EML 4230 Introduction to Composite Materials

Chapter 4 Macromechanical Analysis of a Laminate
Objectives and Laminate Code

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Courtesy of the Textbook
Mechanics of Composite Materials by Kaw

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Laminate Stacking Sequence

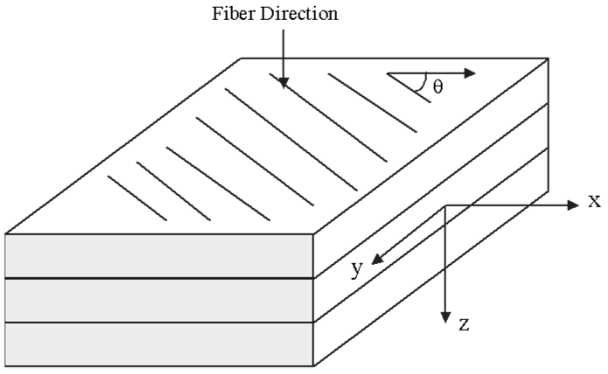


FIGURE 4.1
Schematic of a lamina

Chapter Objectives

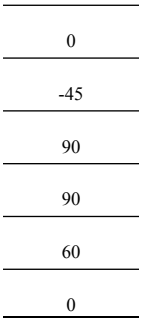
- Understand the code for laminate stacking sequence
- Develop relationships of mechanical and hygrothermal loads applied to a laminate to strains and stresses in each lamina
- Find the elastic stiffnesses of laminate based on the elastic moduli of individual laminas and the stacking sequence
- Find the coefficients of thermal and moisture expansion of a laminate based on elastic moduli, coefficients of thermal and moisture expansion of individual laminas, and stacking sequence

Laminate Code

0
-45
90
60
30

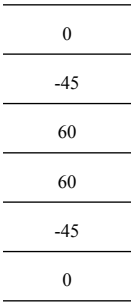
$$[0/-45/90/60/30]$$

Laminate Code



$$[0/-45/90_2/60/0]$$

Laminate Code



$$[0/-45/60]_S$$

Laminate Code

0
-45
60
-45
0

$$[0/-45/\overline{60}]_S$$

Laminate Code

Graphite/Epoxy	0
Boron/Epoxy	45
Boron/Epoxy	-45
Boron/Epoxy	-45
Boron/Epoxy	45
Graphite/Epoxy	0

$$[0^{Gr}/\pm 45^{B}]_S$$

Special Types of Laminates

- **Symmetric Laminate:** For every ply above the laminate midplane, there is an identical ply (material and orientation) an equal distance below the midplane.
- **Balanced Laminate:** For every ply at a $+\theta$ orientation, there is another ply at the $-\theta$ orientation somewhere in the laminate.

Special Types of Laminates

- **Cross-ply Laminate:** Composted of plies of either 0° or 90° (no other ply orientation).
- **Quasi-isotropic Laminate:** Produced using at least three different ply orientations, all with equal angles between them. Exhibits isotropic extensional stiffness properties.

Laminate Behavior

- Elastic Moduli
- The Stacking Position
- Thickness
- Angles of Orientation
- Coefficients of Thermal Expansion
- Coefficients of Moisture Expansion

Strains in a beam

$$\sigma_{xx} = \frac{P}{A} \qquad (4.1)$$

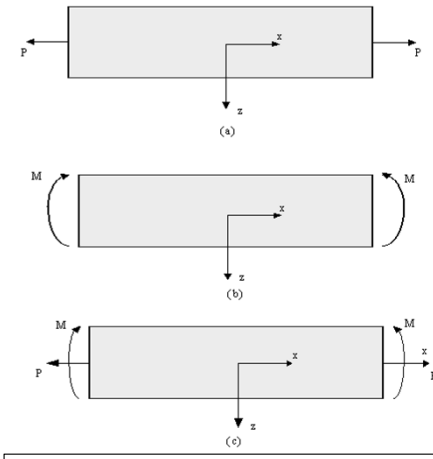


FIGURE 4.2
A beam under (a) axial load, (b) bending moment, and (c) combined axial and bending moment.

$$\varepsilon_{xx} = \frac{P}{AE}$$

$$\sigma_{xx} = \frac{Mz}{I}$$

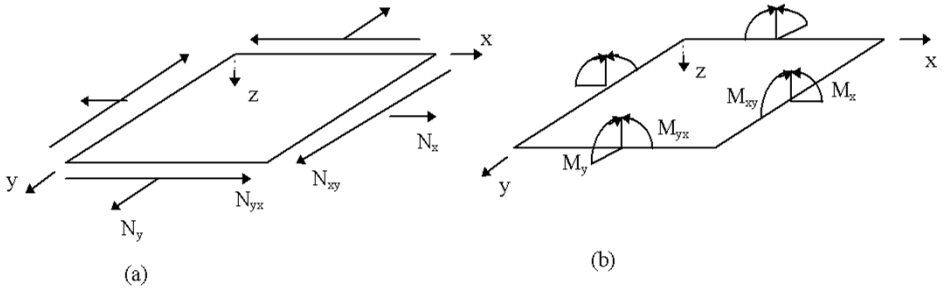
$$\varepsilon_{xx} = \frac{z}{\rho}$$

$$\varepsilon_{xx} = \left(\frac{1}{AE}\right)P + \left(\frac{z}{EI}\right)M$$

$$= \varepsilon_0 + z\left(\frac{1}{\rho}\right)$$

$$= \varepsilon_0 + z\kappa$$

Types of loads allowed in CLT analysis



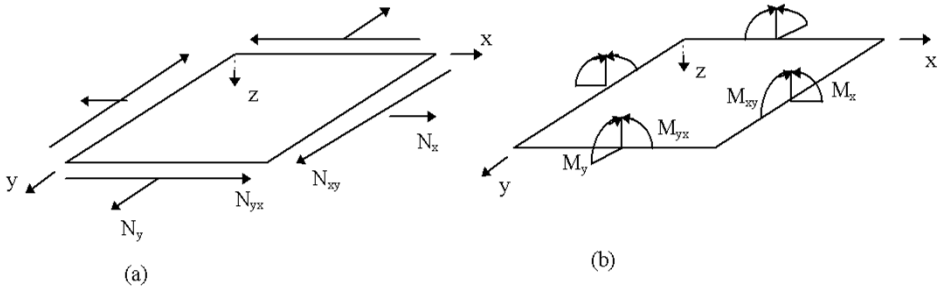
N_x = normal force resultant in the x direction (per unit length)

N_y = normal force resultant in the y direction (per unit length)

N_{xy} = shear force resultant (per unit length)

FIGURE 4.3
Resultant forces and moments on a laminate.

Types of loads allowed in CLT analysis



M_x = bending moment resultant in the yz plane (per unit length)

M_y = bending moment resultant in the xz plane (per unit length)

M_{xy} = twisting moment resultant (per unit length)

END