*** *analysis of a laminated composite.*

Macromechanics of composites

Laminate

Micromechanics -Determine the properties of individual layers /laminae /plies → use only these layer properties to describe the (macroscopic) composite (**Macromechanics)**



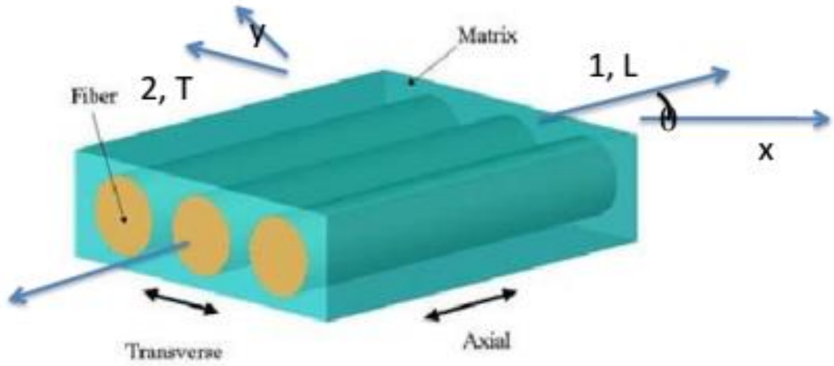


A laminate is made by stacking laminae with different fiber orientations tailored to fulfill specific mechanical requirements in specific directions. Usually, the laminae have the same thickness, same matrix/fibers, and the same fiber content.

However, this is not a limitation, and hybrid laminates, i.e., made with laminae of different matrix/fibers or with different amounts of fibers, can be stacked is necessary.

Macromechanics of composites

Lamina



- The main reference system has the axes x,y oriented along the directions of the applied load, that can coincide (or not) with the directions of the fibers (1,2 or L,T)

- In a laminate, the laminae have different orientations, and the loading directions that are coded as x,y may not coincide with 1,2 or L,T.

- The angle θ between the system x,y and the system 1,2 (or L,T) is considered to be positive when, as in the figure, is clockwise with respect the main reference system.

Macromechanics of composites

Properties

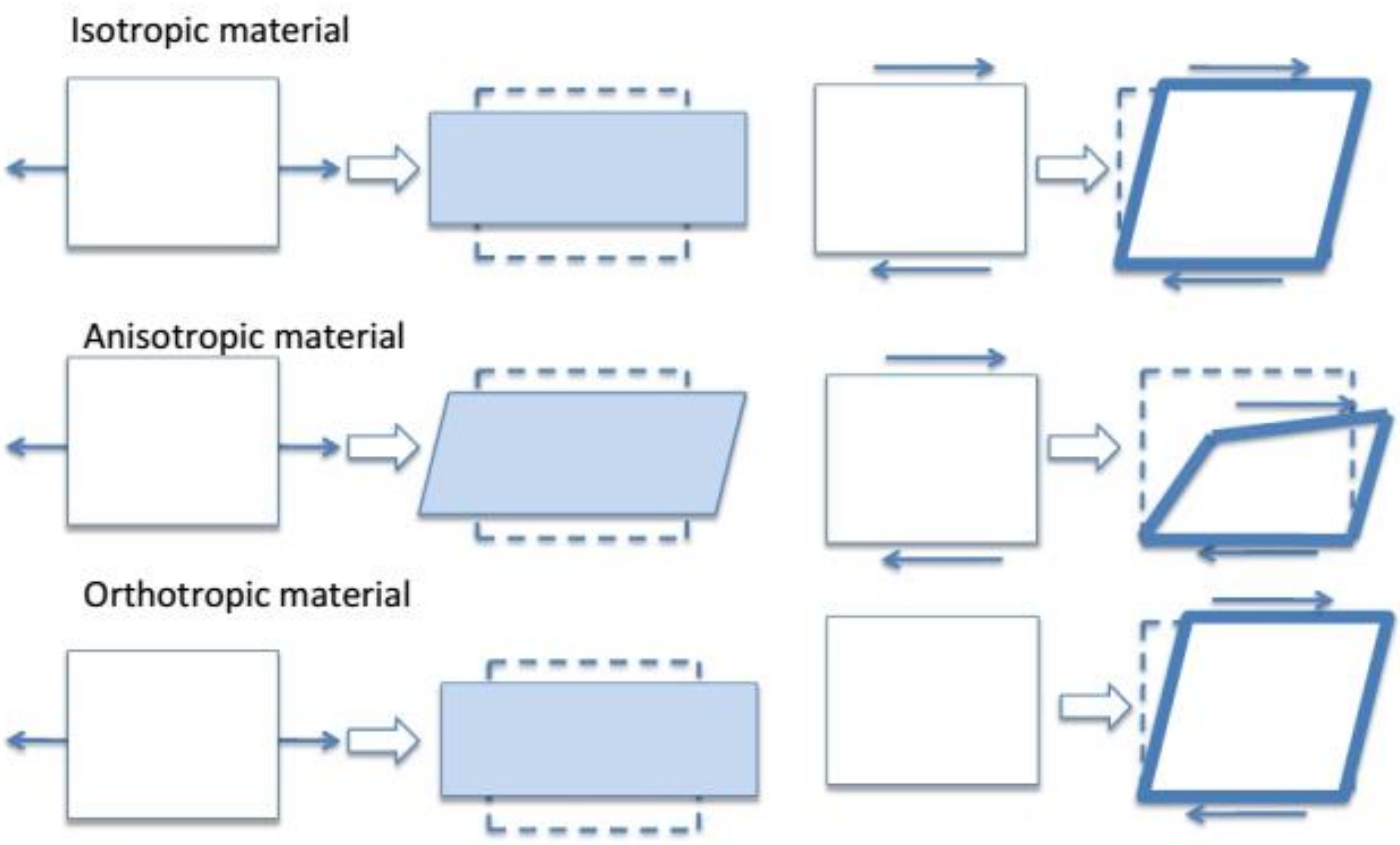
Isotropic materials: the deformation behavior does not depend on the directions of the applied stress (normal stresses produce normal deformations and shear stresses produce shear deformations)

Anisotropic materials: the deformation behavior depends on both applied stress and directions (normal stresses induce normal and shear deformations, and shear stresses induce shear and normal deformations)

Orthotropic materials: In general they behave as an anisotropic material. However, if stresses are applied along the principal directions, the deformation behavior of these material is similar to the one of isotropic materials

Macromechanics of composites

Properties

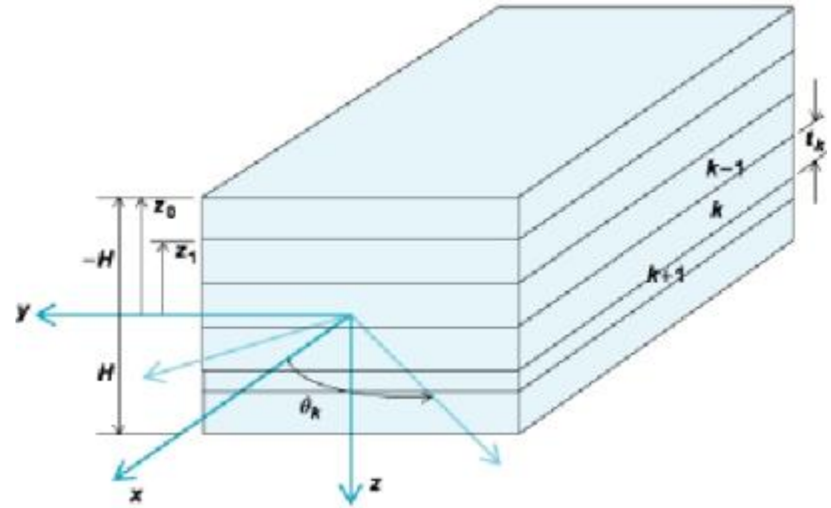


When stressed along the principal directions an orthotropic materials deforms as an isotropic one

Macromechanics of composites

Lamina, x, y directions

A lamina is subjected to stresses/ deformations that usually develop in in multiple directions

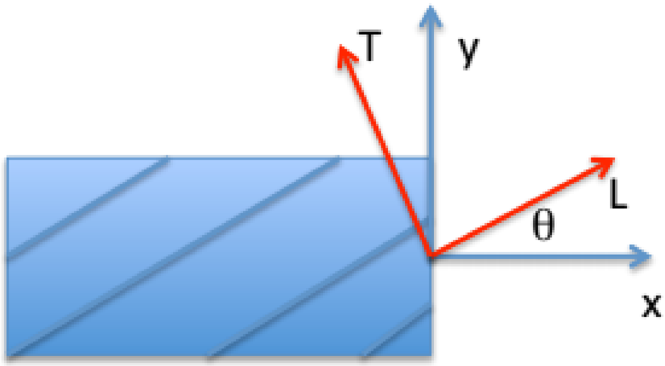


In the previous lessons we have calculated for a lamina stressed in the 1,2 directions the relationship between the components of the applied stress and the resulting deformations.

This lesson deals with the calculation of the relationships between the components of stresses and the components of the resulting deformations in the x, y directions, being x, y a coordinate system making an angle θ with the 1,2 system.

Lamina, x, y directions

Considering a lamina stressed in the x, y directions making an angle θ with the 1,2 directions.



Stresses and deformation components along 1, 2 can be transformed in the stress and deformation components along x, y, by using the second order transformation matrix T as follows:

$$\begin{Bmatrix} \sigma_1 \\ \sigma_2 \\ \tau_{12} \end{Bmatrix} = |T| \begin{Bmatrix} \sigma_x \\ \sigma_y \\ \tau_{xy} \end{Bmatrix} \qquad \begin{Bmatrix} \varepsilon_1 \\ \varepsilon_2 \\ \frac{1}{2}\gamma_{12} \end{Bmatrix} = |T| \begin{Bmatrix} \varepsilon_x \\ \varepsilon_y \\ \frac{1}{2}\gamma_{xy} \end{Bmatrix}$$

Where γ_{xy} is the engineering strain, and ½ γ_{xy} is the tensorial strain