Virtual Testing to Determine the Behavior of Orthotropic Materials

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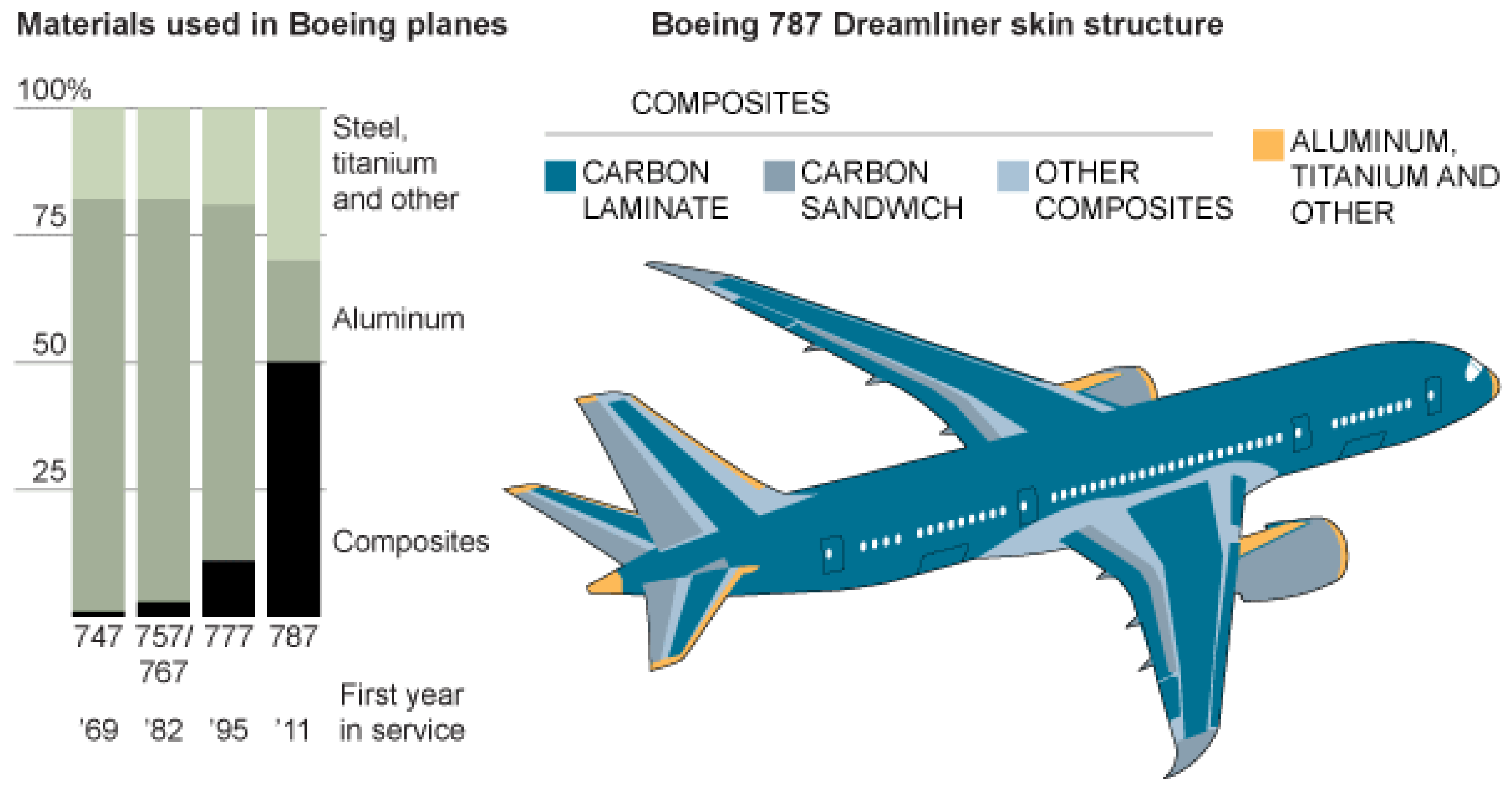
MOTIVATION

Composite materials have gained interest in the aerospace, automotive and civil engineering industry because of the benefits they provide, including high strength-to-weight ratio, durability and high resistance to environmental effects, and high impact strength.

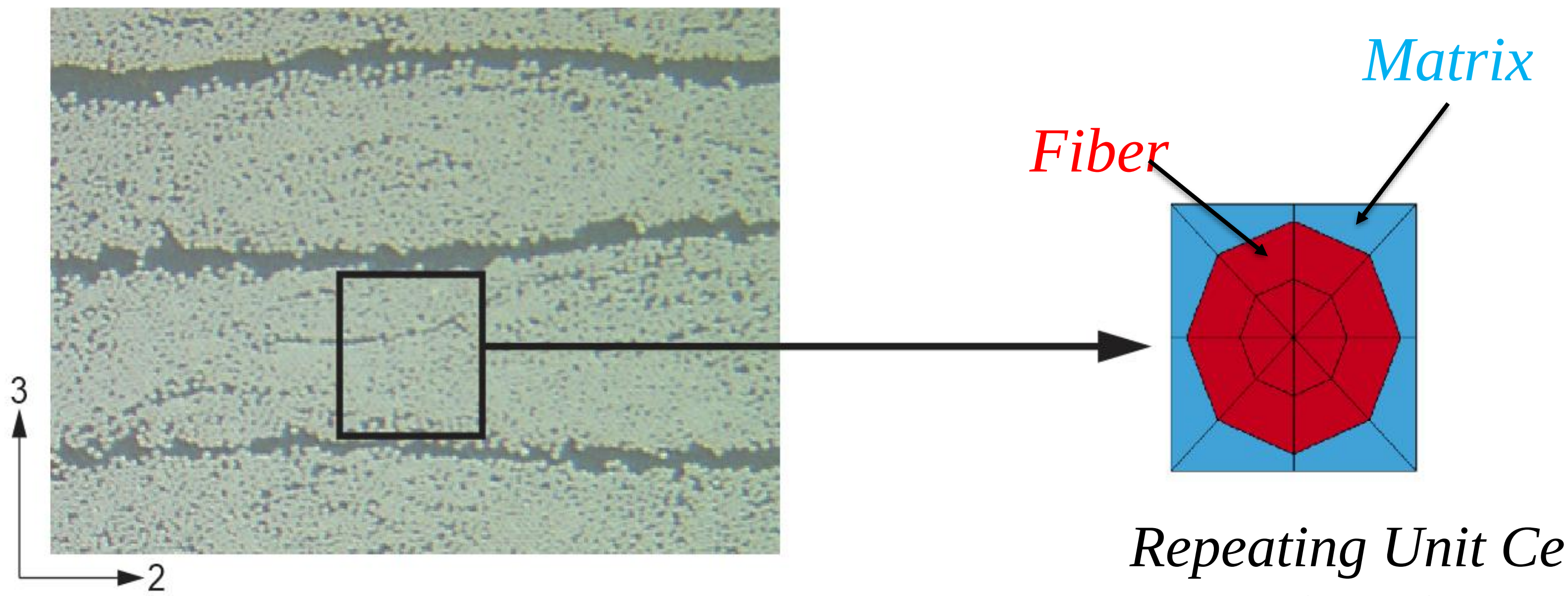


Material used in Boeing 787 Dreamliner skin structure

RESEARCH GOAL

The main goal of this research is to establish a virtual testing framework for predicting the behavior of unidirectional composites including failure so that future designs could be optimized to avoid catastrophic failures. Generation of a failure locus that will be used for the prediction of failure in a Generalized Tabulated Failure Criterion (GTFC) implemented in an orthotropic elasto-plastic material model with rate and temperature dependence will be the focus of this research.

METHODOLOGY



Optical micrograph T800S/F3900 Unidirectional Composite

Repeating Unit Cell (RUC)

A mesoscale modeling technique is employed where a single ply of unidirectional composite is modeled as a two-phase Repeating Unit Cell (RUC). The fiber is modeled as a transversely isotropic linear elastic material and the matrix as an isotropic elasto-plastic model to capture the nonlinear behavior of the matrix. A series of RUCs is used to model the entire ply.

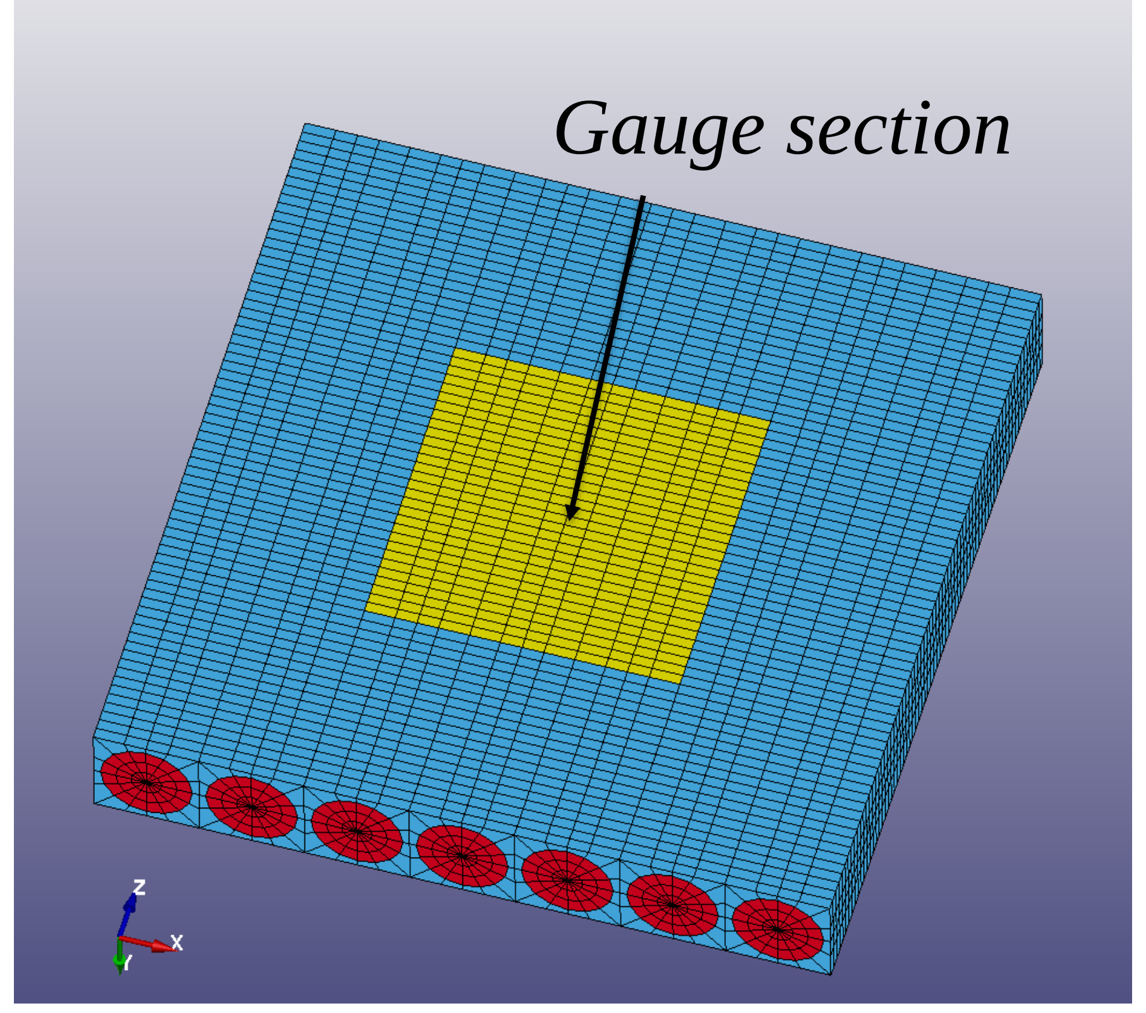
The homogenized response is computed through volumetric averaging over the gauge section as shown in the equation below.

$$\bar{P}_h = \frac{\sum_{j=1}^{e_t} \left(\frac{\sum_{i=1}^{n_{e_t}} \bar{P}_i V_i}{\sum_{i=1}^{n_{e_t}} V_i} \right)_j V_j}{\sum_{j=1}^{e_t} V_j}$$

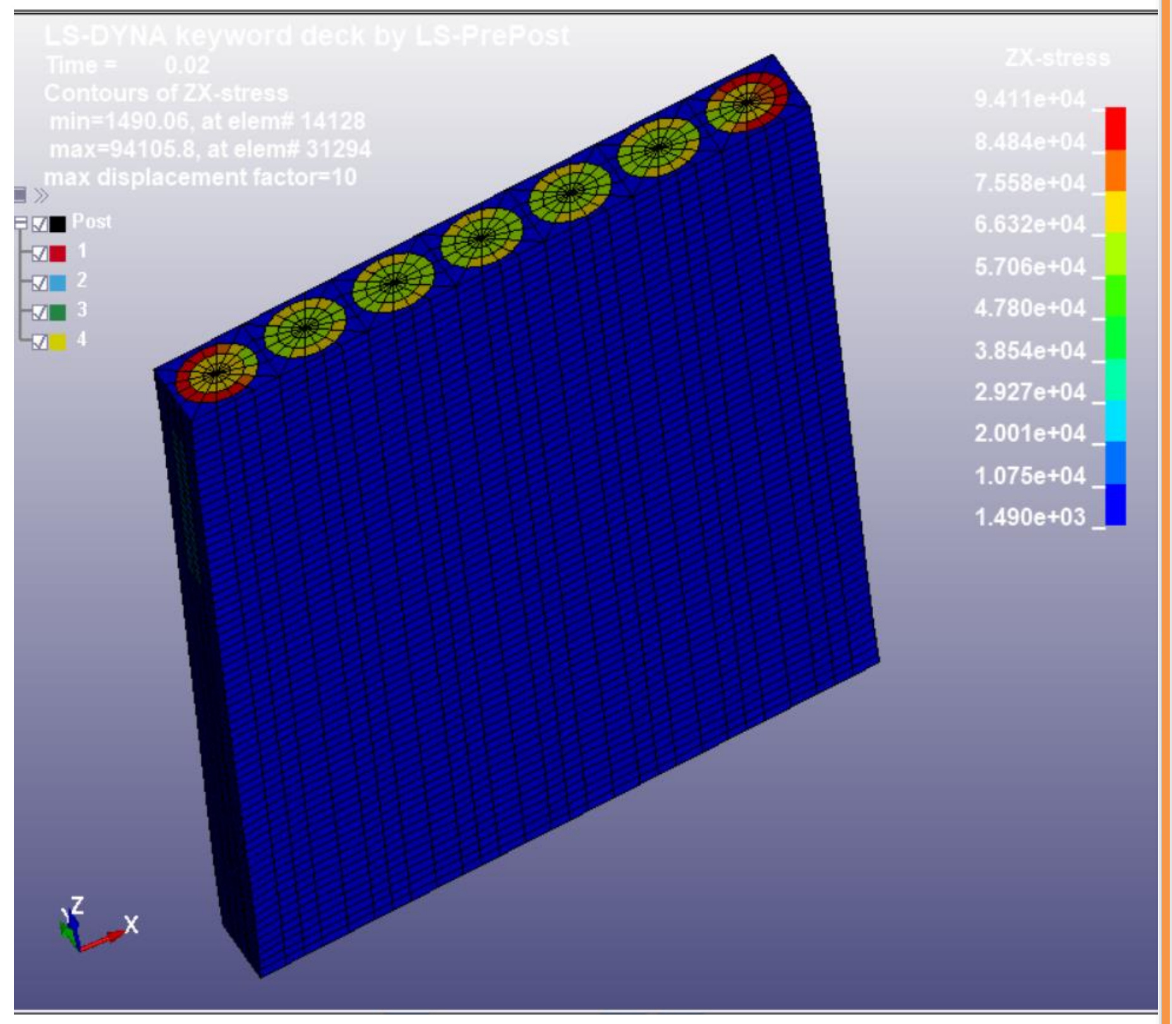
$\bar{P}_h$: the homogenized response
$\bar{P}$: numerical average response of an element
V : volume of an element
V : volume of an element
n_{e_t}: number of element in type t
e_t: number of element types

PROGRESS THUS FAR

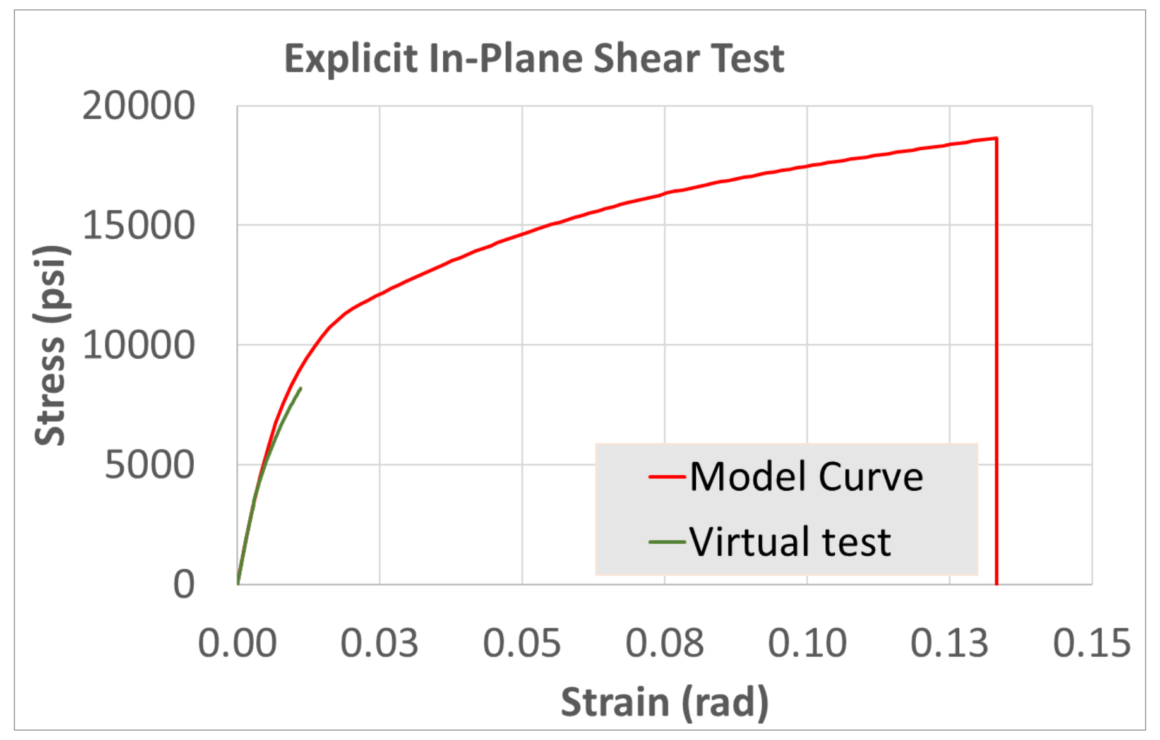
An explicit shear test in the X-Z plane was carried out to simulate pure shear deformation



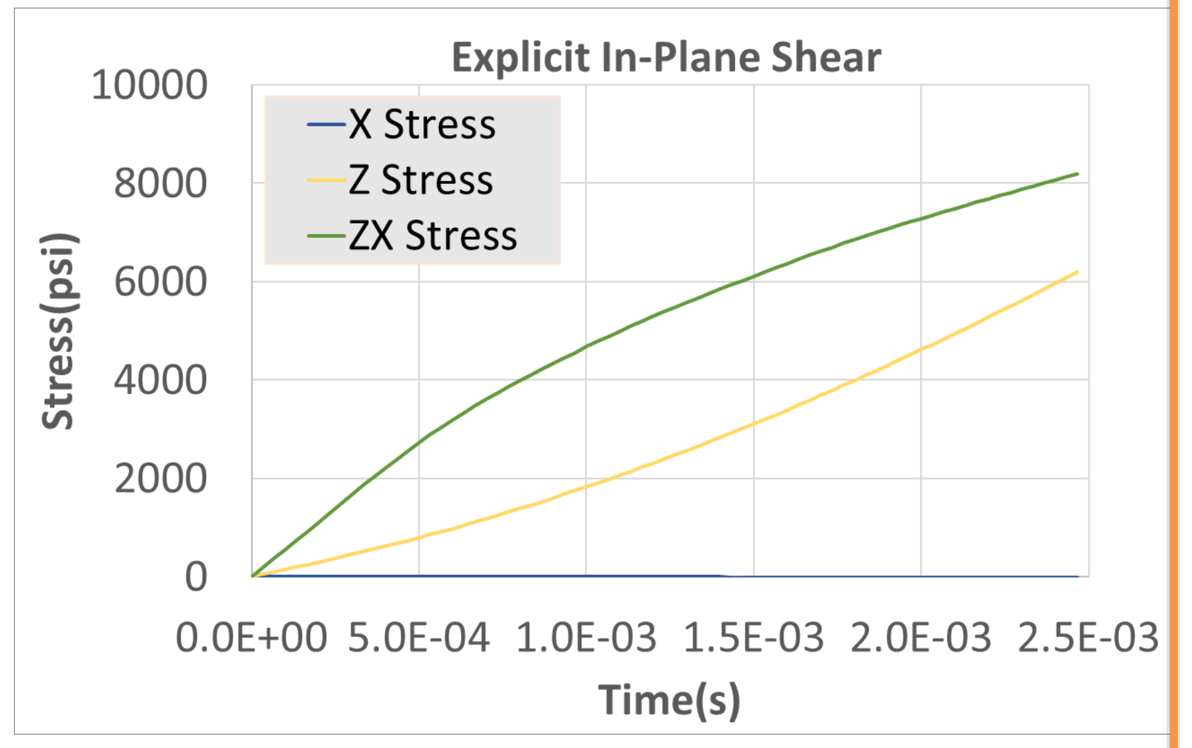
49 RUC Model



ZX Stress contour



ZX Stress vs Strain curve



Stress vs Time curve

CONCLUSIONS AND FUTURE WORK

In a pure shear test, the 49 RUC model develops a normal stress component along the fiber direction. To improve this, a model with V-notch similar to an Iosipescus shear test will be generated and used for subsequent multiaxial (tension/compression in combination with shear) stress test. The failure state of stress will be plotted on an invariant stress space.

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Masters Opportunity for Research in Engineering

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