Lecture 29

Module IV - Macro-mechanics of laminate

Macro-mechanics of laminate

Laminate Structure:

Laminate consists of number of layers, bonded together by the resin in the thickness direction. A layer may consist of short fibers, unidirectional continuous fibers or woven fibers embedded in matrix. Properties of the laminate can be altered by controlling orientation of fibers in each lamina. Adjacent layers (plies) having the same material and the same orientation are referred to as a ply group.

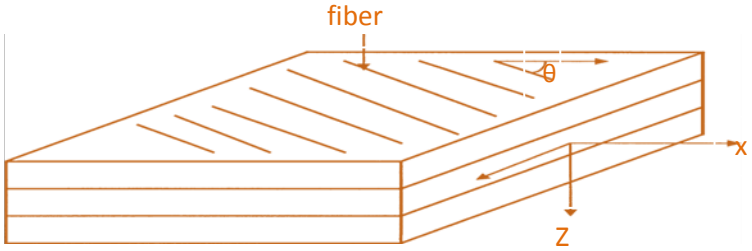

Figure 4.1 laminate

Laminate Description System:

Laminate description includes the following details:

(i) Orientation of each lamina with respect to the x-axis

(ii) Number of laminate for each orientation

(iii) The exact geometric sequence of laminate

The orientation angle θ is positive in the counter-clockwise direction. The number of layers within the ply group is specified by a numerical subscript. For example the laminate designated as $[90^o/45_3/0^o]_s$. This laminate contains totally 10 layers, one 90^o layer on the top and bottom, three 45^o layers next to 90^o layer on both sides and two 0^o layers in the middle. The subscript 's' denotes that the laminate is symmetric.

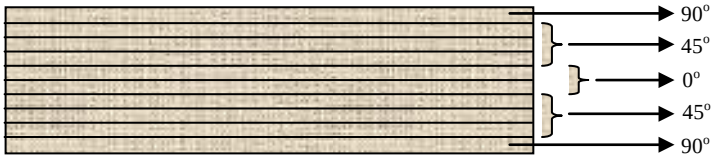

Figure 4.2: Figure showing the orientation of $[90^o/45_3/0^o]_s$ laminate

Symmetric laminate:

In a symmetric laminate, the ply orientation is symmetrical about the mid plane of the laminate; that is, for each ply above the mid-plane, there is an identical ply (in material, thickness, and fiber orientation angle) at an equal distance below the mid-plane. Thus, for a symmetric laminate,

$$\theta(z) = \theta(-z) \qquad (4.1)$$

where, z is the distance from the mid-plane of the laminate. Some examples for symmetric laminates are:

(i) $[45^o/0^o/-45^o]_s \rightarrow [45^o/0^o/-45^o/-45^o/0^o/45^o]$

(ii) $[45^o/0^o/\overline{-45^o}]_s \rightarrow [45^o/0^o/-45^o/0^o/45^o]$

(iii) $[0^o/\pm 45^o/90^o]_s \rightarrow [0^o/+45^o/-45^o/90^o/90^o/-45^o/+45^o/0^o]$

(iv) $[30^o/60_2/45^o]_s \rightarrow [30^o/60^o/60^o/45^o/45^o/60^o/60^o/30^o]$

(v) $[(\pm 45^o)_2/0^o]_s \rightarrow [+45^o/-45^o/+45^o/-45^o/0^o/0^o/-45^o/+45^o/-45^o/+45^o]$

(vi) $[0^o/90^o/45^o]_{2s} \rightarrow [0^o/90^o/45^o/0^o/90^o/45^o/45^o/90^o/0^o/45^o/90^o/0^o]$ (4.2)

In case (1), there are six layers, in case (ii), there are five layers as $\overline{45^o}$

Anti-symmetric laminate:

For every ply (lamina) above the mid plane with orientation angle 'θ', there is another ply below the mid plane with orientation angle '-θ'. Both plies will have identical mechanical and physical properties. Thus, for an anti-symmetric laminate,

$$\theta(z) = -\theta(-z) \qquad (4.3)$$

For example, [θ/-θ/θ/-θ] is an anti-symmetric laminate. In anti-symmetric laminate there is always even number of layers.

Un-symmetric laminate:

A laminate neither symmetric nor anti-symmetric is called un-symmetric. For example, [0^o /45^o /90^o], [0^o /0^o/0^o/90^o], [+θ/-θ/-θ], [-θ/+θ/+θ] etc are un-symmetric laminates.

Quasi-isotropic laminate:

These laminates are made of three or more laminae of identical thickness and material with equal angle between each adjacent lamina. Thus, if the total number of laminae is N, the

orientation angles of the laminate are at an increment of π/N. The laminate properties are isotropic in the 1-2 (x-y) plane. For example, $[+ 45^o/0^o/-45^o/90^o]$, $[0^o/+ 60^o/-60^o]$, $[0^o/\pm 45^o/90^o]_s$ etc are quasi-isotropic laminates.

Unidirectional laminate:

All the laminate has the same fiber orientation angle. For example, in unidirectional 0^o laminates, $\theta = 0^o$ in all laminate.

Angle-ply laminate:

Fiber-orientation angles in alternate layers are θ and $-\theta$, but θ is not equal to either 0^o or 90^o. For example, $/\theta/-\theta/\theta/-\theta$, is an angle ply laminate.

Cross-ply laminate:

Fiber-orientation angles in alternate layers are 0^o and 90^o. For example, $/0^o/90^o/0^o/90^o$ is a cross ply laminate. In a cross ply laminate there will not be extension- shear coupling.

Balanced laminate:

For every lamina, with orientation angle 'θ', there exists another lamina with orientation '$-\theta$' anywhere in the thickness direction. In a balanced laminate there will not be extension- shear coupling. For example $[30^o/-30^o/60^o/-60^o]$ is a balanced laminate.

Anti symmetric cross ply laminate:

Anti-symmetric laminate consists plies oriented in 0^o and 90^o directions, such that for each 0^o degree ply there is another 90^o degree ply at equal distance from the mid plane. These laminates will have extension/bending coupling.

Laminates of $[0^o/90^o/0^o/90^o]$ is anti-symmetric cross ply laminate.

Anti-symmetric balanced laminate:

These laminates will have of plies with orientations θ and $-\theta$ at equal distance from the mid plane above or below the mid plane.

Laminates of $[30^o/40^o/45^o/60^o]$ are anti symmetric, because the laminates are neither symmetric nor anti-symmetric.

Reference:

"Mechanics of Composite Structural Elements", H Altenbach, J Altenbach and W Kissing, Springer publications.

" Principles of Composite Material Mechanics", Ronald F Gibson, CRC Press.