On the Use of Crossply and Quasi-Isotropic Laminates to Measure the Unidirectional Compression Strength of Composites*

(*While Developing the Combined Loading Compression (CLC) Test Method)

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In honor of my father…

Dr. Donald F. Adams

9/22/1935 – 12/22/2022

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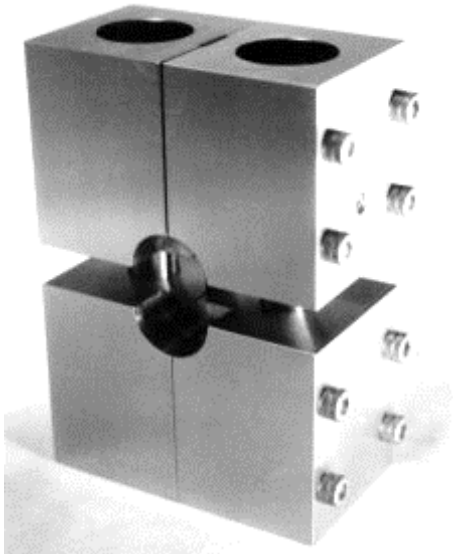
Combined Loading Compression (CLC) Test: ASTM D 6641

- Developed at the University of Wyoming (1990's)
- Standardized in 2001 (untabbed specimens), intended for use with cross-ply laminates
- Revised in 2009 to include tabbed specimens for use in testing unidirectional laminates
- Combined end loading and shear loading "Just enough shear loading to prevent end failure"



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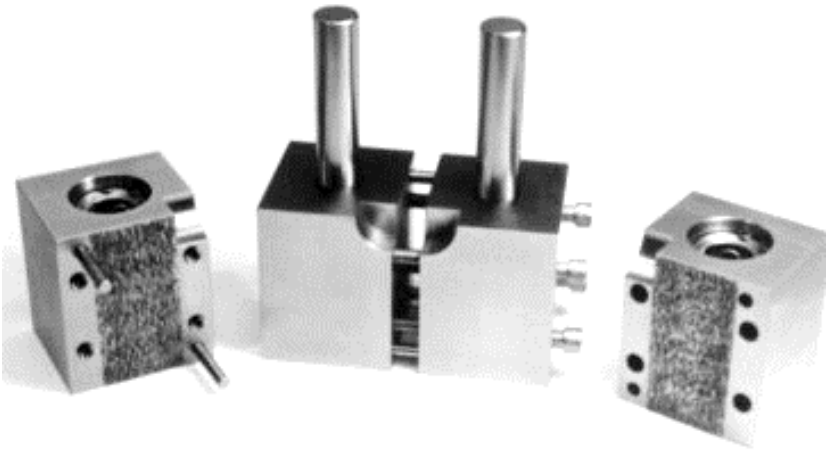
Why Perform Compression Tests Using Multidirectional Laminates?

Compression testing of multidirectional laminates…

- **Reduces the applied stress (force) required to fail specimen**
- **Allows for the use of untabbed specimens**
- **Reduces stress concentrations associated with gripping**



However…

- **Requires the use of a "back-out factor" to obtain the unidirectional strength (*Not approved to date for ASTM standard*)**

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Back-Out Factors (BF):

Unidirectional Strength From Cross-Ply Laminates

- Used for both stiffness and strength
- Based on Laminated Plate Theory (LPT)
- For symmetric, cross-ply laminates $[0/90]_{ns}$ & $[90/0]_{ns}$

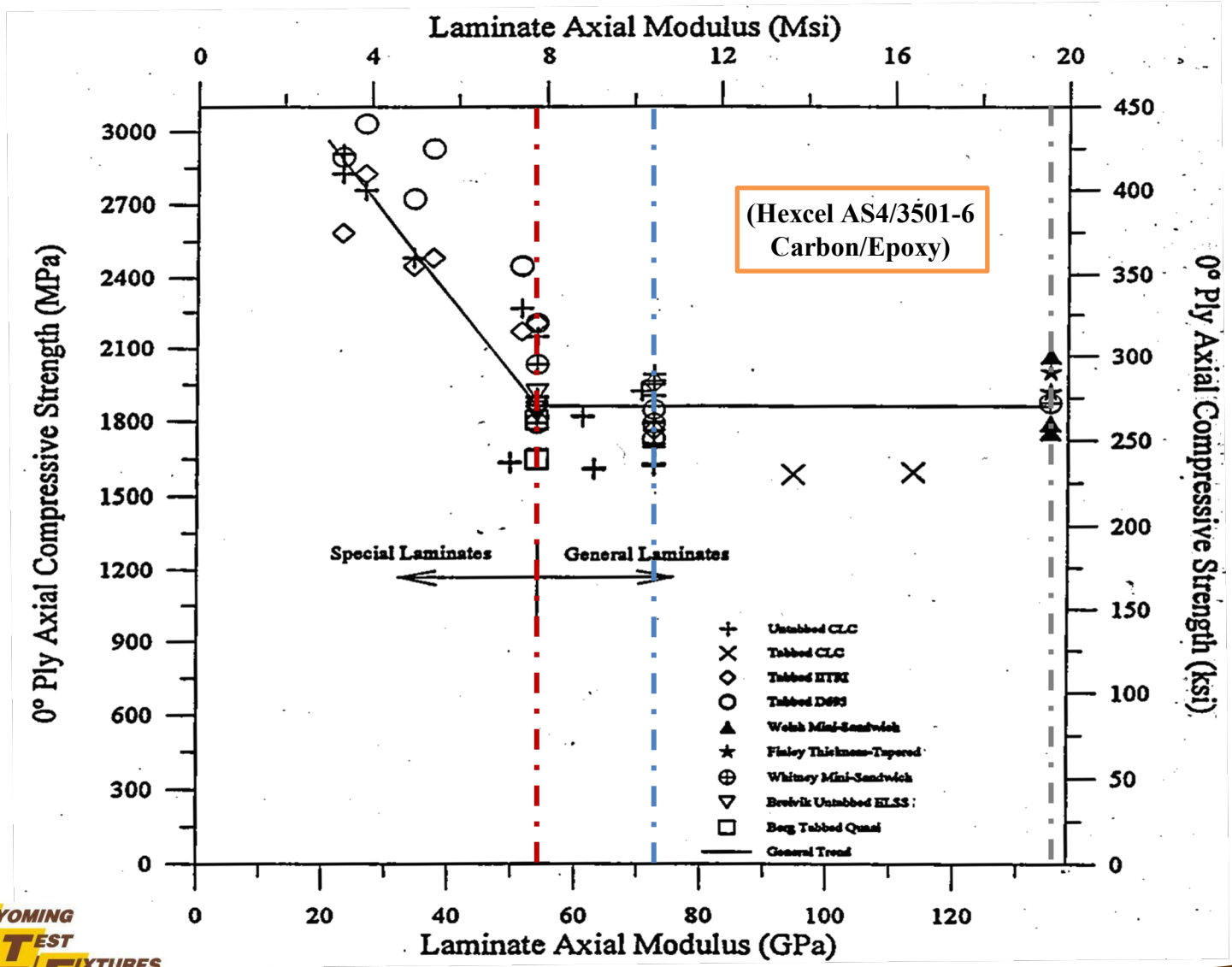
$$BF = \frac{\frac{1}{2} E_1(E_1 + E_2) - (\nu_{12} E_2)^2}{\frac{1}{4} (E_1 + E_2)^2 - (\nu_{12} E_2)^2}$$

where E_1, E_2, and ν_{12} are the axial modulus, transverse modulus, and Poisson's ratio of the unidirectional composite

- Value of BF increases as axial modulus of laminate decreases
  - Unidirectional laminate, $[0]_n$ BF = 1.0
  - Cross-ply laminates, $[0/90]_{ns}$ & $[90/0]_{ns}$ BF ≈ 1.8
  - Quasi-isotropic laminates, $[0/\pm45/90]_{ns}$ BF ≈ 2.5

$$BF = (Q^{\circ}_{11}A_{22} - Q^{\circ}_{12}A_{12})\, t/\, (A_{11}A_{22} - A_{12}^2)$$

Back-Out Factors:
Effect of Tested Laminate on Unidirectional Strength



In Summary…

Using Crossply and Quasi-Isotropic Laminates to Measure Unidirectional Compression Strength

- Historical data suggests that backed-out unidirectional strengths from cross-ply and quasi-isotropic laminates is comparable to well-performed tests with unidirectional laminates
- The use of cross-ply or quasi-isotropic laminates with back-out factors has not been approved to date in ASTM standards (but is presented/discussed in CMH-17 Handbook and used in some NCAMP databases).
- Compression testing of cross-ply and quasi-isotropic laminates is much easier than with unidirectional laminates!