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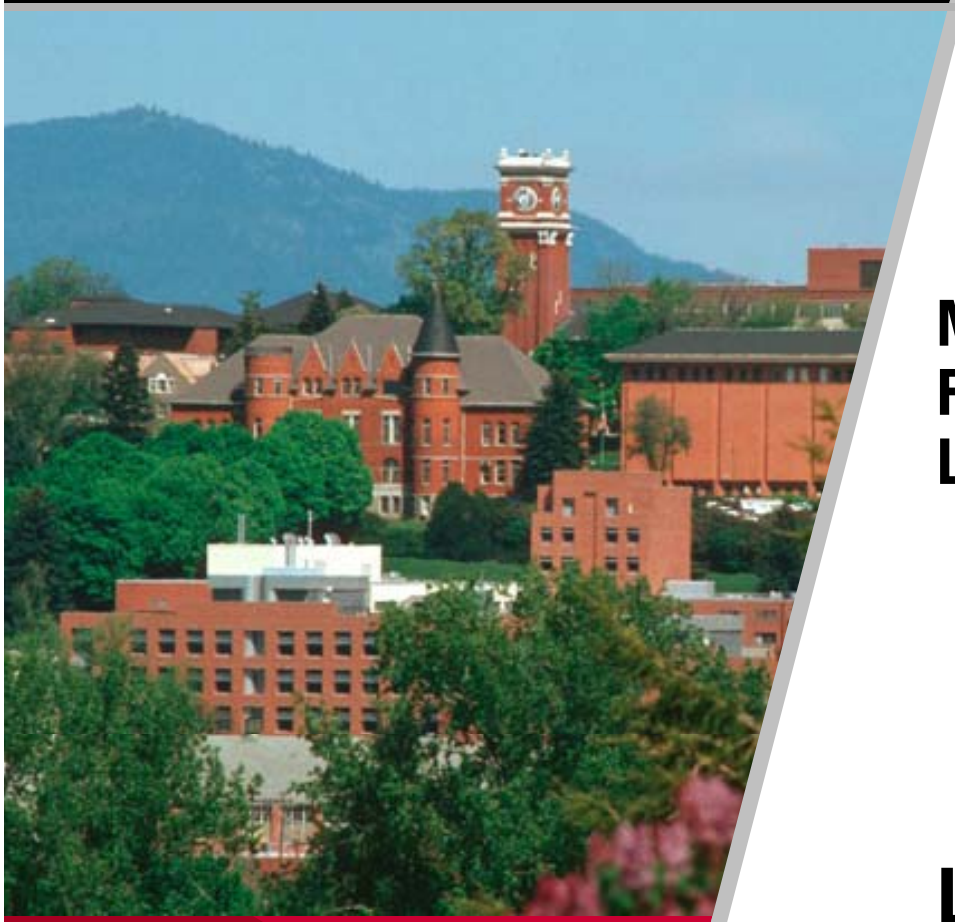

Maximum Strain as a General First Ply Failure Criterion in Laminated Composites

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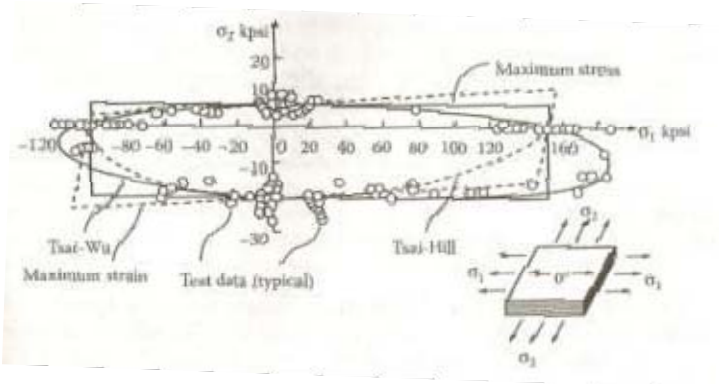
AMTAS 4-23-09

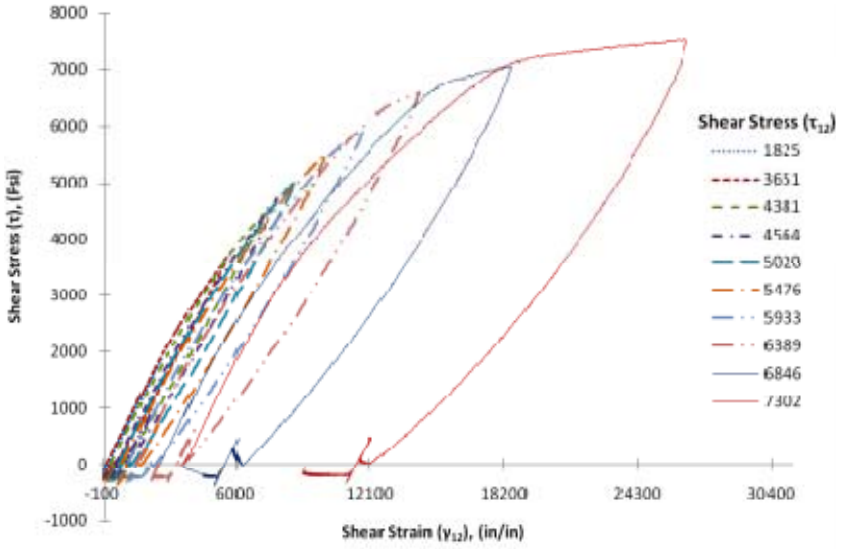
Background

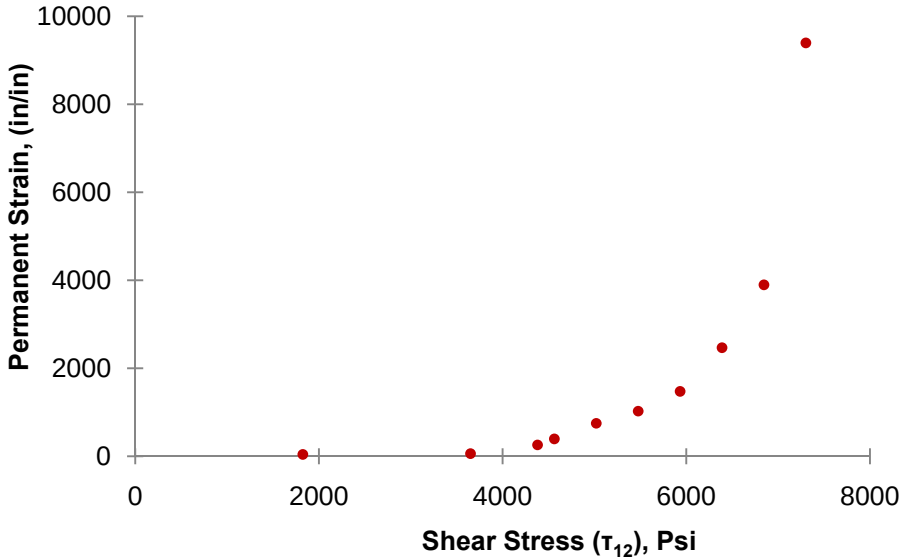
- Composite failure criteria tend to be:
  - too simple (often do not agree with experiment)
  - too complex (can be easier to build and test)
  - More multi-axial data is needed
- Maximum Strain (stress) Failure Criterion
  - Often used for fiber failure
  - Not applied to matrix failure
  - Sighted data is from lamina



Strength Properties

- Non-linear shear response decoupled from damage by loading-unloading of $\left[(\pm 45)_3\right]_s$

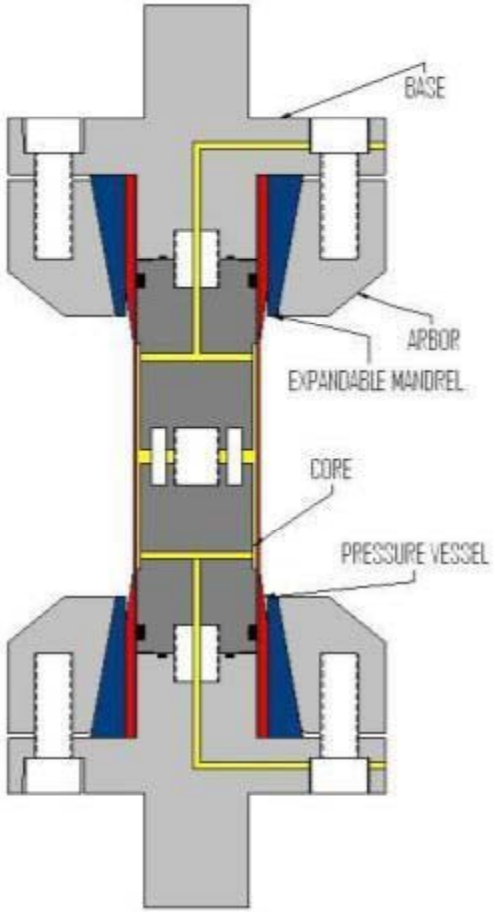




Two Examples

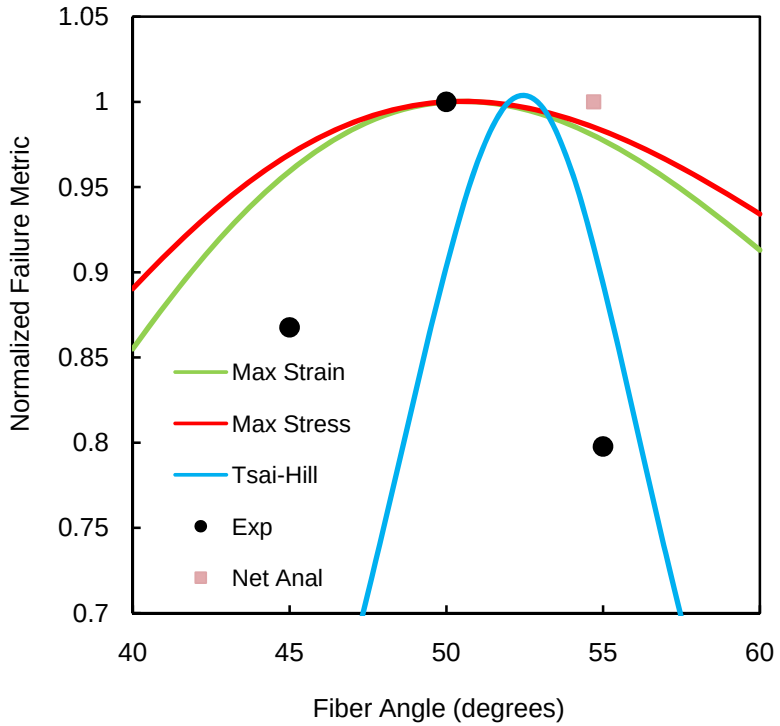
- Some data suggest Maximum Strain may apply to matrix failure
- Examples
  - Pressure vessel with bias fiber orientation
  - Open hole tension test coupon

Pressure Vessel

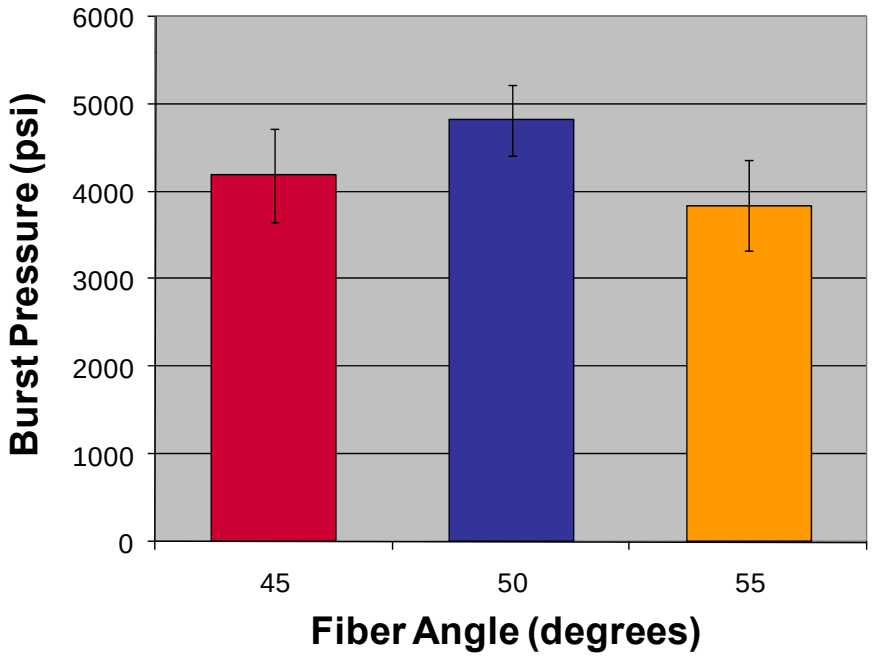


Failure Criteria Results

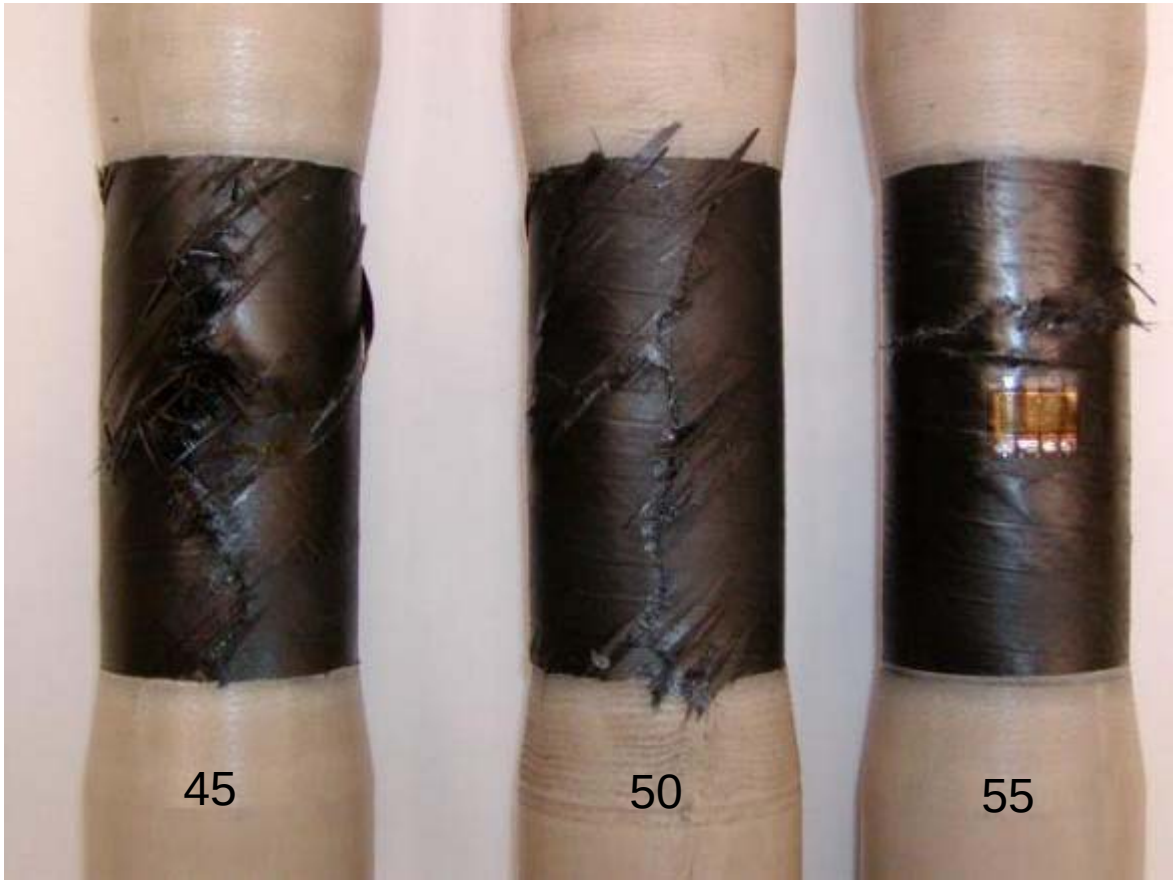
- Maximum stress and strain
  - Optimum angle minimizes matrix strain
- Tsai-Hill
  - Does not identify failure mode
  - Optimum angle found by maximizing load factor



Results of Pressure Vessel Tests



Transverse Failure Mode



Hoop Biaxial Axial

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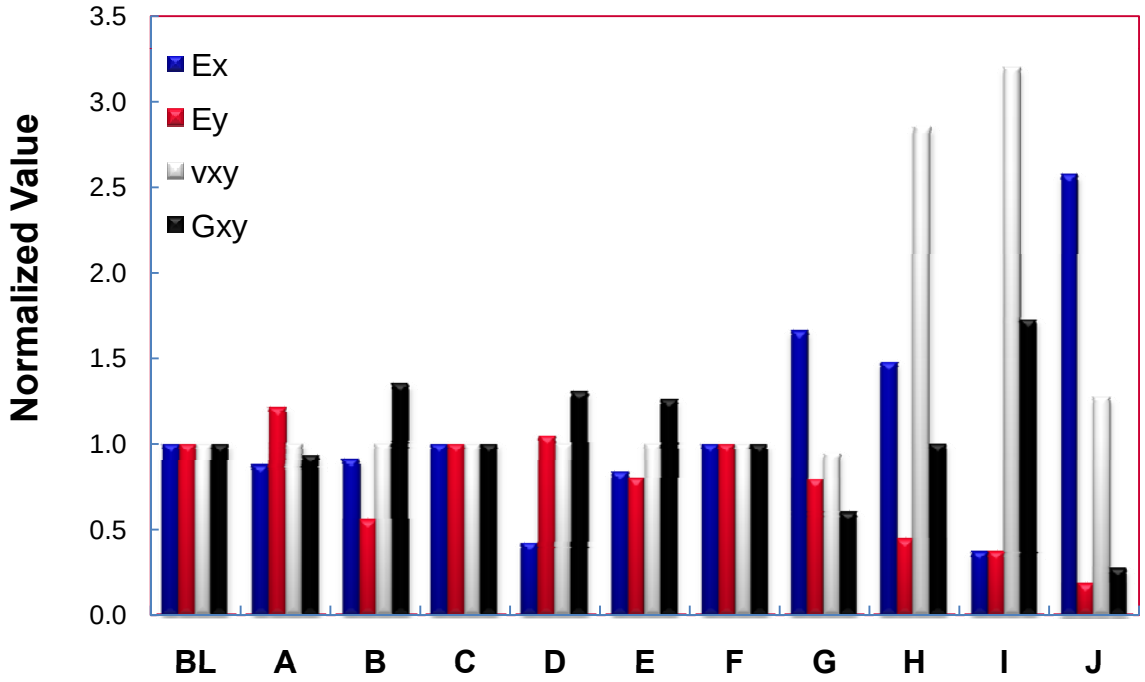
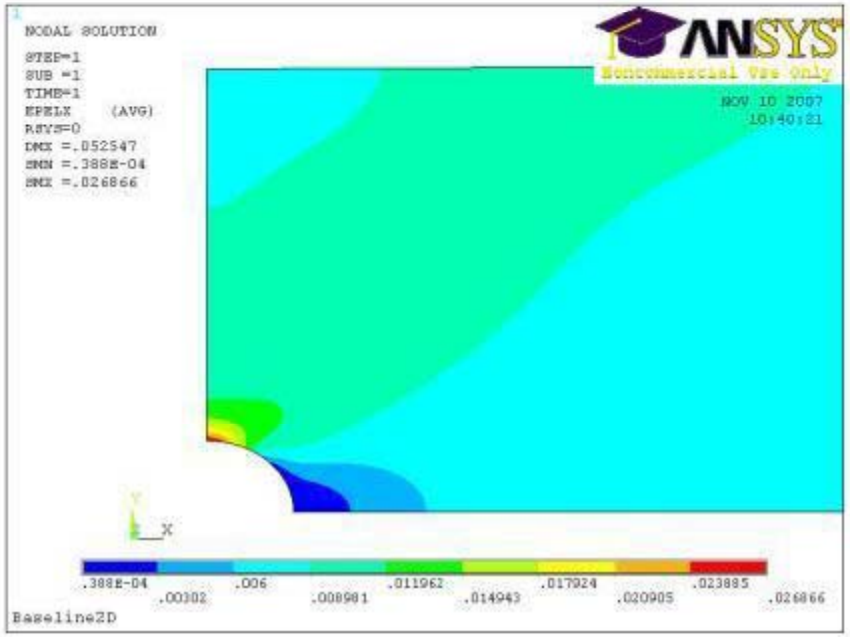
Open Hole Tension

Laminate	Layup
BL	[(45/90/-45/0)2]s
A	[(54/90/-54/0)2]s
B	[(45/51/-45/0)2]s
C	[(45/0/-45/90)2]s
D	[(45/90/-45/57)2]s
E	[(54/54/-54/0)2]s
F	[(45/-45/90/0)2]s
G	[(21/90/-21/0)2]s
H	[(45/0/-45/0)2]s
I	[(±45)4]s
J	[0]16

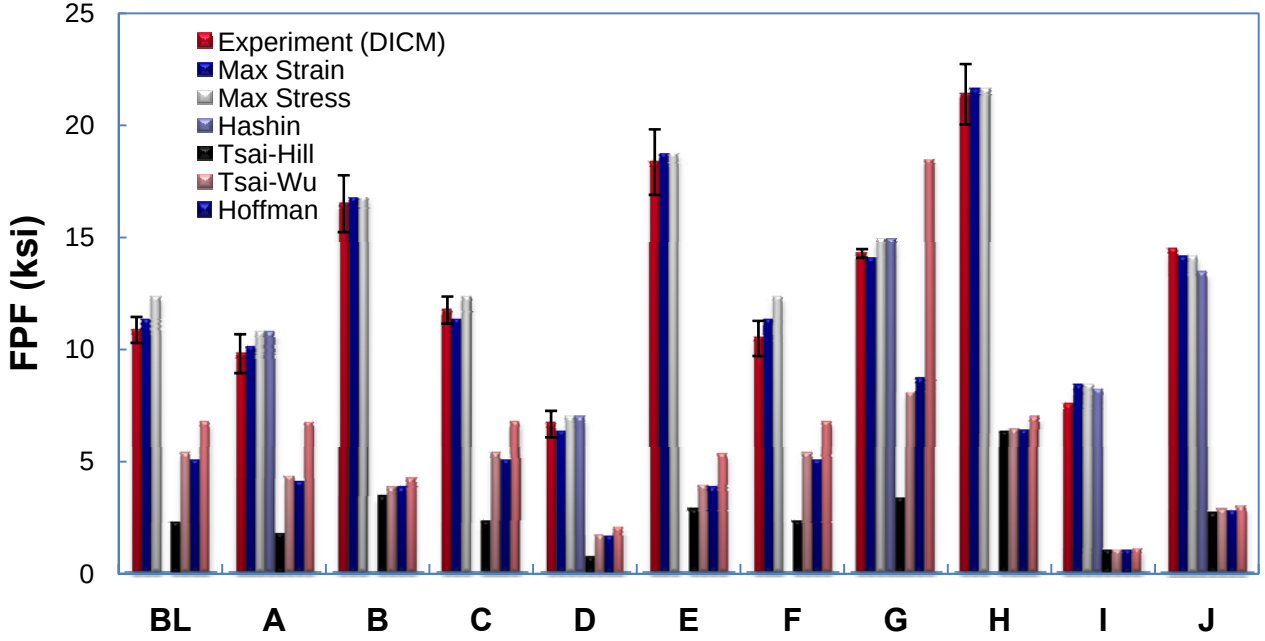


Strain State From FEA



Results

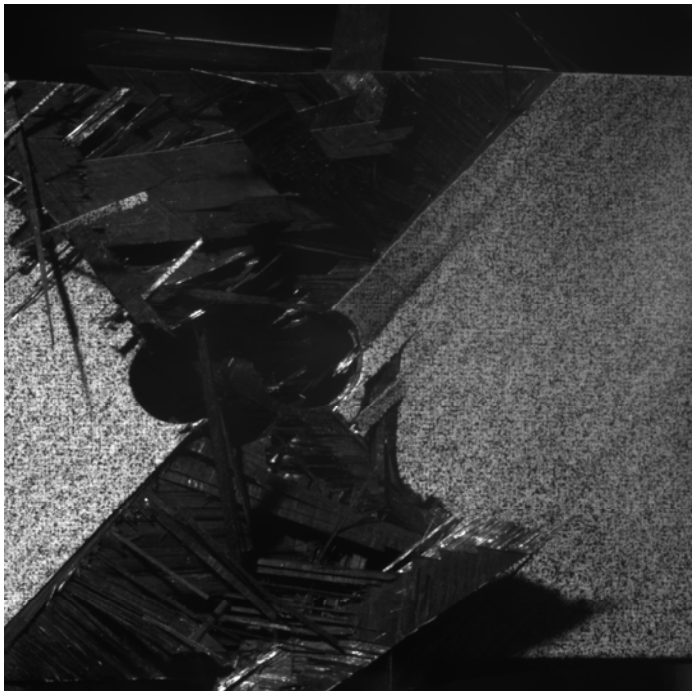
- Interactive criteria tend to be conservative
- Limit criteria correlate with failure for transverse and shear failure



Failure Modes

Laminate A
Transverse

Laminate B
Shear



Next Steps

- Biaxial results involved 2:1 stress ratio
  - Examine full failure envelope (normal and shear)
  - Consider notch under multi-axial stress
- Notched results involved tension and shear
  - Consider notched compression and flexure
- Evaluate brittle and toughened matrix systems
- Apply maximum strain to damage evolution and ultimate strength prediction