Images of Warped Panels from Unsymmetric Layups

M.E. 7502 – Lecture 4: Laminate Properties (cont’d)
Types of Woven Fabrics

Plain Weave – each warp yarn passes over one pick yarn and under the next pick yarn, and vice versa.

5 harness satin weave – each warp yarn passes under 5 pick yarns before surfacing. Each pick yarn passes over 5 warp yarns before moving under a warp yarn.
Fabric Reinforced Composites

• Two-directional fabrics are frequently used to reinforce refractory matrix composites, including carbon-carbon, carbon/silicon carbide, and silicon carbide/silicon carbide
  – For convenience, fabrics are also used to reinforce polymer matrix composites, including bismalylimides (BMI) and polyimides

• The fabrics are used in place of unidirectional lamina, which involve prepreging with the matrix material

• The fabrics are laid up in tools and the refractory matrix is introduced into the tooled preform
  – Phenolic resin, subsequently pyrolized to convert to carbon in the case of C-C
  – SiC, either as a pre-ceramic polymer or in gaseous form, in the case of C/SiC or SiC/SiC composites
  – High viscosity BMI or polyimide resins
Fabric Reinforced Composites

- Fabric reinforced laminated composites are designated the same way as laminates with unidirectional plies are designated—e.g. \([0/45/-45/90]_s\)

- The difference, however, is that in the case of fabric plies, the angle cited designates the direction of the warp fiber of the fabric
  - For the \([0/45/-45/90]_s\) laminate, the actual fiber orientations are \((0/90), (45/-45), (-45/45), (90/0), (0/90), (45/-45), (-45/45), (90/0)\)
Fabric Reinforced Composites

- To accomplish a balanced and symmetric laminate using fabric reinforced lamina, the fabrics must be flipped over, once past the mid-plane.
- In other words, even though there are the exact same number of fibers oriented in each different direction with a fabric reinforced laminate of \([0/45/-45/90]_2\) construction (here the plies are not flipped over, once past the mid-plane) as in the \([0/45/-45/90]_S\) construction (here the plies are flipped over, once past the mid-plane), a fabric reinforced laminate of \([0/45/-45/90]_2\) construction is not the same as a fabric reinforced laminate of \([0/45/-45/90]_S\) construction.
- This is because the weave style, even in the case of a plane weave, influences the actual positioning of the yarns relative to the mid-plane.
When this layup approach is not observed, i.e. when a fabric reinforced \([0/45/-45/90]_2\) construction is fabricated instead of a \([0/45/-45/90]_S\) construction, panel warpage typically occurs (unless the matrix is very compliant).

Following slides show images of composites fabricated without proper care used in the layup process.

– Panel warpage results
Warped Fabric Reinforced Polyimide Matrix Panels

• Photos illustrating the curvature issue with the polyimide panels
  – These show the worst case

• The top photo shows the C/polyimide against the table, allowing the corner to curl up towards the main structure

• The bottom photo shows the C/polyimide on top, allowing it to curve away from the structure

• Actual architecture used was [0/45/-45/90], while the correct architecture to use was [0/45]_S
Warped Fabric Reinforced Polyimide Matrix Panel
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Warped $[0/90]_8$ SiC/SiC Panels
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Warp Aligned Panels

• In the [0/90]_8 SiC/SiC panels, all eight fabrics were positioned in a so-called “warp-aligned” orientation
  – The warp fiber in every other ply is oriented in exactly the same direction
  – No flipping of the fabrics was performed after the mid-plane of the laminate