SHEAR CHARACTERIZATION OF COMPOSITE LAMINATES AND ADHESIVES

Jeff Kessler

Dan Adams

Department of Mechanical Engineering
University of Utah
Salt Lake City, UT

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Advanced Materials in Transport Aircraft Structures

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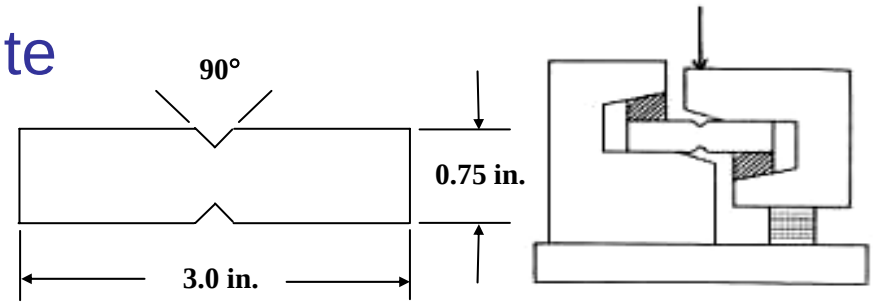
FAA Sponsored Project Information

- P.I. - Dr. Dan Adams
- Graduate Student Researchers:
  - Mike Moriarty
  - Adam Gallegos
  - Matt Nielson
  - Nick Burst
- FAA Technical Monitors
  - Peter Shyprykevich
  - Curt Davies
- Industry Participation
  - Vishay MicroMeasurements, Inc.

Shear Characterization of Composite Laminates

Motivation: Improved shear testing required for composite laminates and textiles

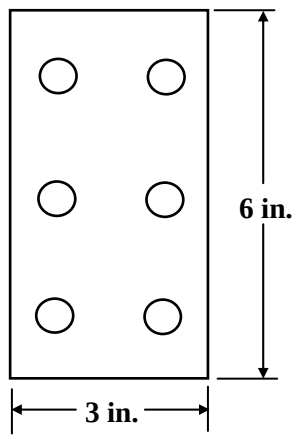
- High shear strengths
- Coarse architectures require larger gage section



Objective: Measurement of shear modulus and shear strength

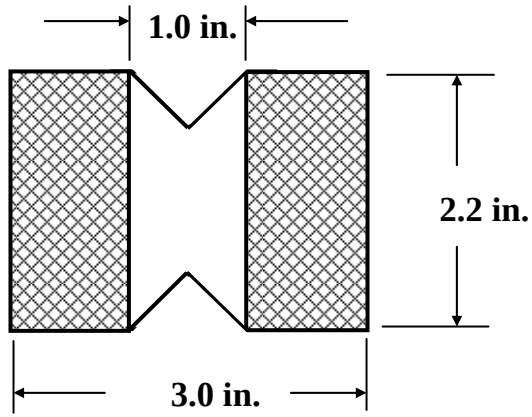
Approach: Combine attractive features of existing shear tests

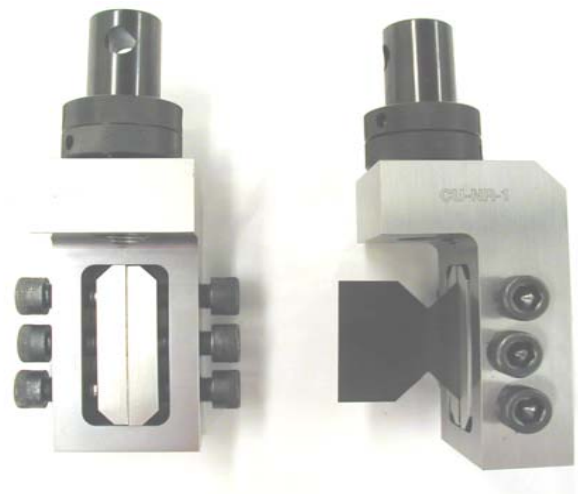
- Iosipescu Shear (ASTM D 5379)
- Two Rail Shear (ASTM D 4255)



The V-Notched Rail Shear Test
ASTM D 7078

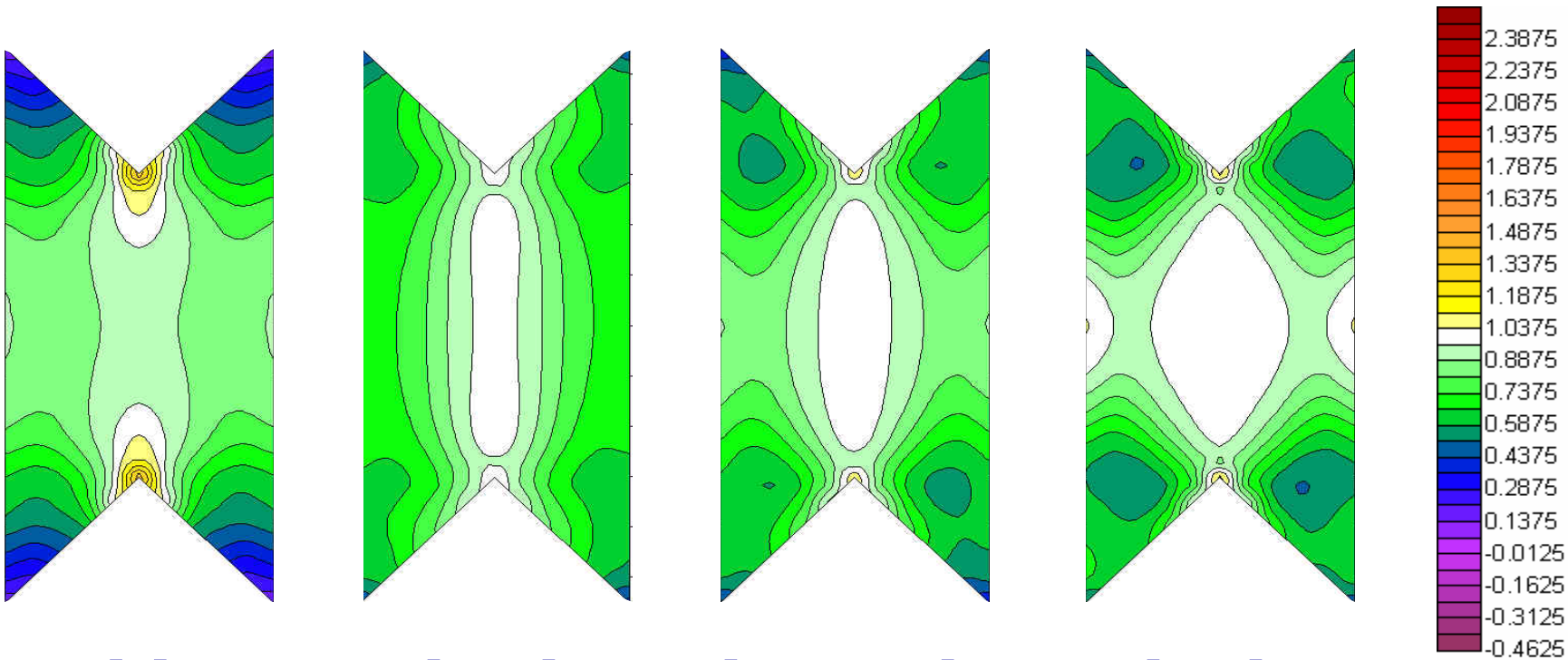
- 3.0 in. x 2.2 in. notched specimen
- 1.0 in. wide gage section
- Same notch configuration as Iosipescu specimen
- Face loaded as in standard rail shear test
- Tension loading of rail-type test fixture





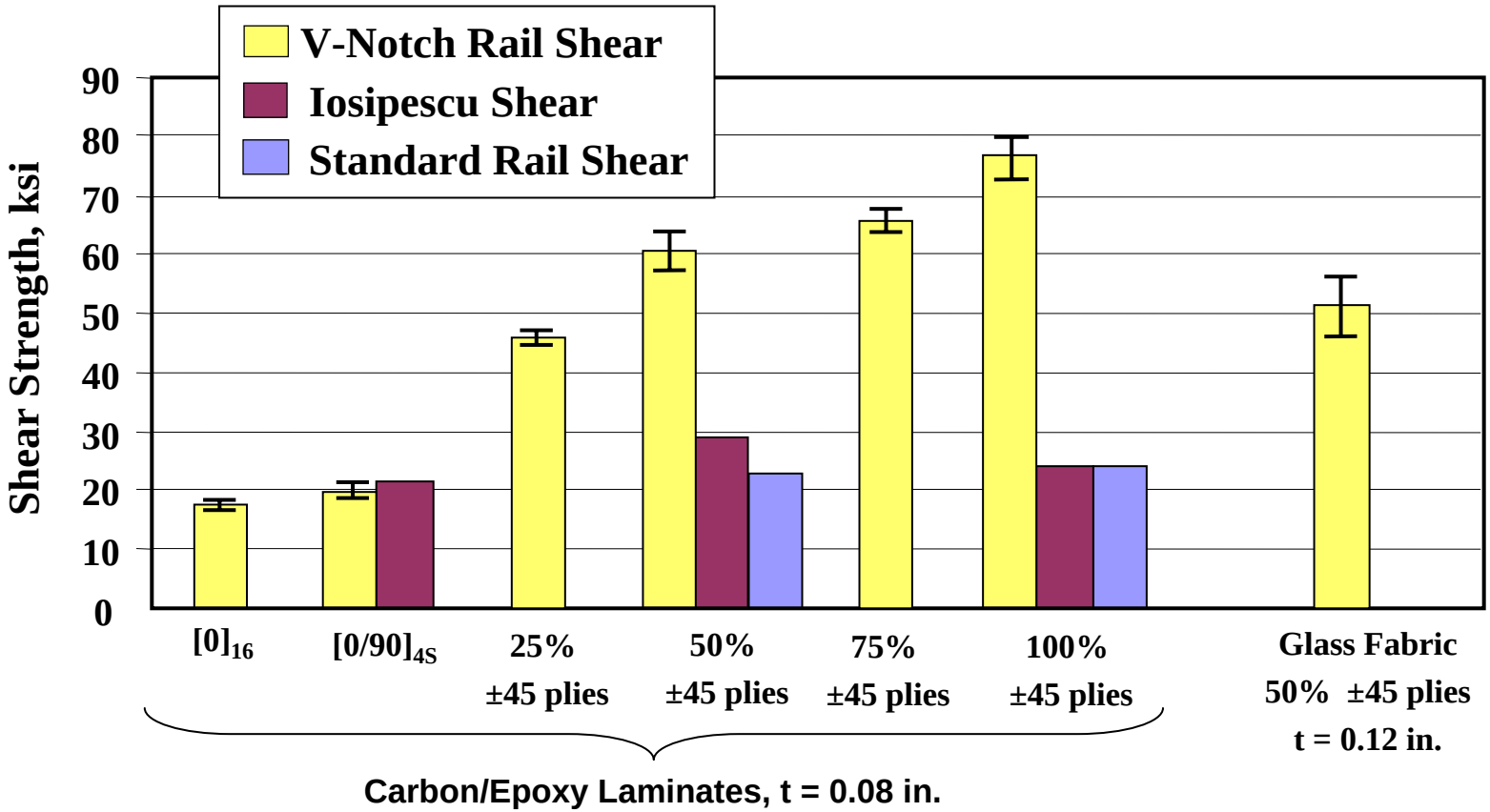
Uniformity of Shear Stress in V-Notched Rail Shear Specimen

Finite element predictions for carbon/epoxy laminates

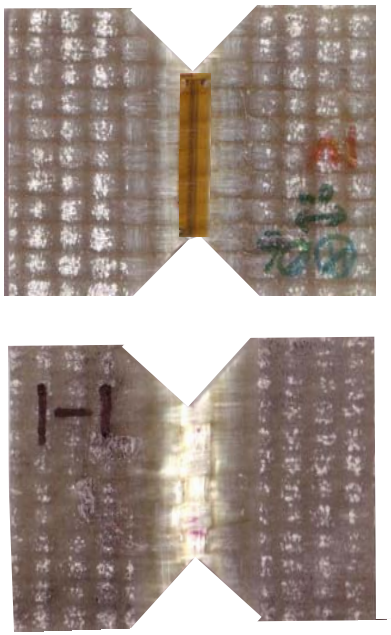


$[0]_{16}$ $[0/90]_{4S}$ $[0/\pm45/90]_{2S}$ $[\pm45]_{4S}$

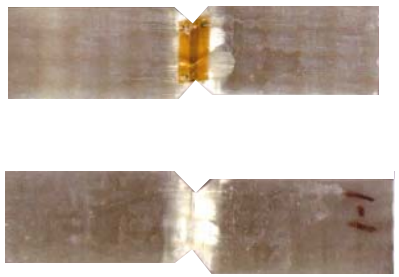
Experimental Results:
Apparent Shear Strengths of Composite Laminates



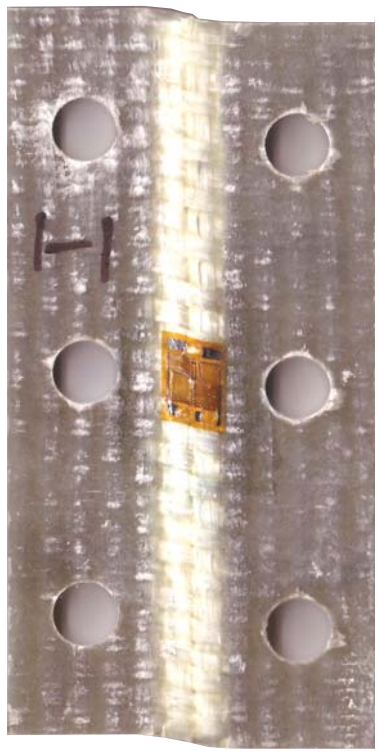
Comparison of Specimen Sizes: Woven Composites



V-Notched Rail Shear
ASTM D 7078



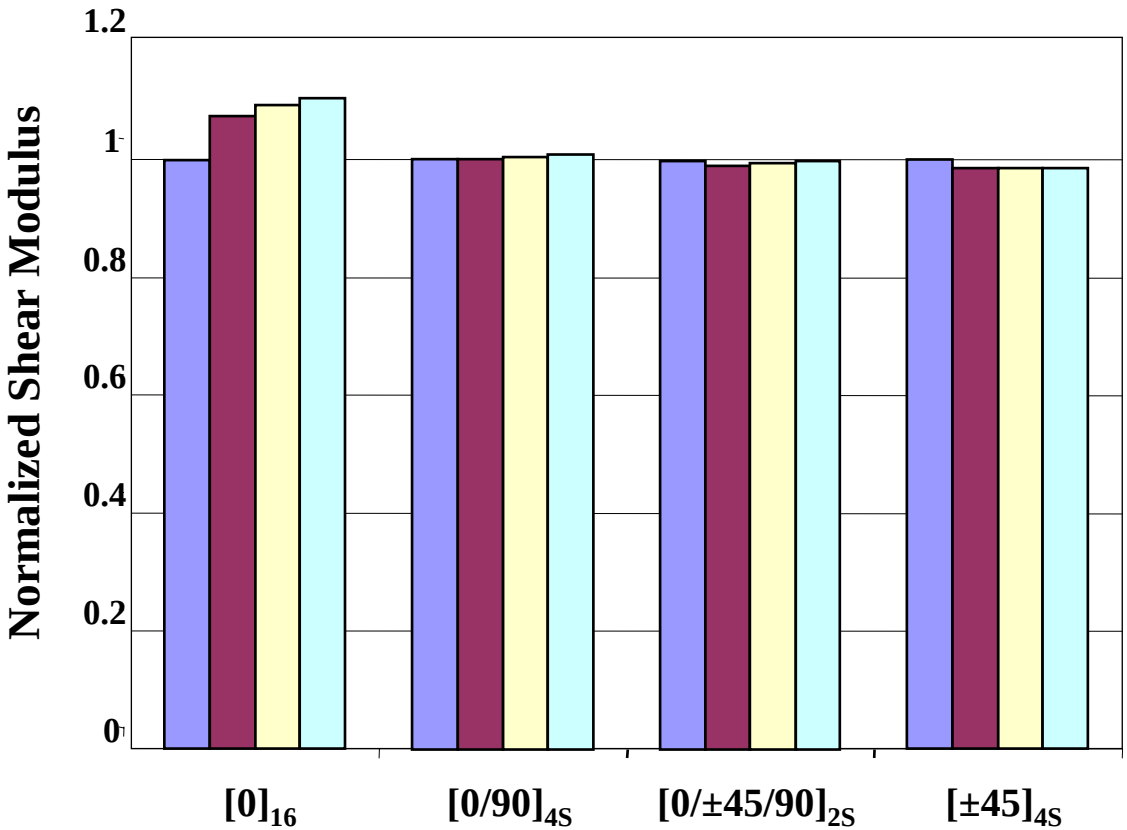
Iosipescu Shear
ASTM D 5379

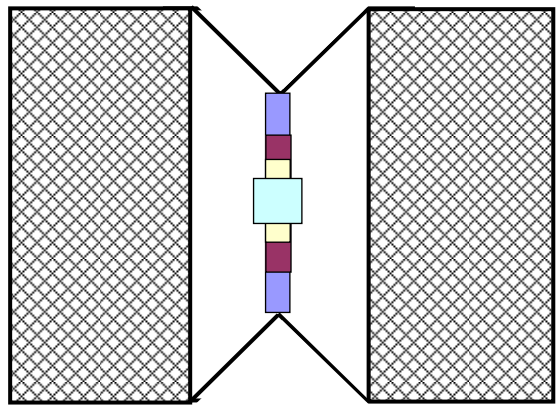


2-Rail Shear
ASTM D 4255

Effect of Strain Gage Size on Apparent Shear Modulus

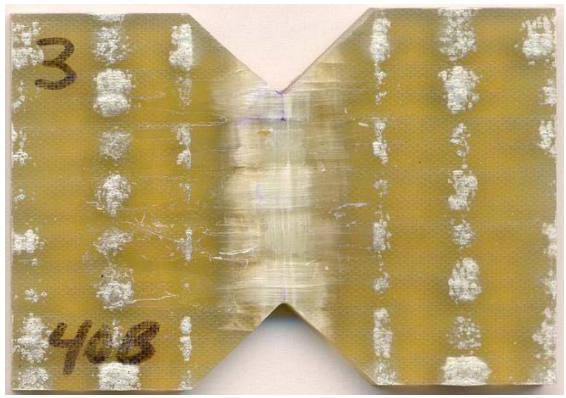
Finite element predictions for carbon/epoxy laminates



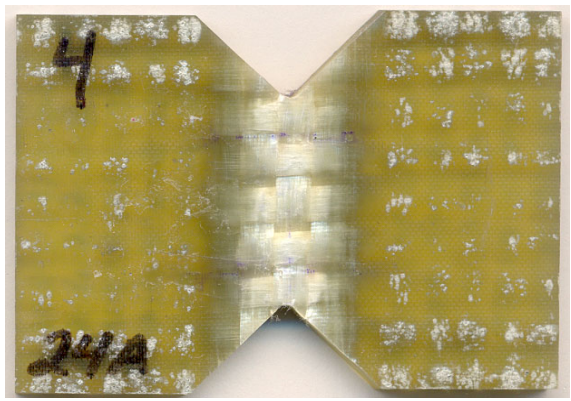


- Notch-to-Notch Gage (1.2 in.)
- "Compact Gage" (0.75 in.)
- "Iosipescu" Gage (0.45 in.)
- Standard Gage (0.25 in.)

Optimal Shear Gage for Textile Composites

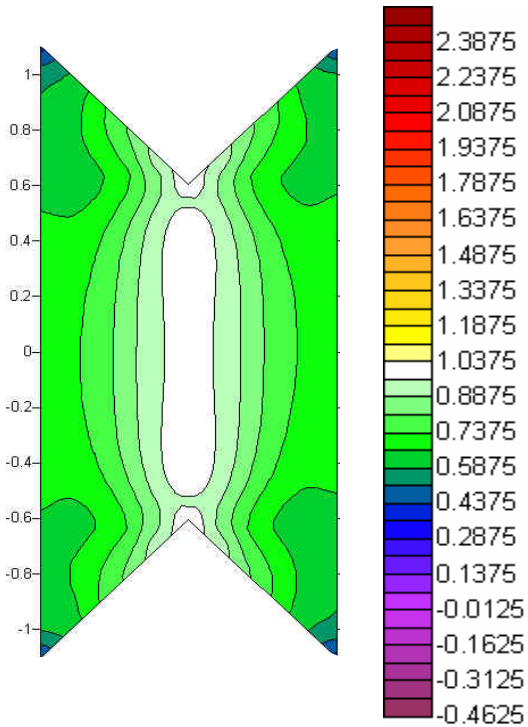


1.4 x 0.9 tows/cm



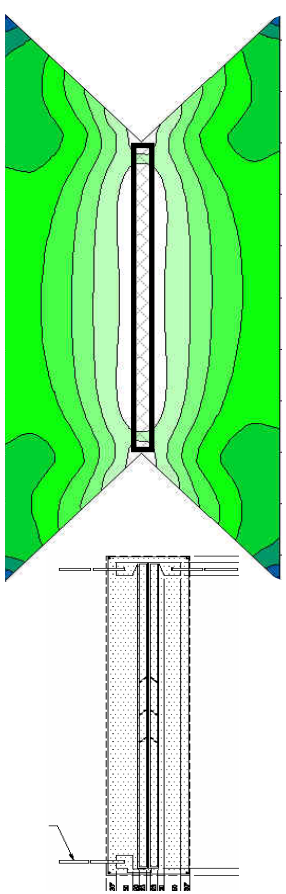
2 x 1.6 tows/cm

- Adequate gage width desired for coarse textiles
- Narrow region of uniform shear strain

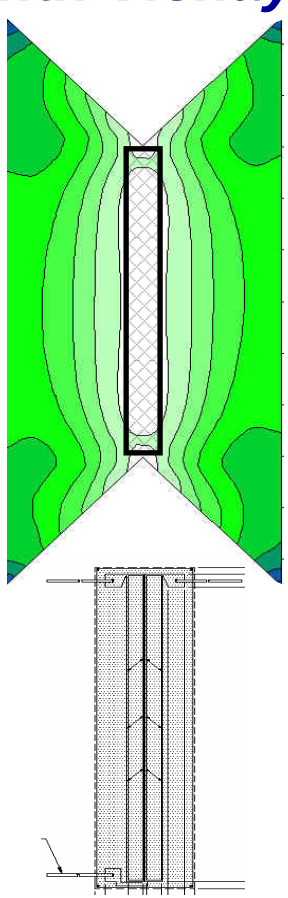


Candidate Shear Gages for V-Notched Rail Shear Test

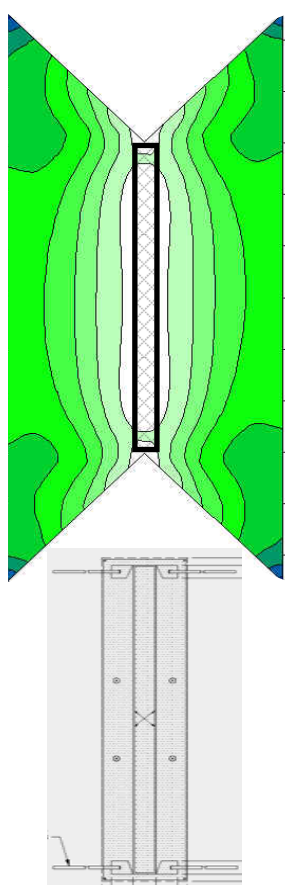
In collaboration with Vishay Micromeasurements Corp.



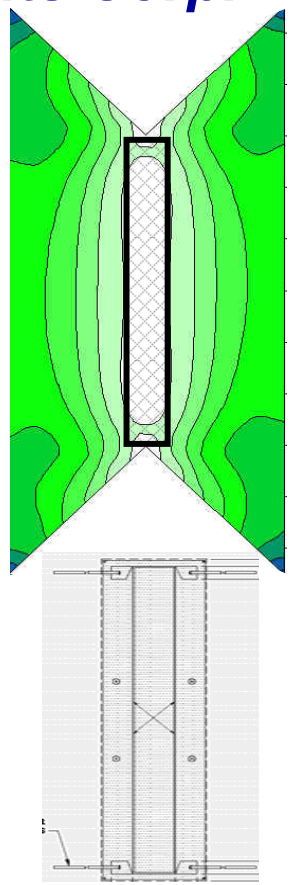
2 x 0.023 in. Width



2 x 0.046 in. Width



0.070 in. Width



0.130 in. Width

Shear Characterization of Adhesives

Motivation:

- Lack of consensus on whether mechanical properties of an adhesive are affected by bondline thickness
- Need for shear response of adhesives for use in the design and analysis of adhesive joints

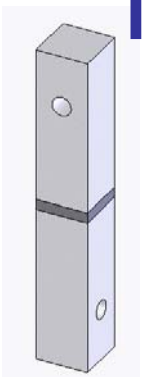
Objectives:

- Determine the influence of bondline thickness on the shear properties of aerospace adhesives
- Develop test methodology for shear characterization of adhesives.

Approach: Use of V-notched Iosipescu shear specimen developed for composite materials

Determination of Adhesive Properties

In-Situ Properties

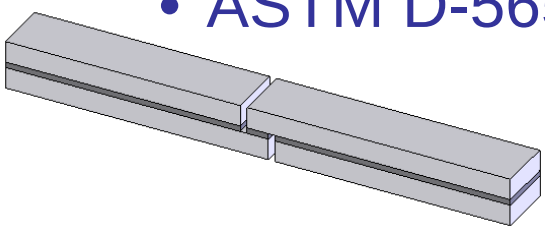


Tensile: Butt-Joints

- ASTM D-2094 and D-2095

Shear: Lap Joints

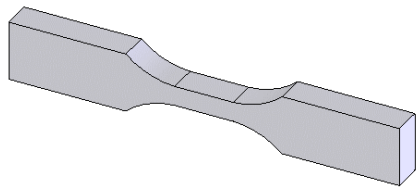
- ASTM D-1002
- ASTM D-3165
- ASTM D-5656



Bulk Properties

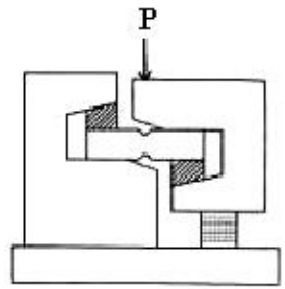
Tensile: Dog-Bone

- ASTM D-638

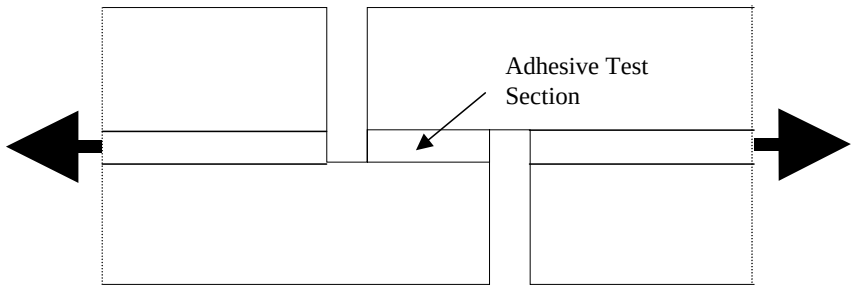


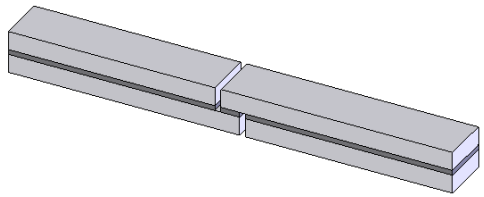
Shear: Iosipescu

- ASTM D-5379



Non-Uniformity of Shear Stress:
Thick-Adherend Lap Joint (ASTM D 5656)

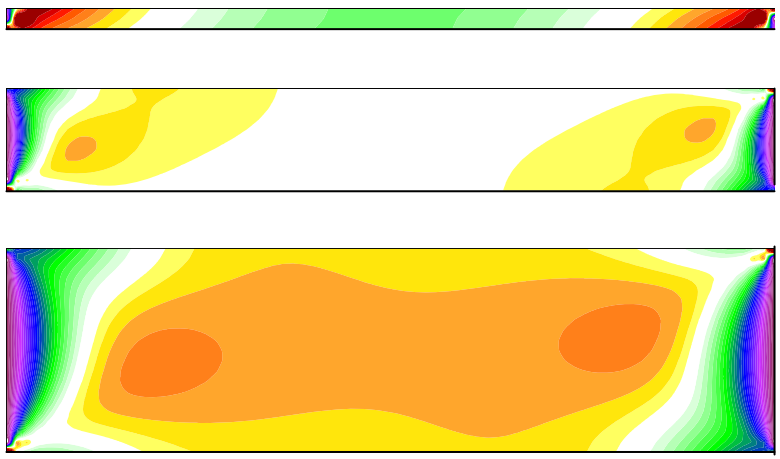


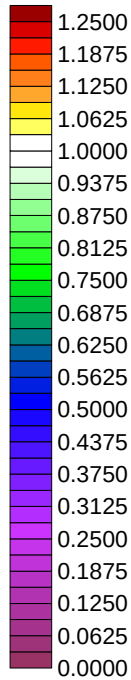


0.25 mm (0.01 in.)

1.27 mm (0.05 in.)

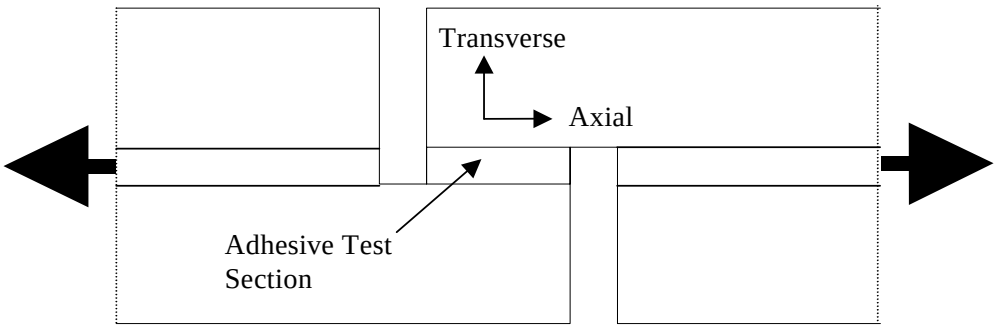
2.54 mm (0.10 in.)

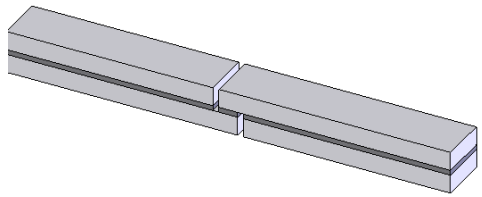




Normalized Shear Stress Distribution in Adhesive

Presence of "Peel" Stresses:
Thick-Adherend Lap Joint (ASTM D 5656)

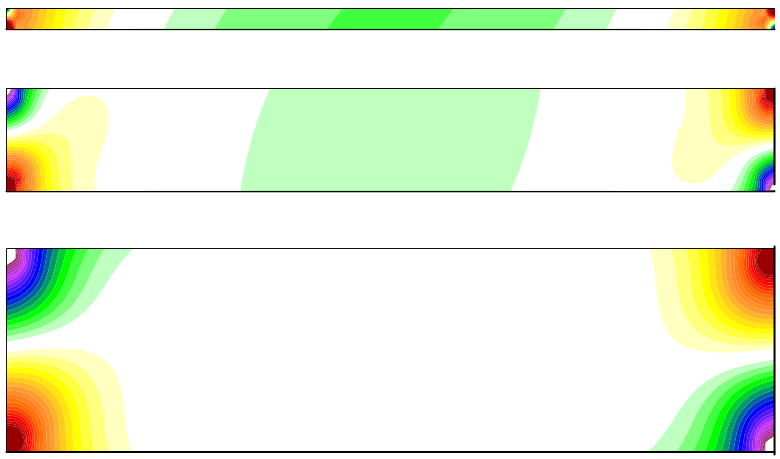


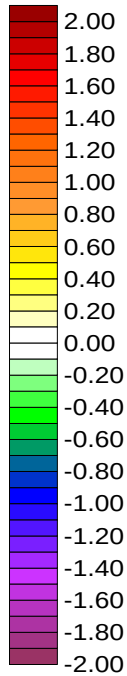


0.25 mm (0.01 in.)

1.27 mm (0.05 in.)

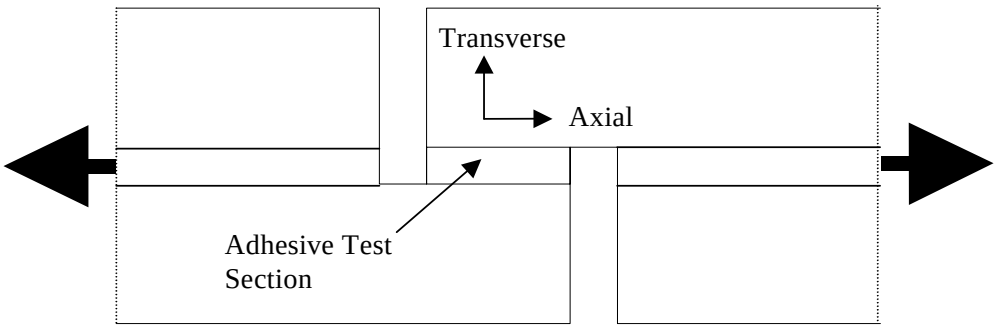
2.54 mm (0.10 in.)

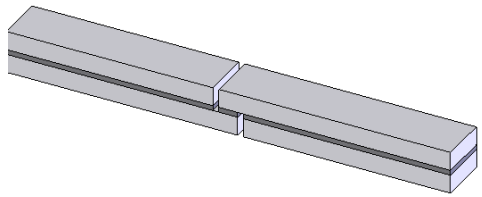




Normalized Transverse Stress Distribution in Adhesive

Presence of Axial Stresses:
Thick-Adherend Lap Joint (ASTM D 5656)

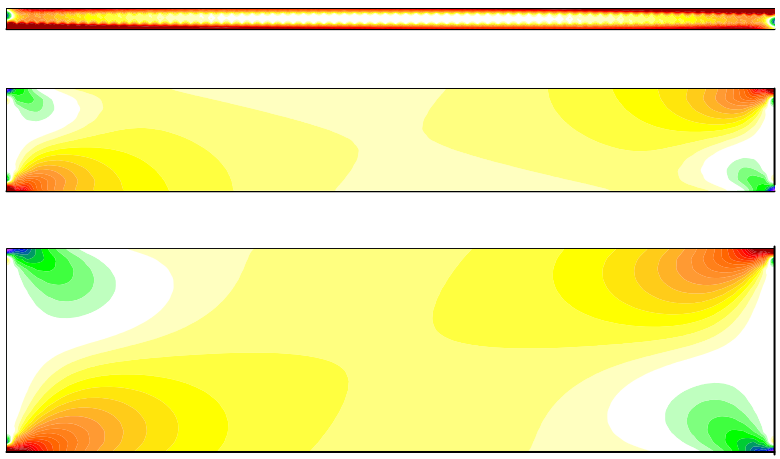


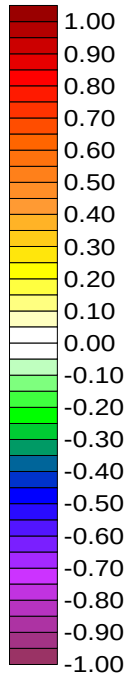


0.25 mm (0.01 in.)

1.27 mm (0.05 in.)

2.54 mm (0.10 in.)



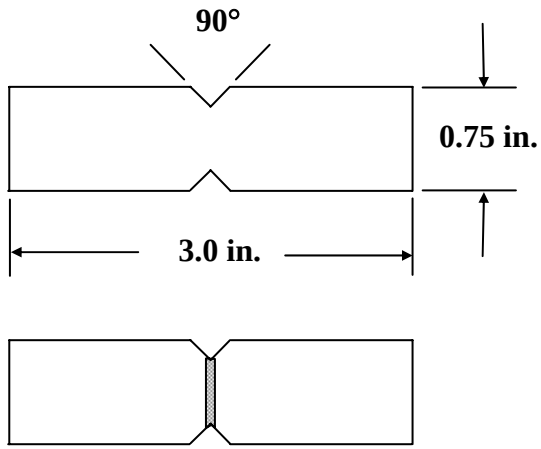


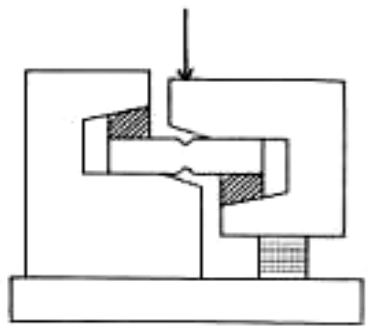
Normalized Axial Stress Distribution in Adhesive

Shear Testing of Adhesives:
Use of the Iosipescu Shear Test

Why use the Iosipescu shear test for adhesives?

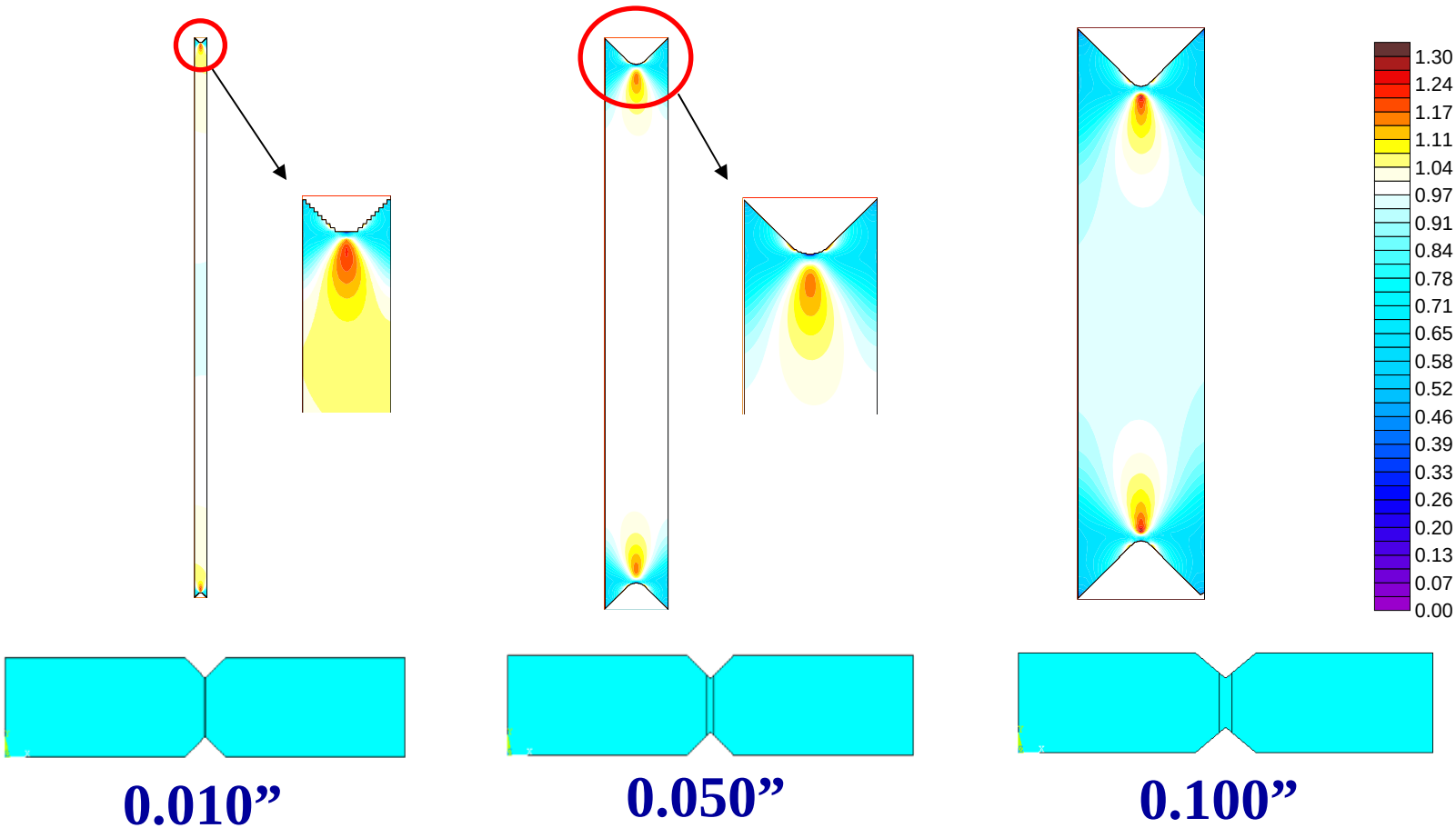
- Relatively low shear strengths expected
  (No need for V-Notched Rail Shear test)
- Relatively uniform shear stress within gage section… for bulk adhesives
- Ability to adopt to both bulk adhesive testing and “in-situ” adhesive testing
- Ability to tailor specimen geometry to optimize stress distribution for adhesively bonded joints



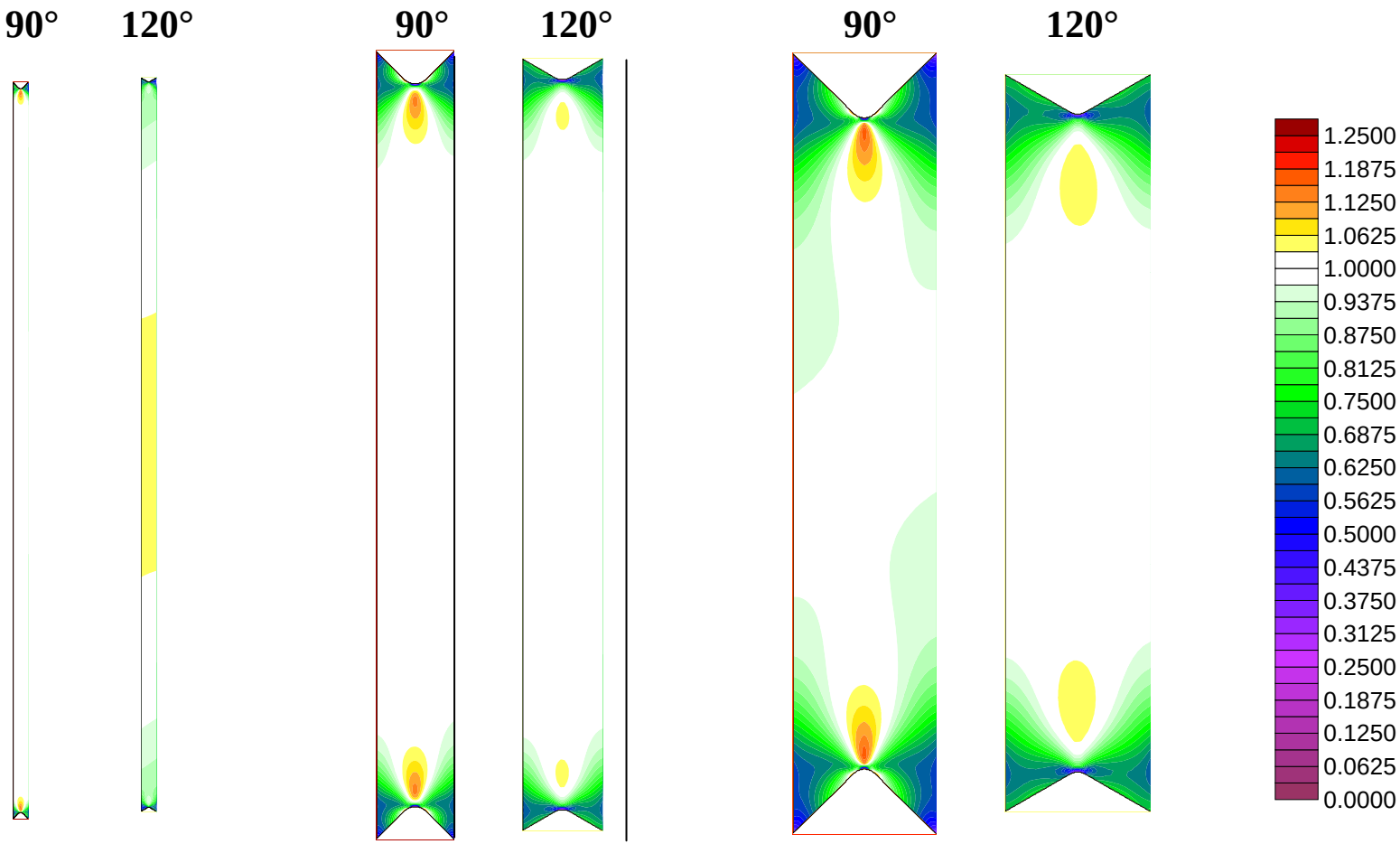


Use of Iosipescu Shear Test for "In-Situ" Adhesive Testing

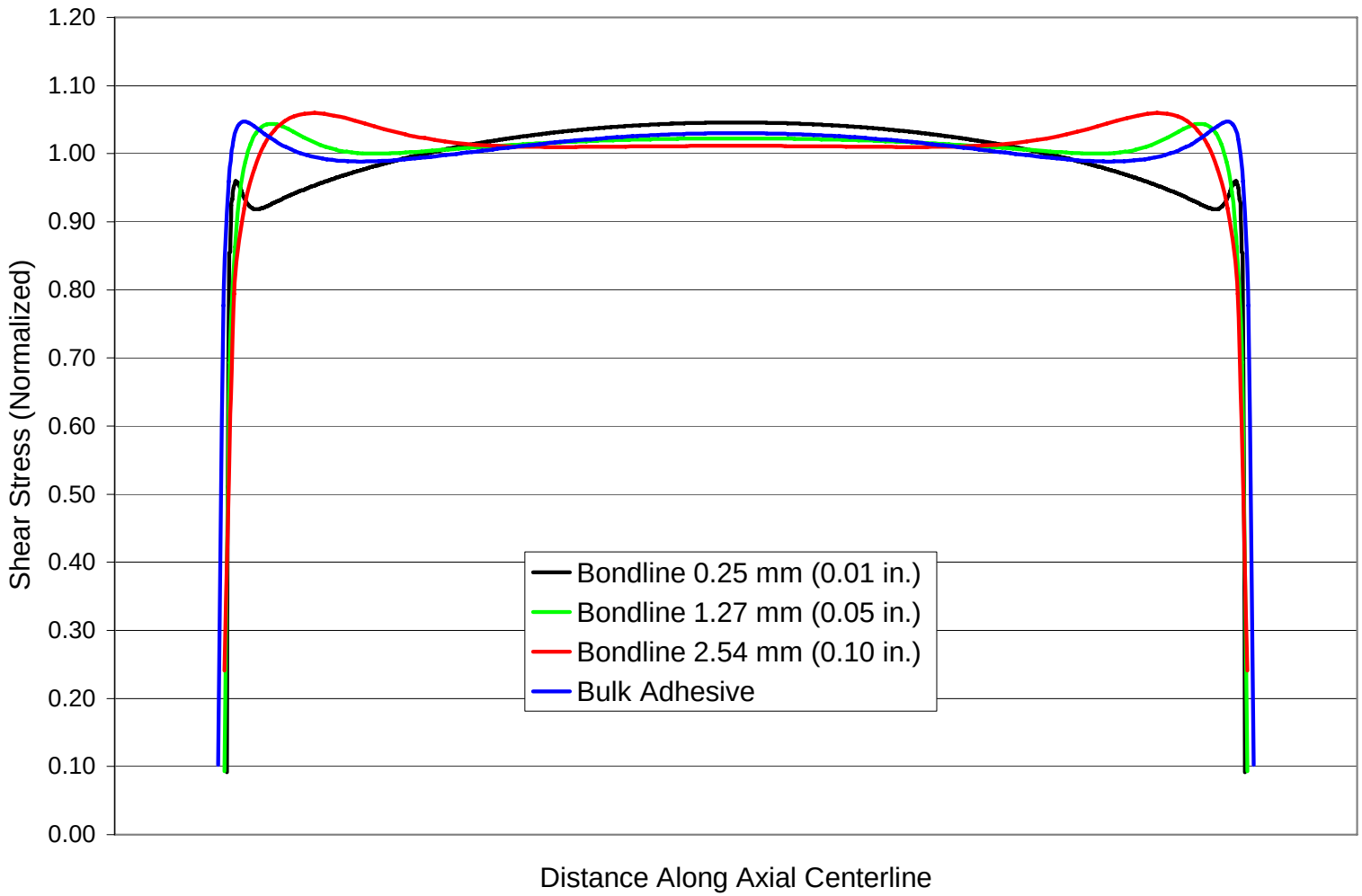
Loctite EA 9394 adhesive with aluminum adherends



Use of Increased Notch Angle to Reduce Stress Concentration



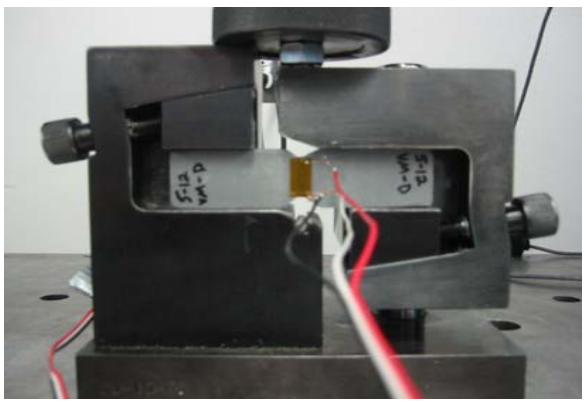
Uniformity of Shear Stress in Adhesive: Iosipescu Shear Test



Mechanical Testing:
Bulk Adhesive and "In-Situ" Shear Specimens

Loctite EA 9394 adhesive

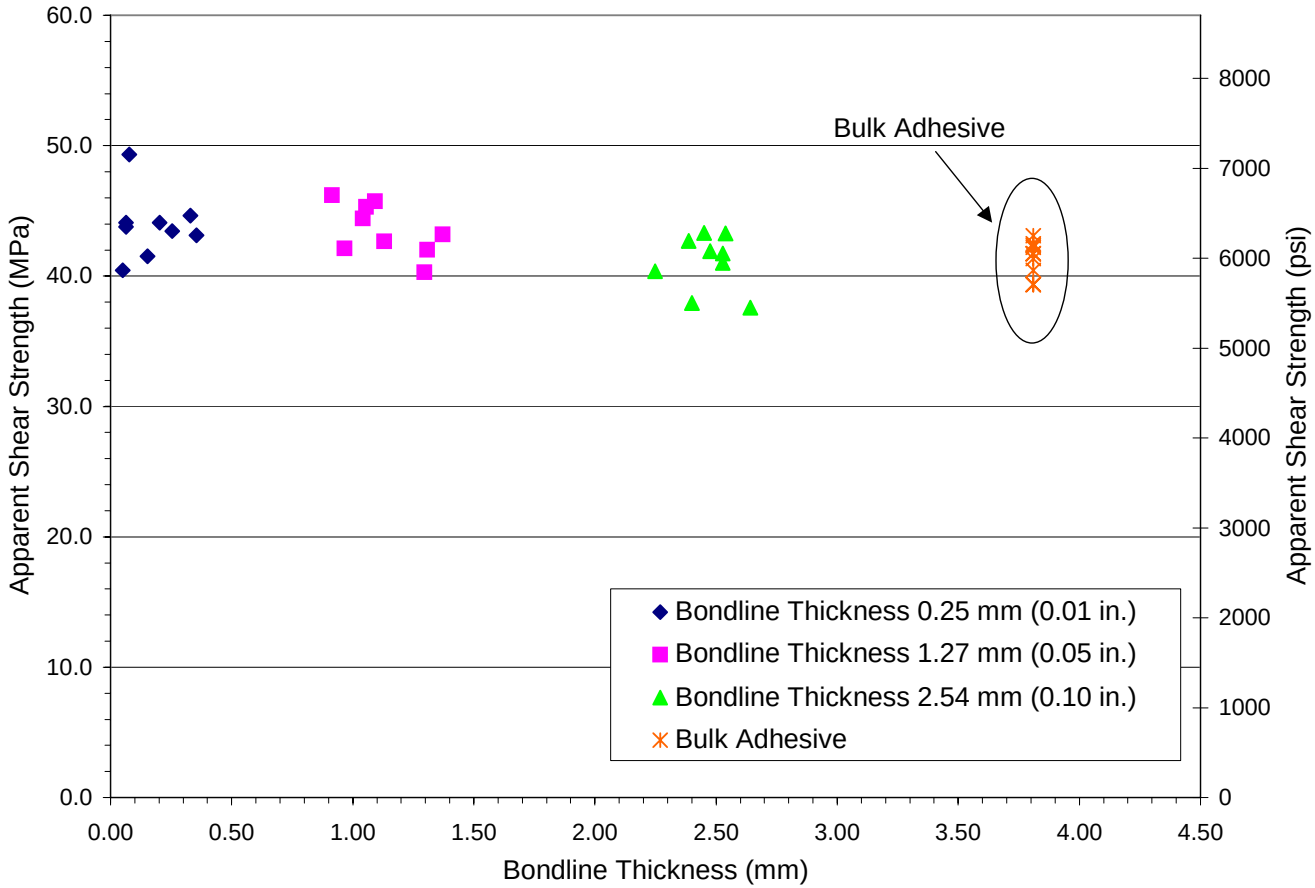
Loctite EA 9360 adhesive



Loctite EA 9394 adhesive with aluminum adherends

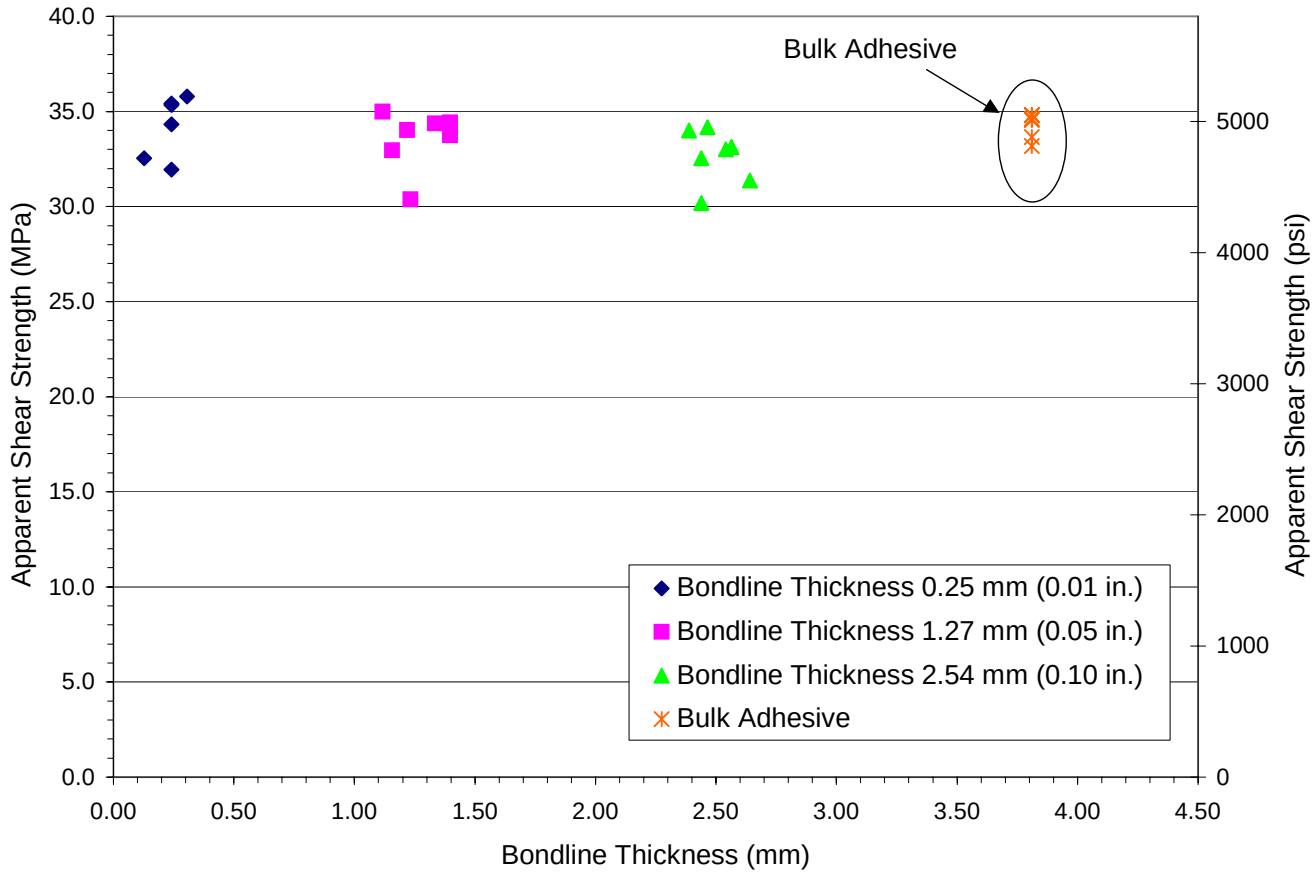
In-Situ Shear Testing
Bonded Iosipescu Results

EA 9394 Adhesive

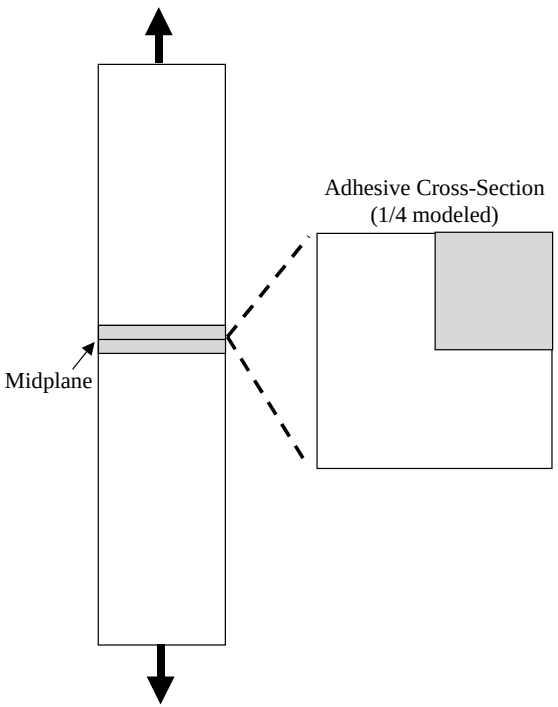


In-Situ Shear Testing
Bonded Iosipescu Results

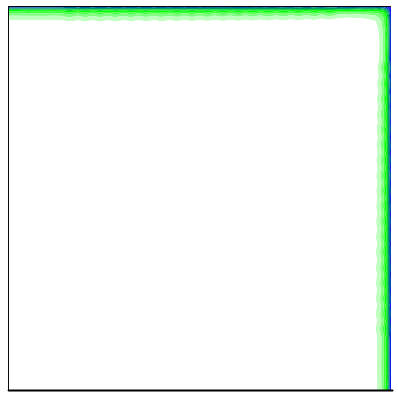
EA 9392 Adhesive

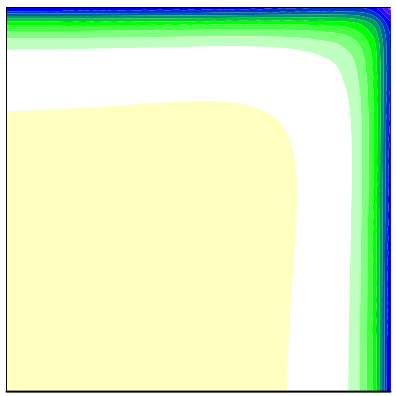


Butt-Tensile Joint
Normalized Axial Stress Distributions

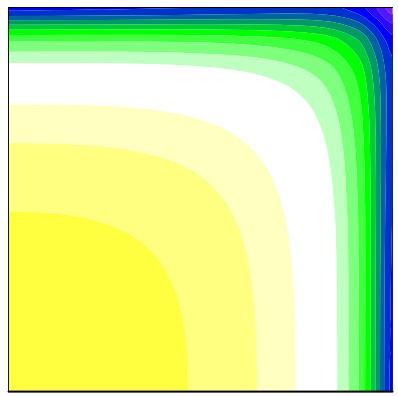


0.25 mm
(0.01 in.)

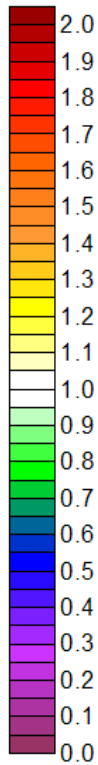




1.27 mm
(0.05 in.)

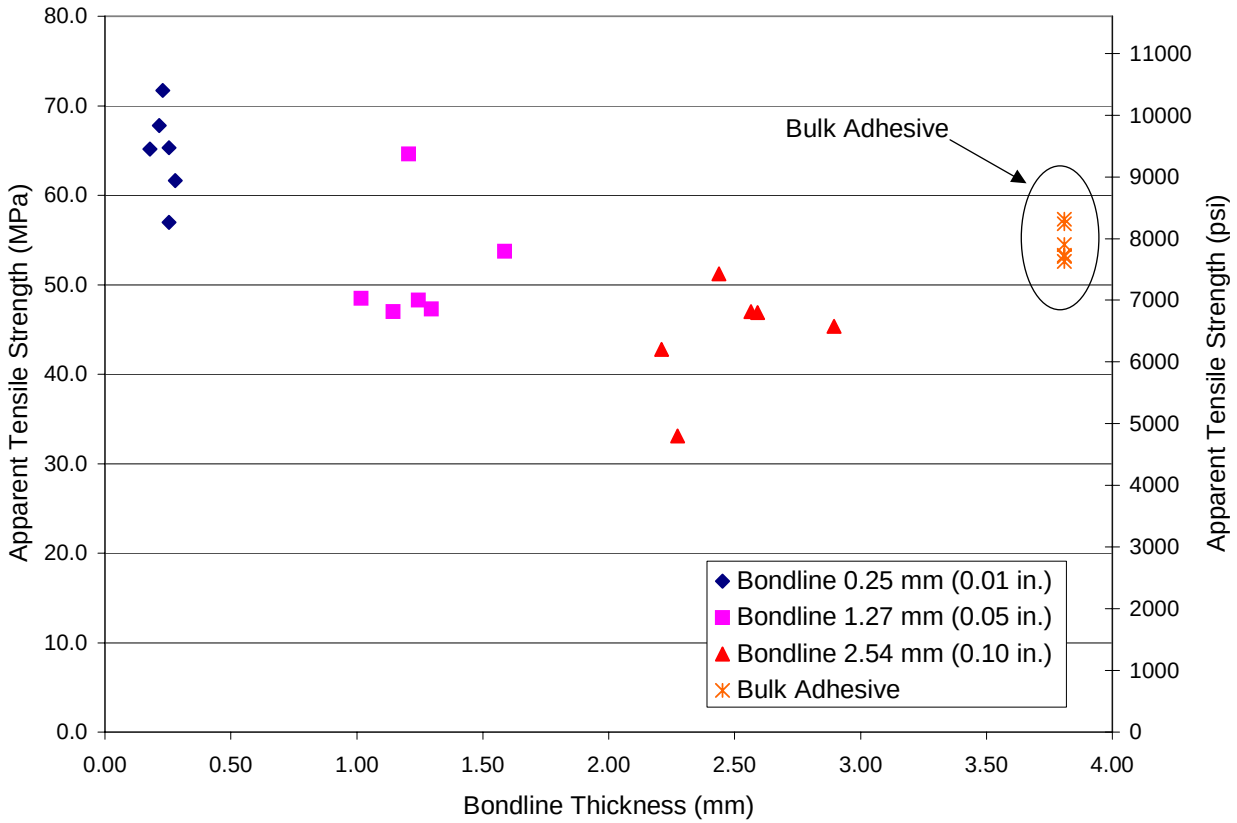


2.54 mm
(0.10 in.)



In-Situ Tensile Testing
Butt-Tensile Results

EA 9394



Conclusions: Adhesive Testing

- Iosipescu shear test appears to be well suited for both bulk and in-situ shear testing
  - 90° notch angle for bulk adhesive testing
  - 120° notch angle for in-situ adhesive testing
- Shear properties (modulus, strength) do not appear to be dependent on adhesive thickness
- Apparent adhesive thickness effect in tensile strength is produced by differences in stress state within adhesive layer
- Bulk adhesive properties may be applied to thin adhesive bondlines

A Look Forward

- Benefit to Aviation
  - A standardized shear test for use with composite laminates and textile composites
    - Shear modulus
    - Shear strength
  - Improved test method for characterizing shear response of adhesives
  - Confidence in using bulk adhesive properties in the analysis of bonded assemblies
- Future needs
  - Optimal strain gage size/shape for use with textile composites
  - Development of fracture mechanics test methods for sandwich composites