Failure of Notched Laminates Under Out-of-plane Bending

Industrial Sponsor: Boeing Commercial Airplane Company

Technical Advisers:

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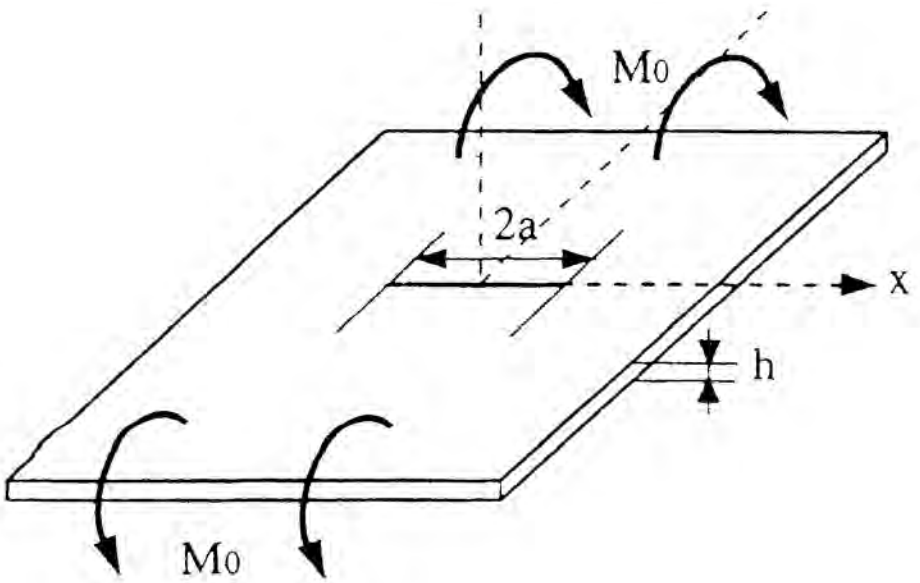
Tom Walker, NSE Composites

Objective: For out-of-plane bending of notched laminates, determine the modes of failure and evaluate the capability of current models to predict failure

Experiments: Four-point bending

Modeling
- **Stress Concentration Factors**
- **Progressive Damage Development**

Experiments: Four-point Bending Tests



Notch Lengths: 2a = 1 inch & 2a = 4 inches

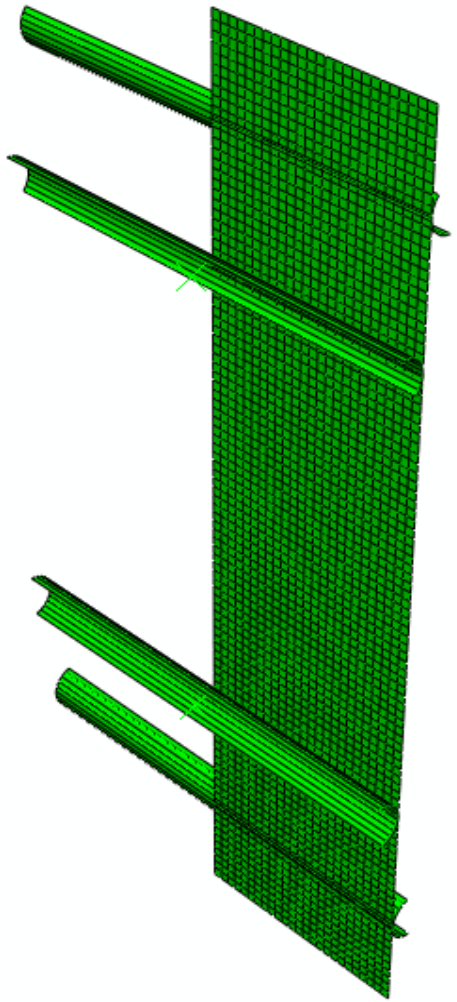
1998
CHAMPIONS
HONDA
Racing
OREGON STATE
UNIVERSITY
Open minds. Open doors.

INSTRON
5500R

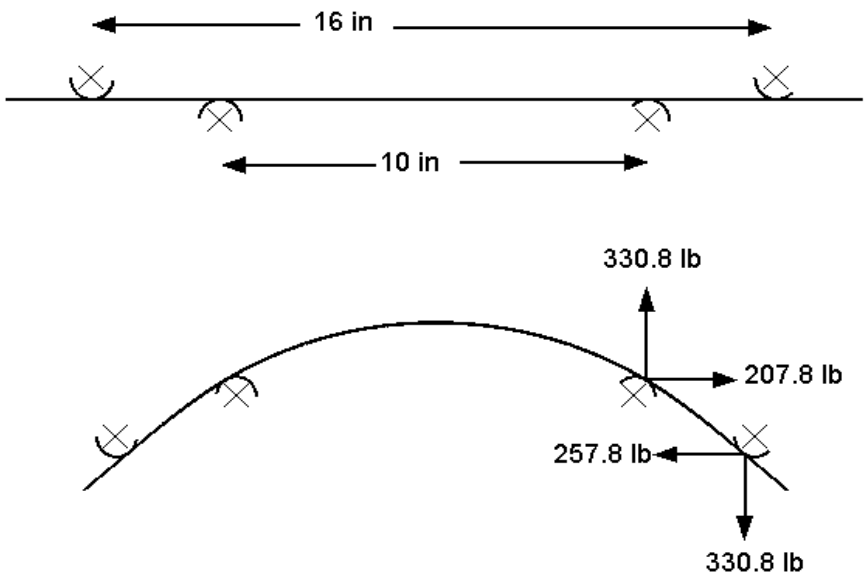
Outer Fiber Strain $\varepsilon = t/2/\rho$

Thickness $t = 0.148$in
Failure Strain $\varepsilon = 0.0061$
Radius of Curvature $\rho = 12$ in

FEA Simulation of the Four-Point Bend Test

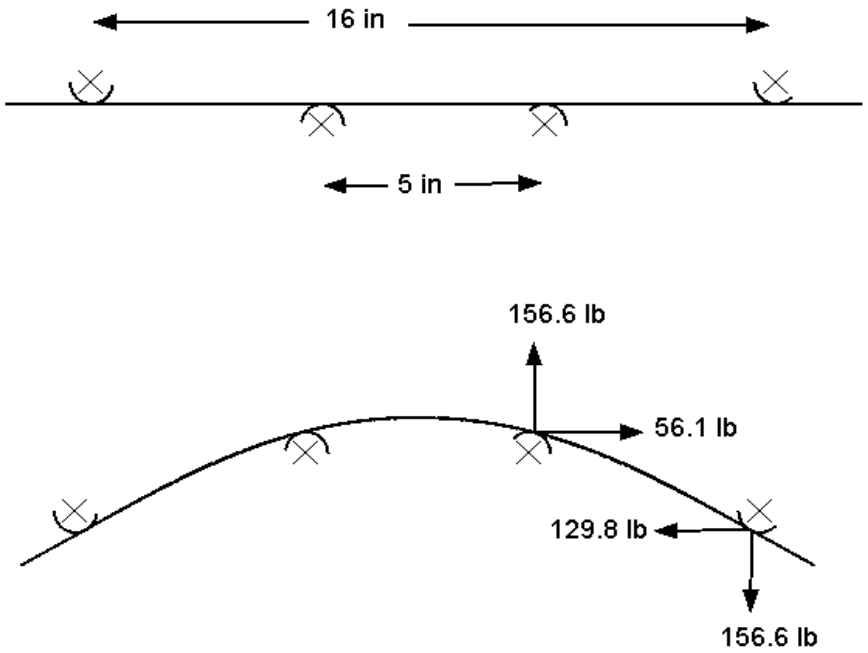


5-in wide laminate



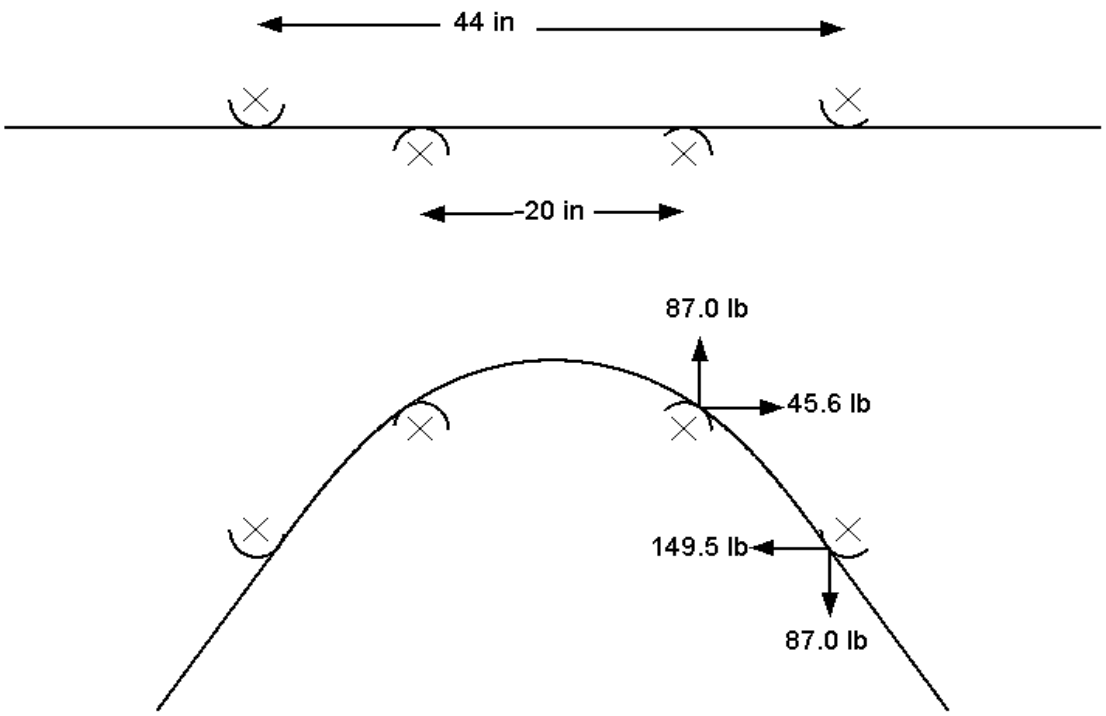
$M_{sd}/M_{ld}=0.91$

5-in wide laminate



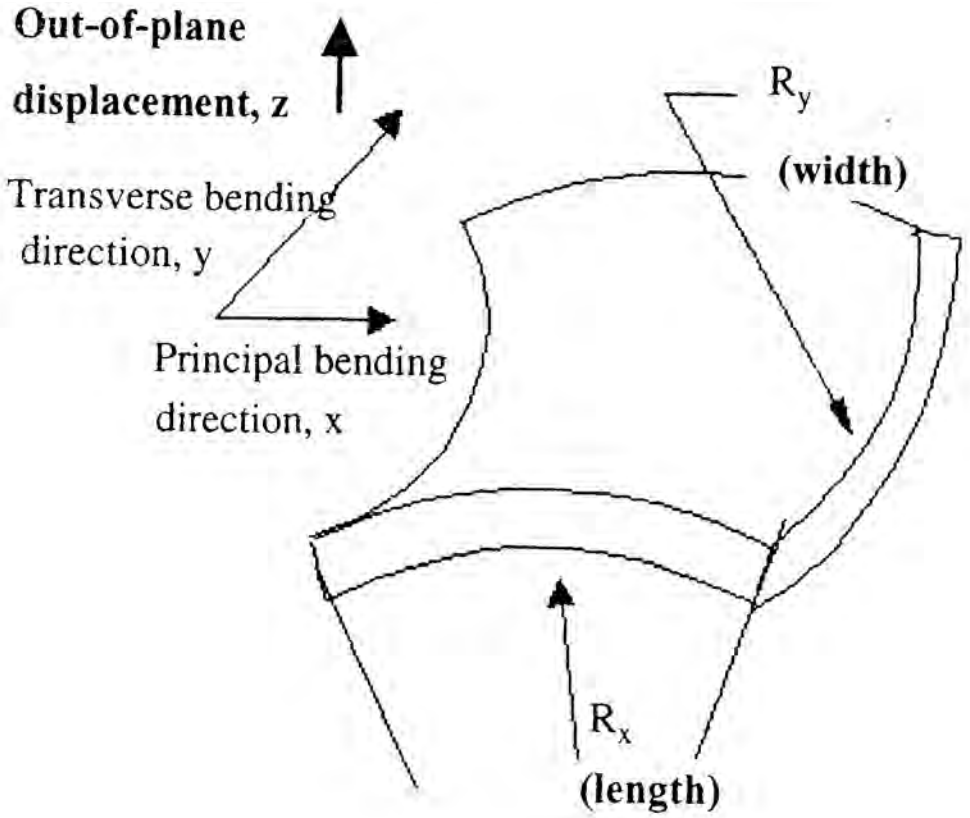
$M_{sd}/M_{ld}=0.76$

20-in wide laminate

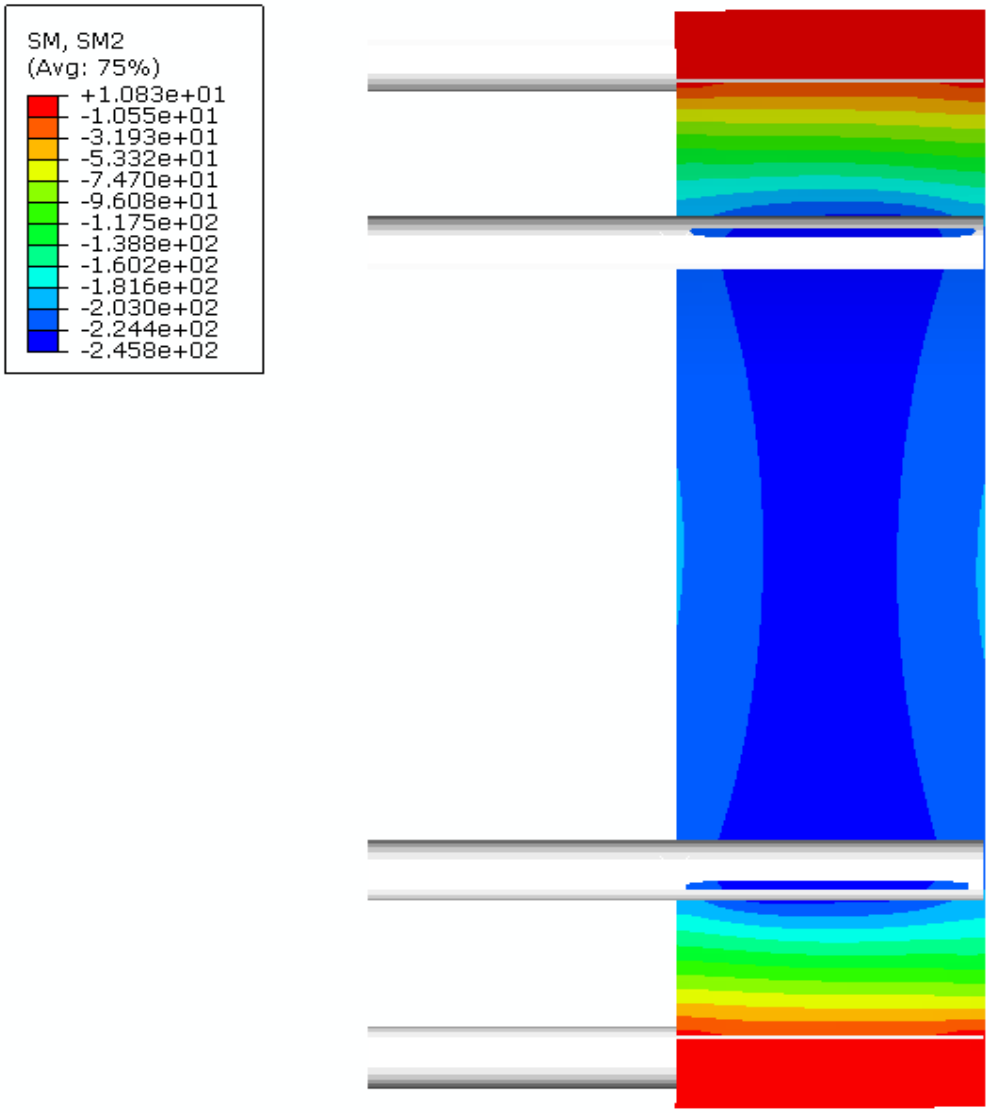


$M_{sd}/M_{ld}=0.38$

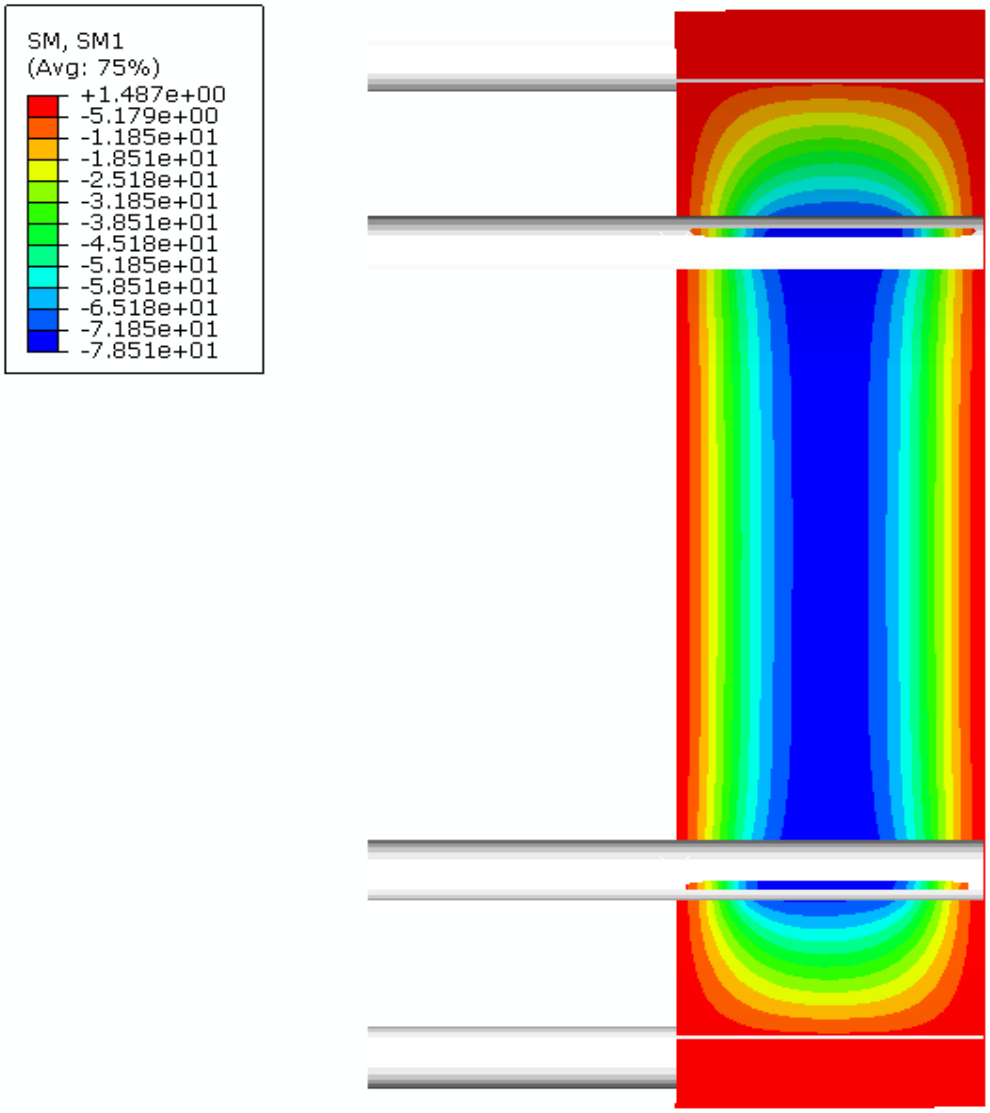
Large Deflection and Anticlastic Curvature Effects



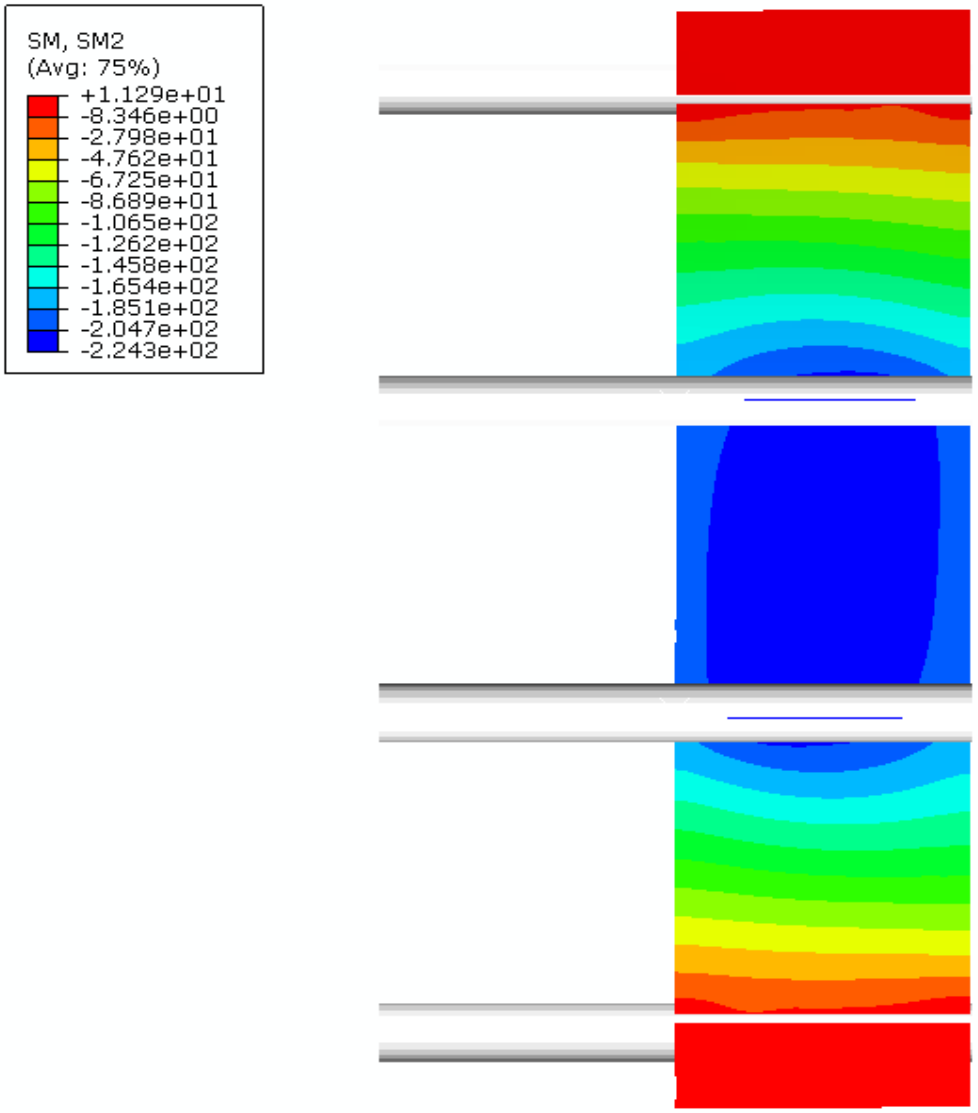
5-in wide laminate – axial bending moment



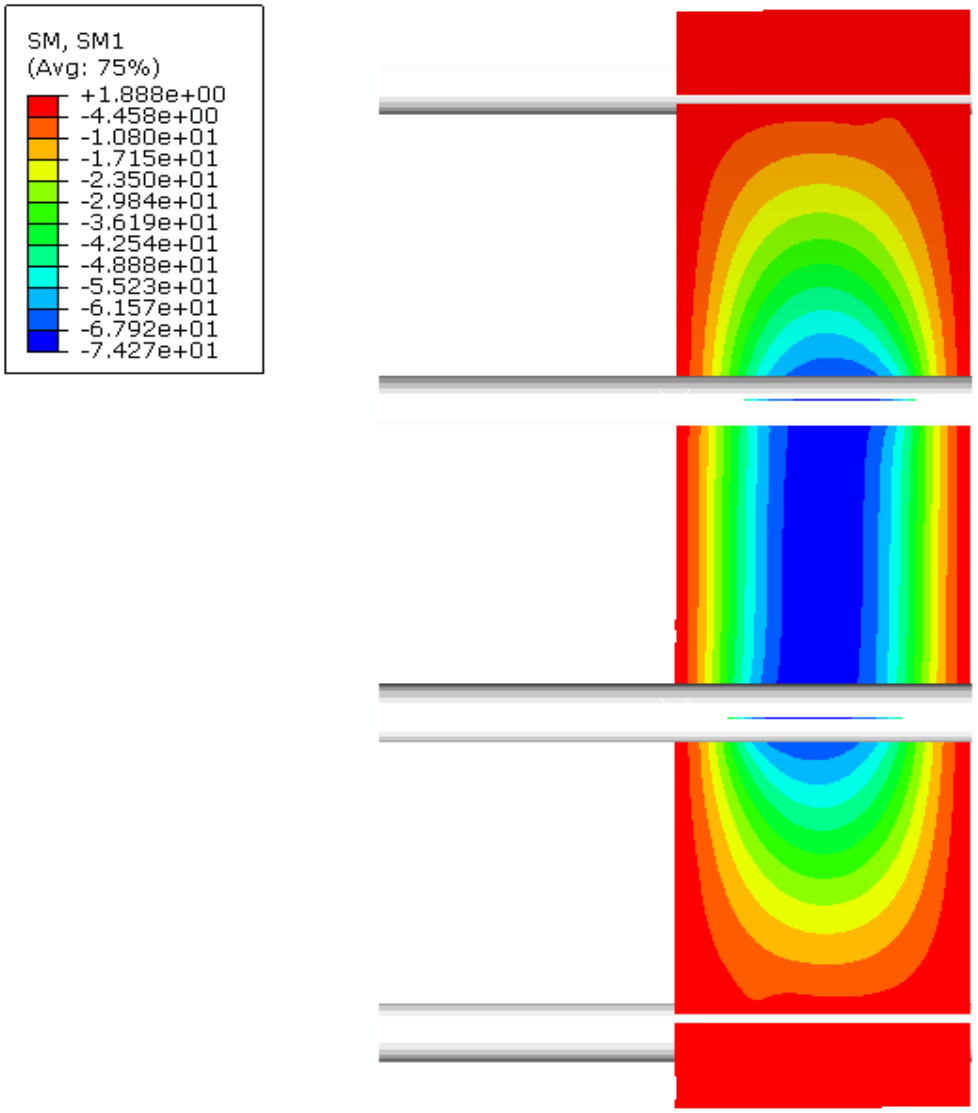
5-in wide laminate – transverse bending moment



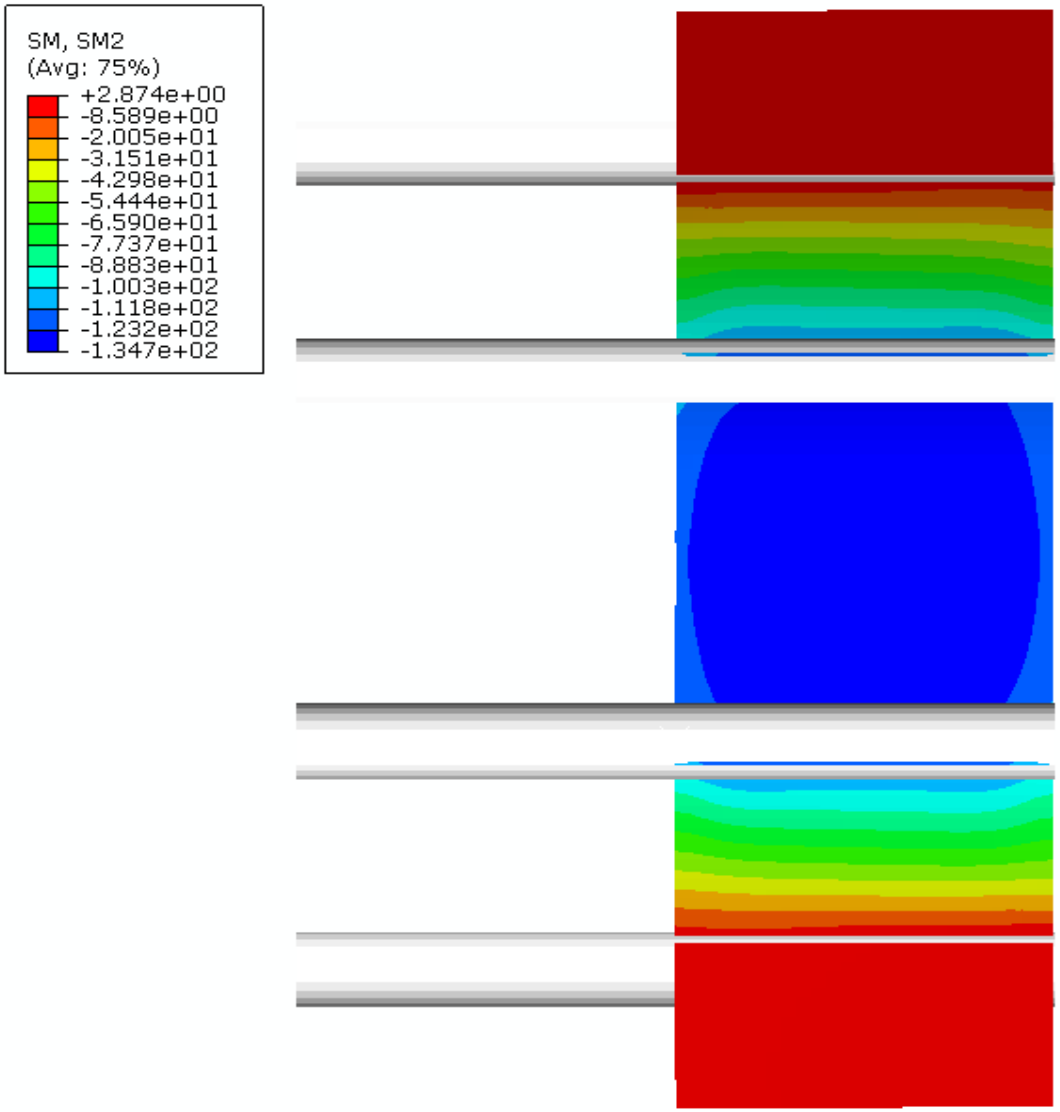
5-in wide laminate – axial bending moment



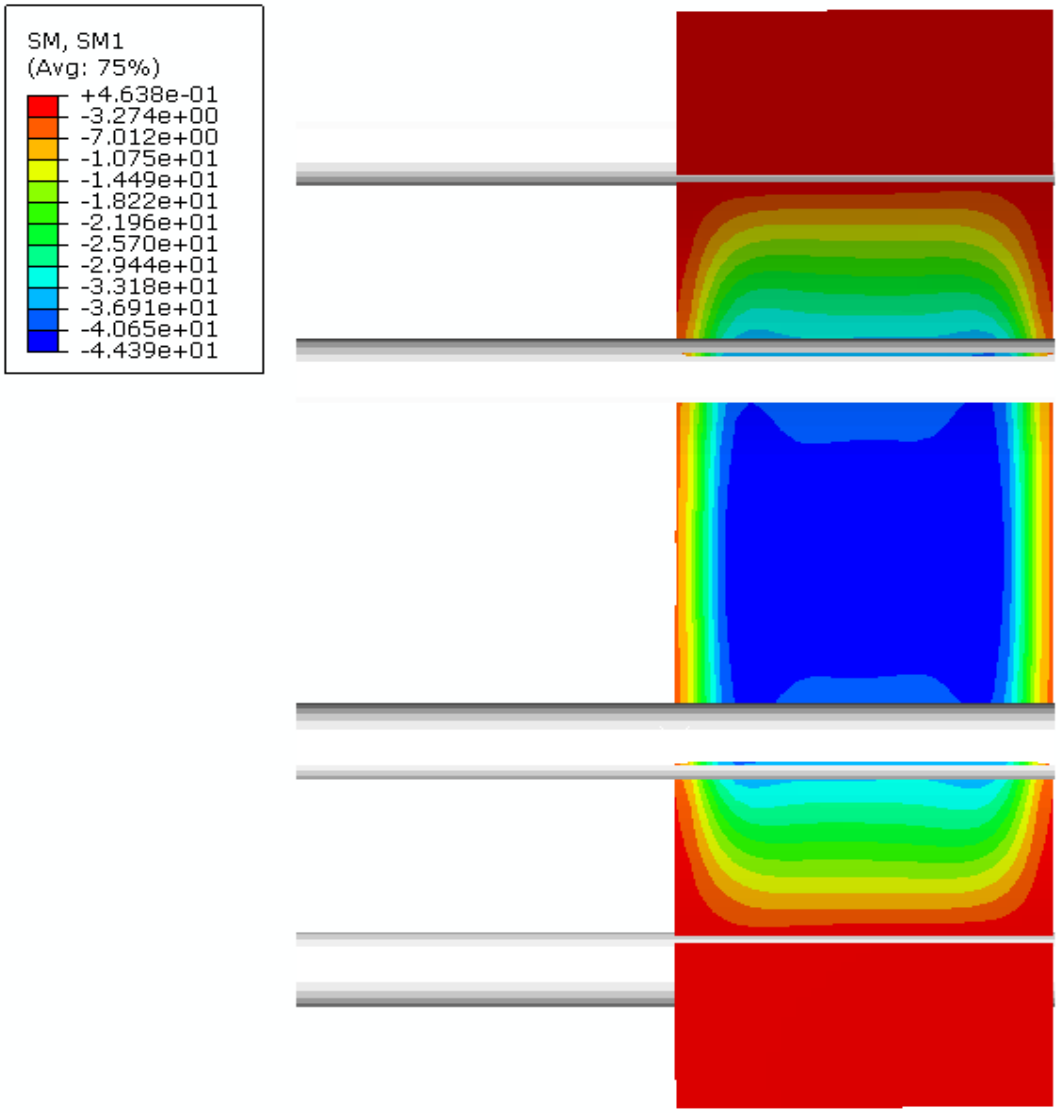
5-in wide laminate – transverse bending moment



20-in wide laminate – axial bending moment



20-in wide laminate – transverse bending moment



NEXT STEPS

- More Analysis (including notch)
- Finalize Selection of Laminate Specimens
- Plan Test Instrumentation