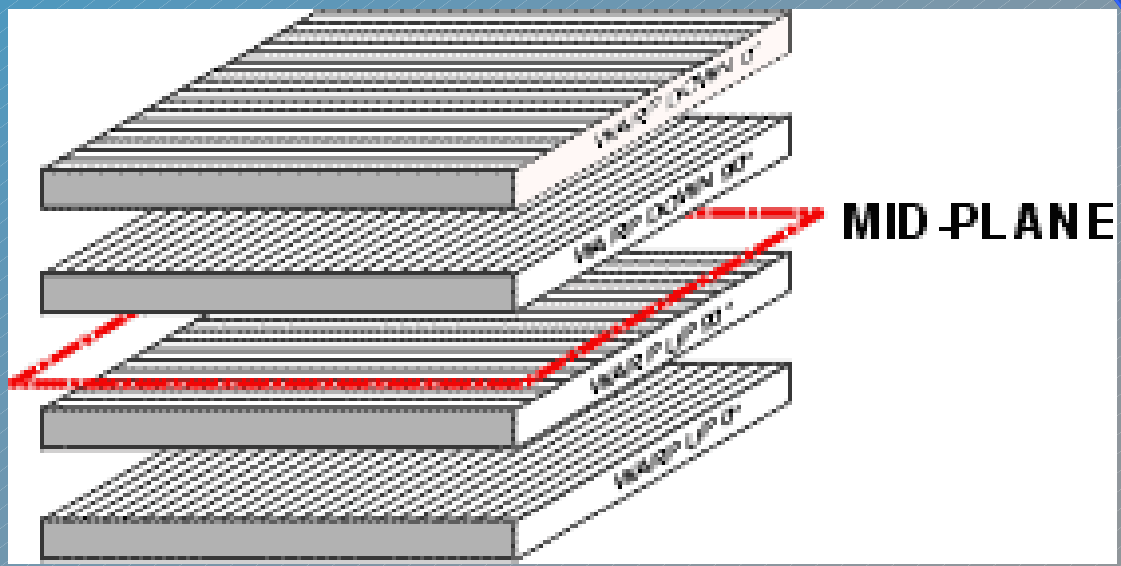
Common Lay-up Terms and Conditions

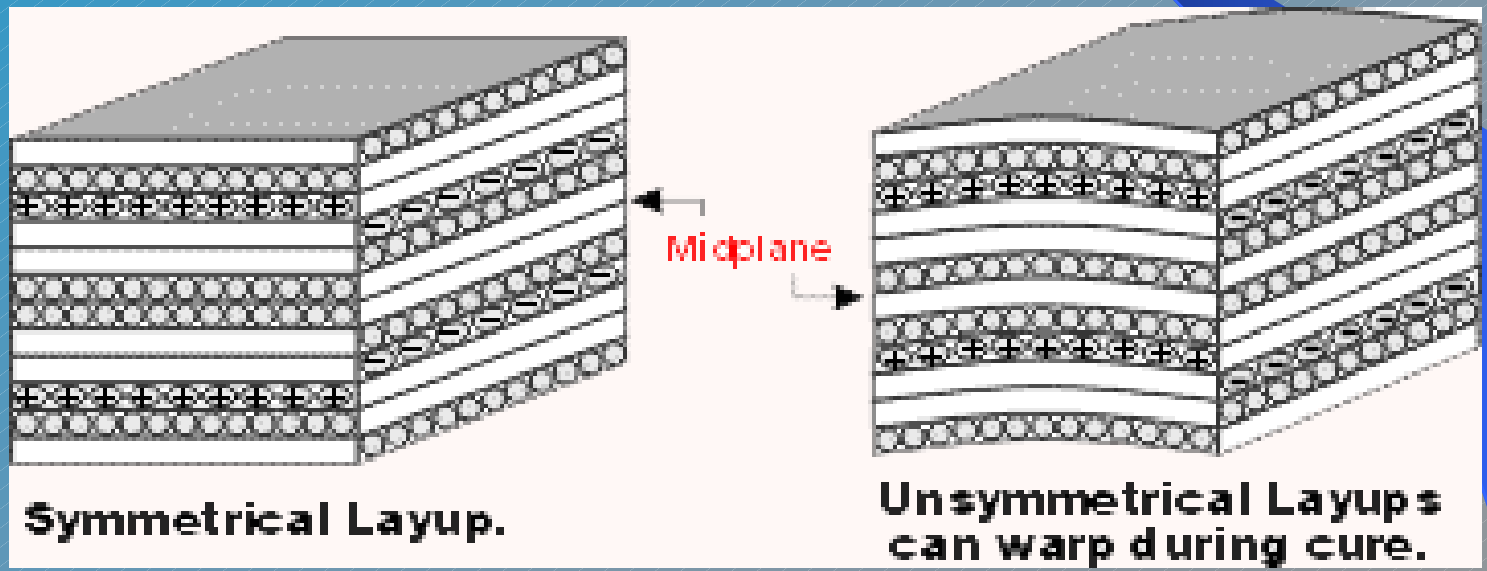
- Mid-Plane: Centerline of the lay-up. Plane forming the mid-line of the laminate.



Common Lay-up Terms and Conditions

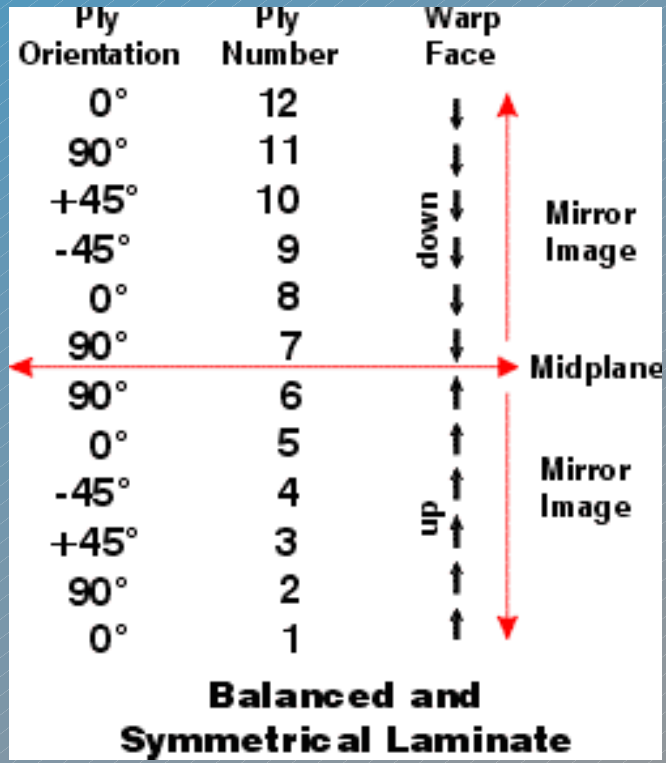
- Symmetry: A laminate is symmetric when the plies above the mid-plane are a mirror image of those below the mid-plane.
- Symmetrical lay-ups help to avoid thermal twisting of parts as they cool down after curing.

Common Lay-up Terms and Conditions



Common Lay-up Terms and Conditions

- Balance: A laminate is balanced when it has equal numbers of – and + angled plies.



Common Lay-up Terms and Conditions

- **Warp Clock**

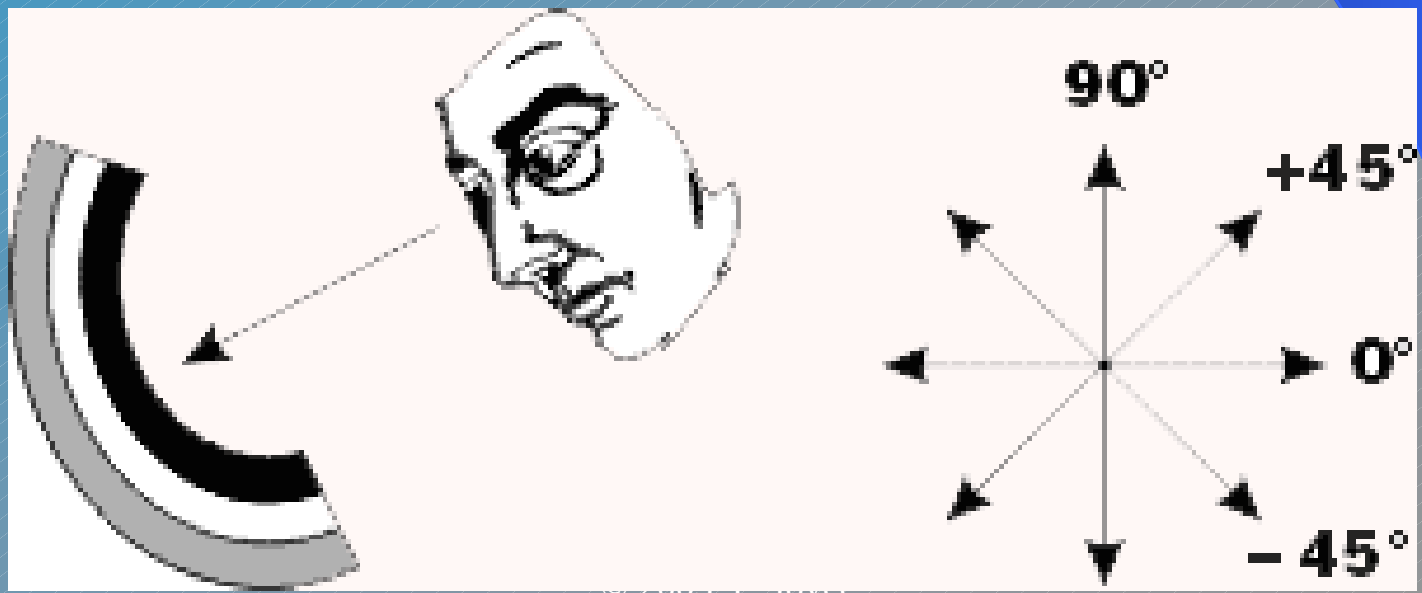
The Warp Clock is the standard for determining ply orientation. It is also how – and + angled plies are defined. The 0º axis is always parallel to the long direction of the structure or rectangular panel. The 90º axis is always perpendicular to the 0º axis. The 45º axis may be determined in two different ways:

Common Lay-up Terms and Conditions

Counter Clockwise

Manufacturing standpoint.

Plies are viewed from the inside of the structure looking toward the tool surface. +45º is located by moving counterclockwise from 0º to 90º.

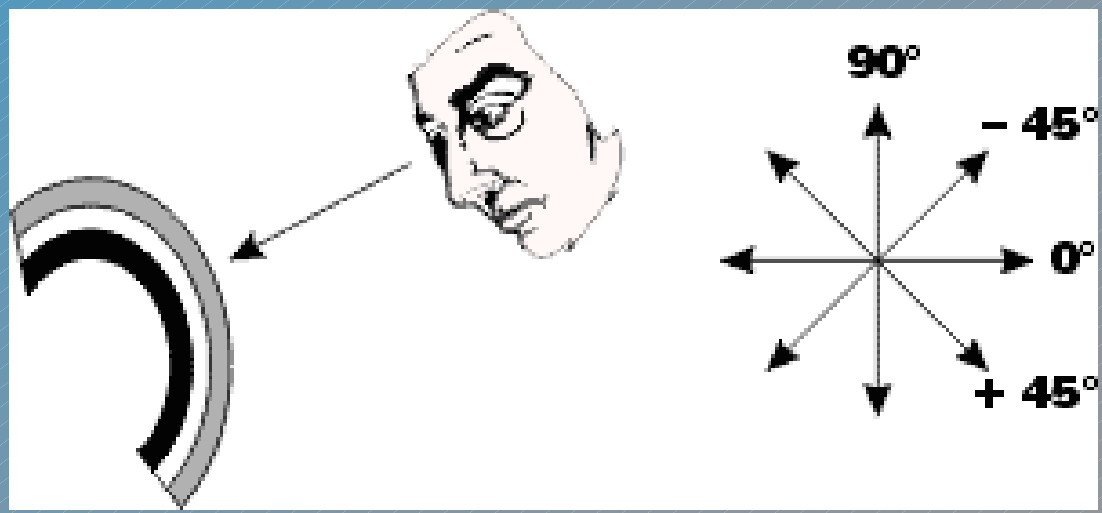


Common Lay-up Terms and Conditions

Clockwise

Repair standpoint.

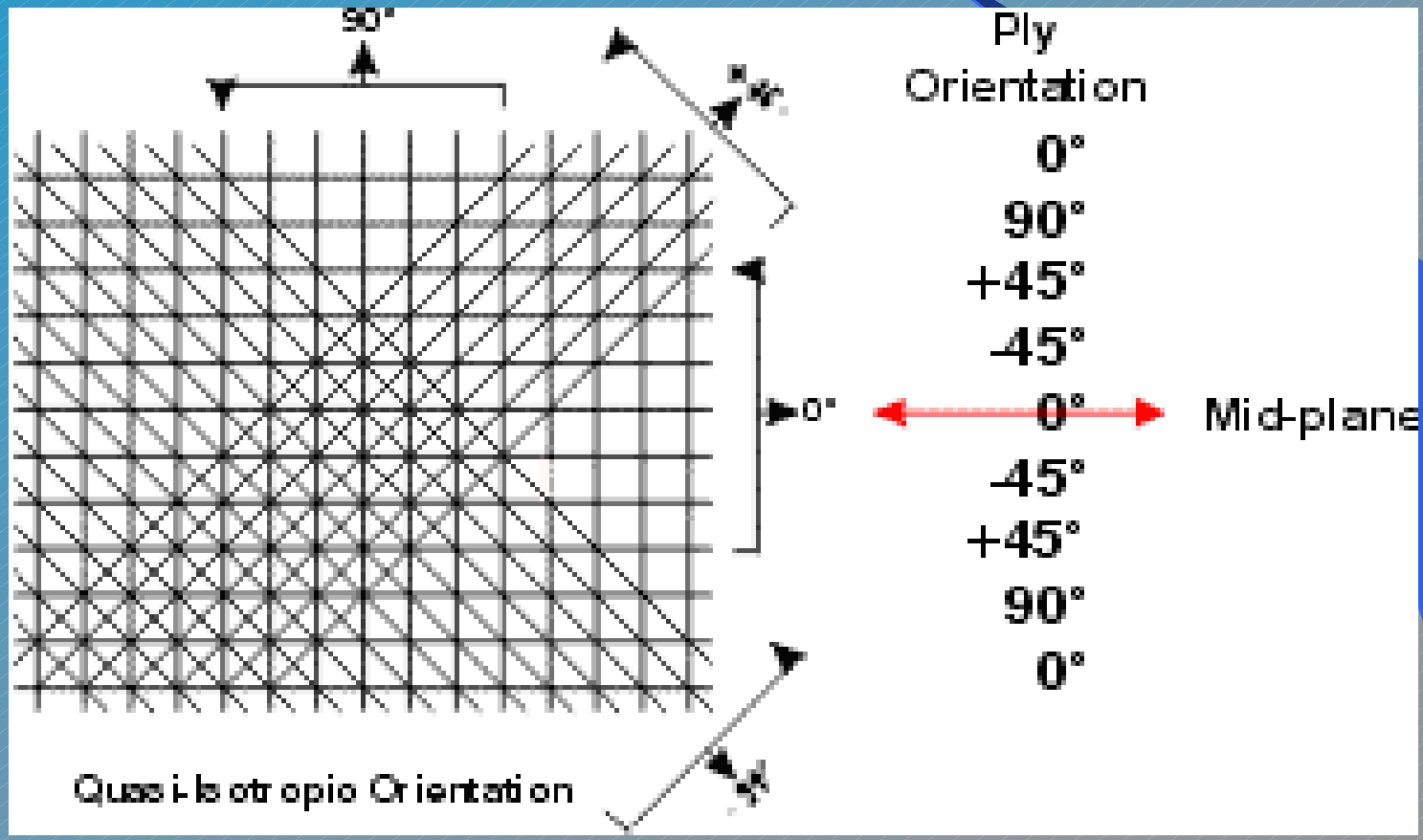
Plies are viewed from the outside of the structure, or the tool surface, looking in.+45º is located by moving clockwise from 0º to 90º.



Common Lay-up Terms and Conditions

- **Quasi-isotropic**
  - Isotropic means having the same properties in all directions.
  - Quasi-isotropic means having isotropic properties in-plane. A quasi-isotropic part has either randomly oriented fiber in all directions, or has fibers oriented such that equal strength is developed all around the plane of the part.
  - Generally, a quasi-isotropic laminate made from woven fabric has plies oriented at 0º, 90º +45º and –45º, with at least 12.5% of the plies in each of these four directions.
  - Quasi-isotropic properties can also be achieved with 0º, 60º and 120º oriented unidirectional plies.

Quasi-isotropic laminate



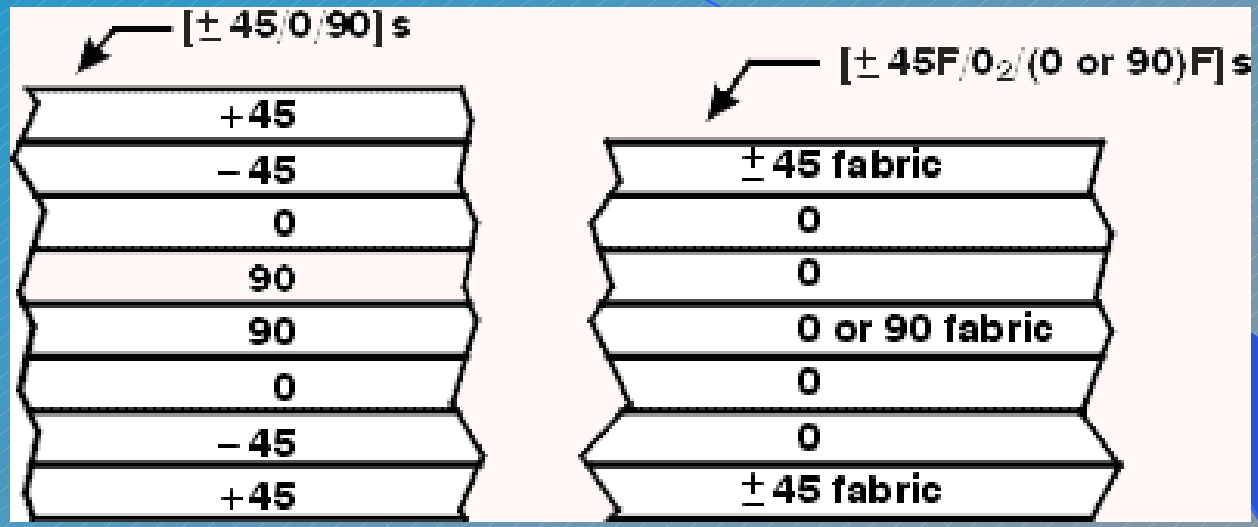
Laminate Orientation Code

- The purpose of the laminate orientation code is to provide a simple easily understood method of describing the lay-up of a laminate.
- The laminate orientation code is based largely on the code used in the Advanced Composites Design Guide
- Shorthand to condense a long descriptive representation of a multi-layer laminate into as few symbols as possible.
- Used during engineering analysis and for other non-drawing uses.

Laminate Orientation Code

- Laminae are listed in sequence starting from the tool surface or surface indicated by the leader arrow
- Each lamina is labeled by its ply orientation
- Each lamina is separated by a slash
- Multiple laminae of the same angle are indicated by a subscript, indicating the number of plies, following the angle indication.

Laminate Orientation Code



- Repeating groups of plies within a laminate can be placed in parentheses.
- Each complete laminate is enclosed in a set of brackets
- Symmetric laminates with an even number of plies are represented by listing all plies on one side of the mid-plane enclosed in brackets, followed by the subscript "s".
- Symmetric laminates with an odd number of plies are listed with a bar over the center ply to indicate it is the mid-plane

Laminate Orientation Code

- **Unidirectional Laminae**
  - ±45 indicates two unidirectional plies starting with a +45 followed by a -45.
  - + 45 indicates two unidirectional plies starting with a – 45 followed by a +45.
- **Fabric Laminae**
  - Fabric plies are identified by either an "F" following the ply angle or the ply may be placed in parentheses.
  - The angle value represents the direction of the warp fibers.
  - ± 45F indicates a woven fabric placed at either a + or – 45º direction.
  - + 45F indicates that the warp fiber must be placed in the +45º direction.

References

- **Engineering Mechanics of Composite Materials**, Daniel, I.M. and Ishai, O., 1994.
- **Mechanics of Composite Materials**, Jones, R.M., 1999.
- **Mil-Hdbk-17 Composite Materials Handbook**, 1997.