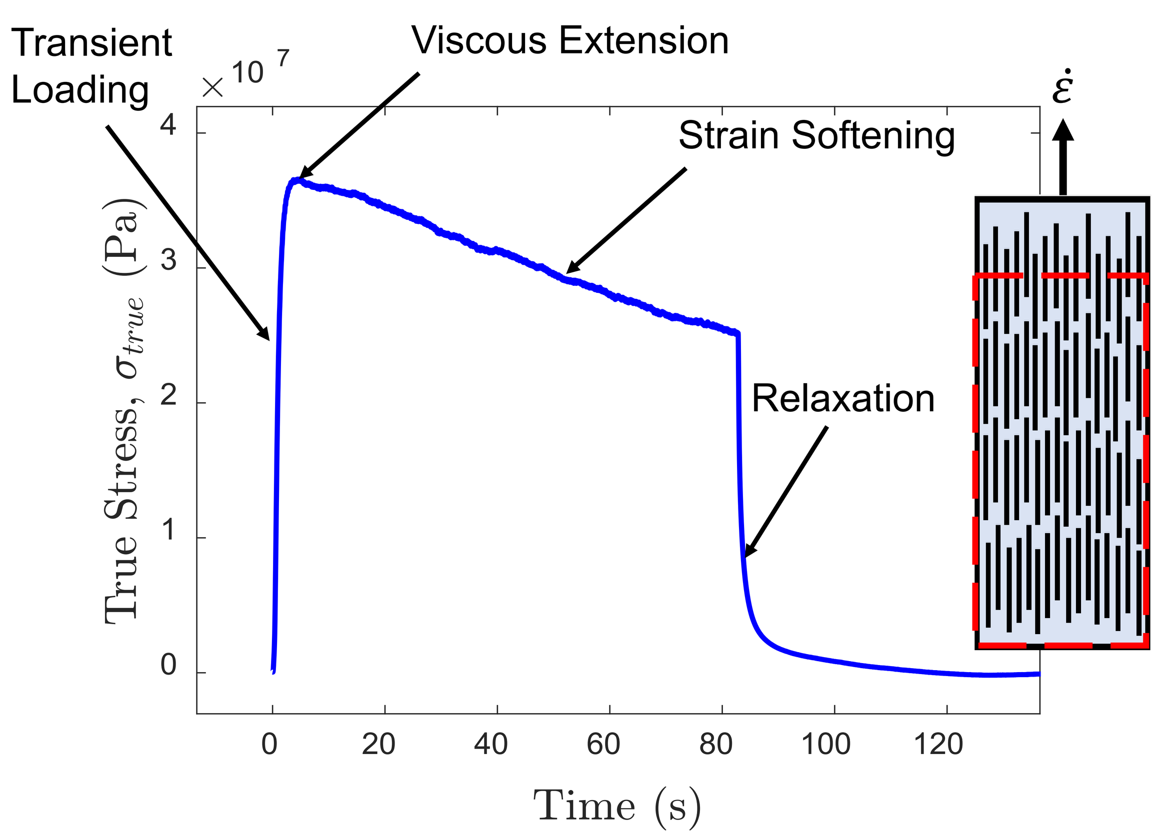
CHARACTERIZATION OF VISCOELASTIC MATERIAL RESPONSE OF HIGHLY ALIGNED DISCONTINUOUS FIBER COMPOSITES

UNIVERSITY OF DELAWARE | CENTER FOR COMPOSITE MATERIALS

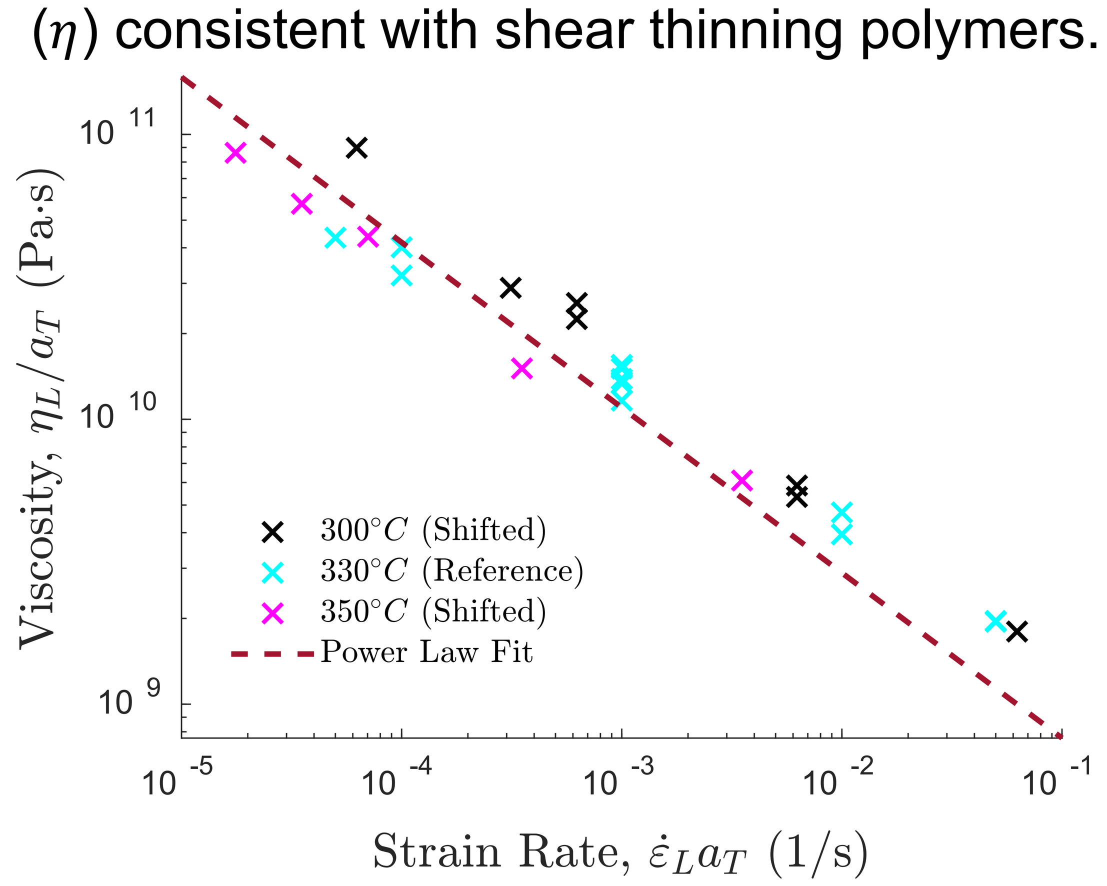
Charles Whealton (BME)[2] | Dr. Thomas A. Cender[1]
University of Delaware | Center for Composite Materials[1] | Department of Mechanical Engineering[2]

Introduction

Tailored universal Feedstock for Forming (T*u*FF) is a highly aligned discontinuous fiber composite (ADFC). T*u*FF has similar directional properties as continuous fiber composites, while being more formable. This formability is of particular interest. To create a model for forming T*u*FF, the material response needs to be understood.



Previous work has focused on the viscous response of the material for loading under constant processing conditions (T, $\dot{\varepsilon}$). This established a power law trend for viscosity (η) consistent with shear thinning polymers.

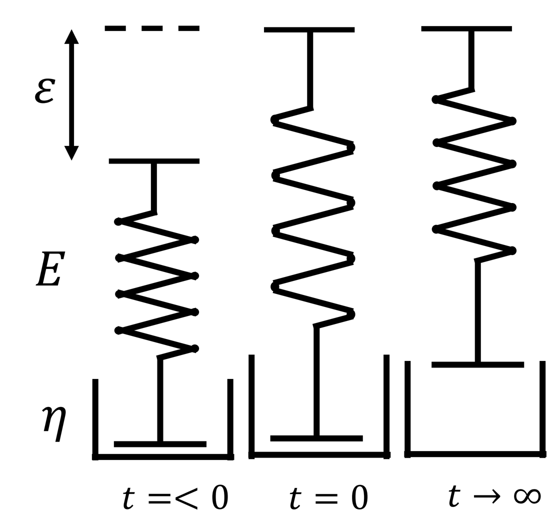


The goal of this work is to understand the viscoelastic response of the material, by analyzing the transient loading and stress relaxation of the material.

Method

Framework

Polymer melts are characterized as a viscoelastic fluid. For this work, the thermoplastic matrix ADFC is modeled as a Maxwell fluid. The model captures the time-dependent transition from elastic to viscous deformation as a spring and dashpot in series.



Governing Equation

$$\dot{\sigma} + \frac{E}{\eta}\sigma = E\dot{\varepsilon}$$

Relaxation Time

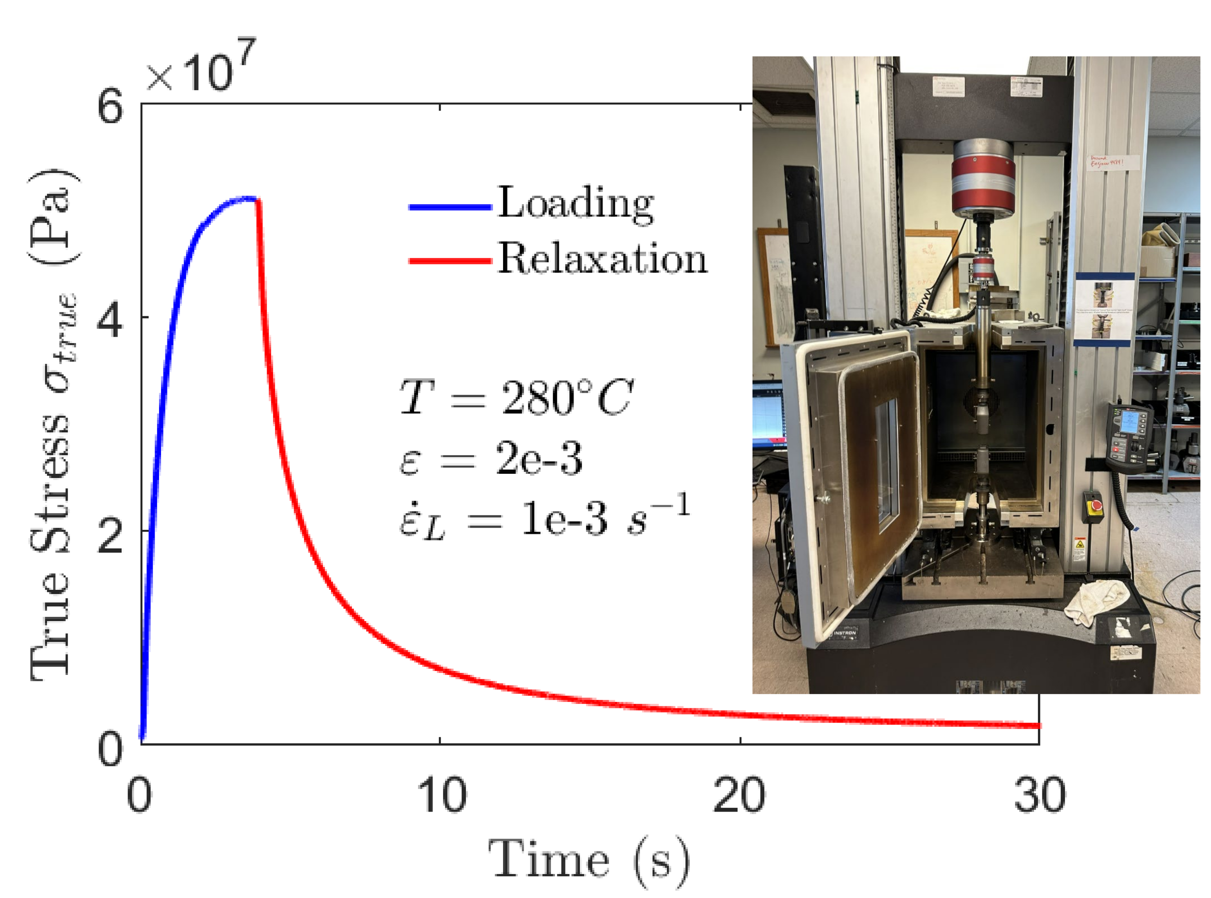
$$\lambda = \eta/E$$

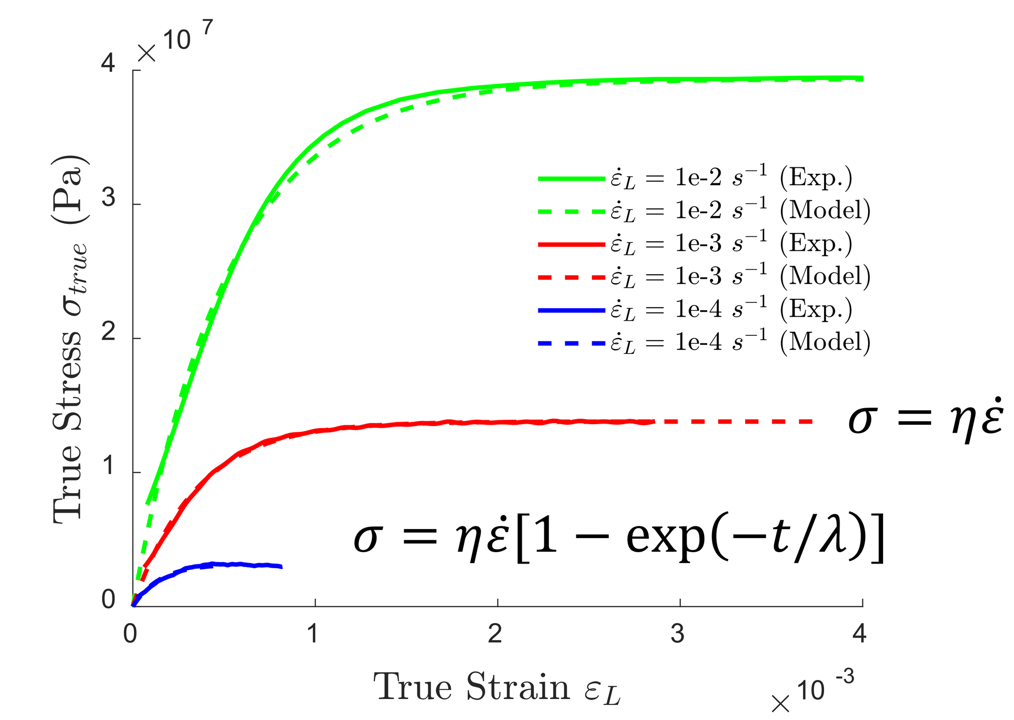
The model can be solved for loading under constant strain rate or stress relaxation at zero strain rate. Both test methods can be implemented to determine material properties.

Materials and Testing

Single ply T*u*FF samples were prepared with a PEI matrix and 3 mm IM7 fibers at 57% fiber volume fraction for extensional testing in the fiber direction.

An Instron load frame with environmental chamber were used to test samples at temperatures between 250°C – 350°C and strain rates between 1e-4 and 1e-1 s^{-1}.

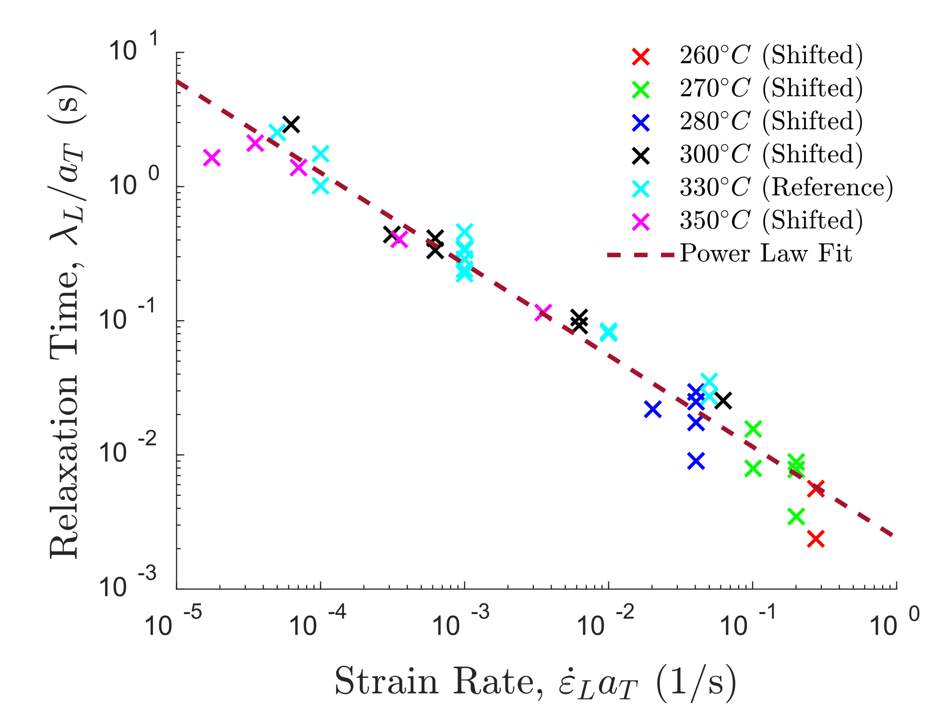




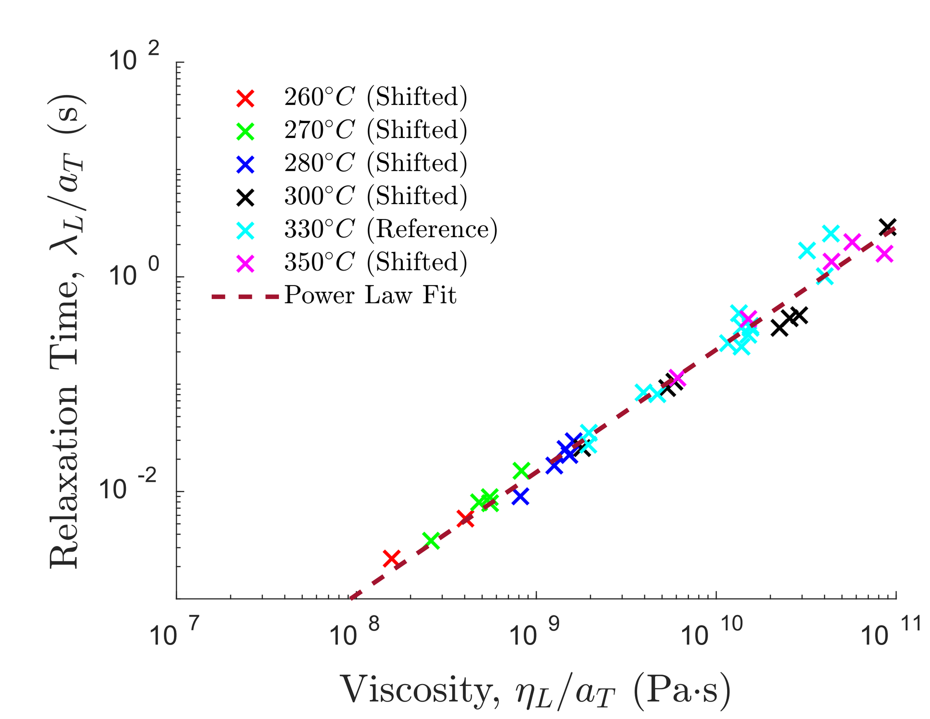
The Maxwell model was fit to the initial loading to determine the relaxation time. An Arrhenius shift was applied to the data to relate all samples to a common temperature of 330°C.

Results

Like the viscosity data relaxation time followed a power law with strain rate.



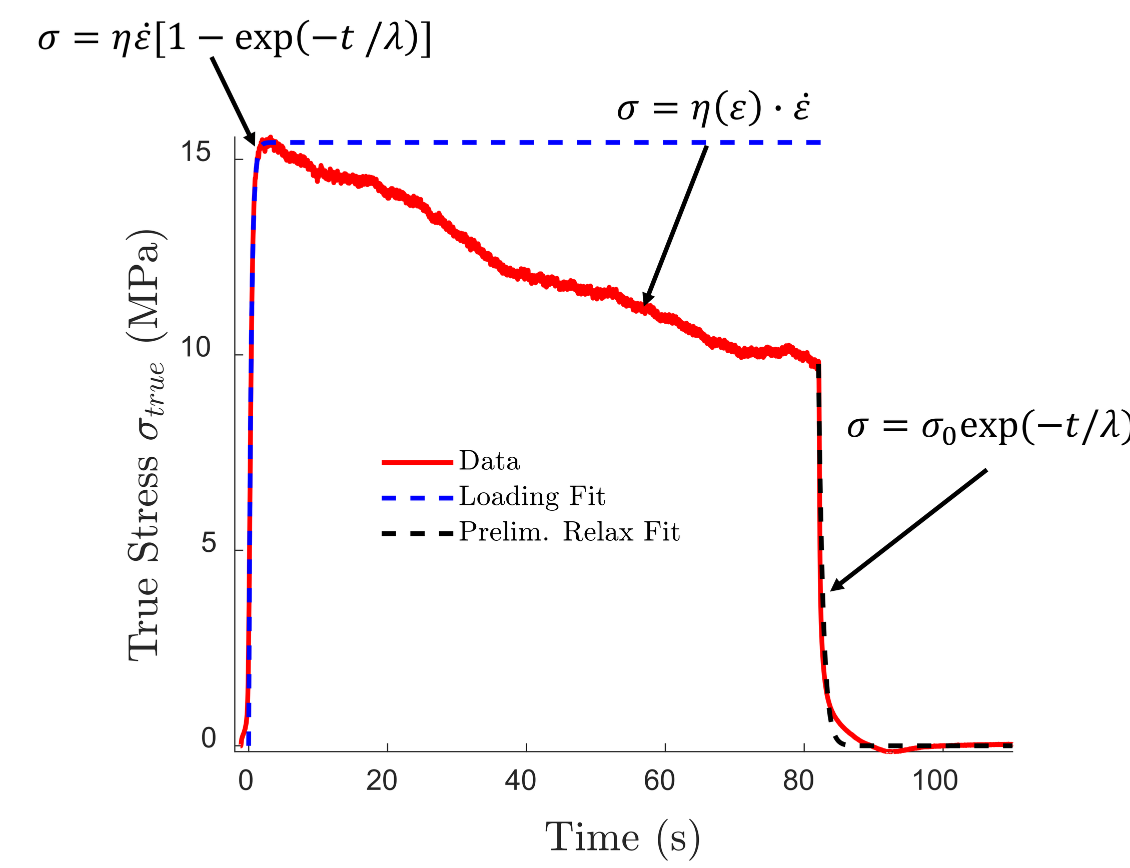
The relationship between η and λ follows a power law behavior.



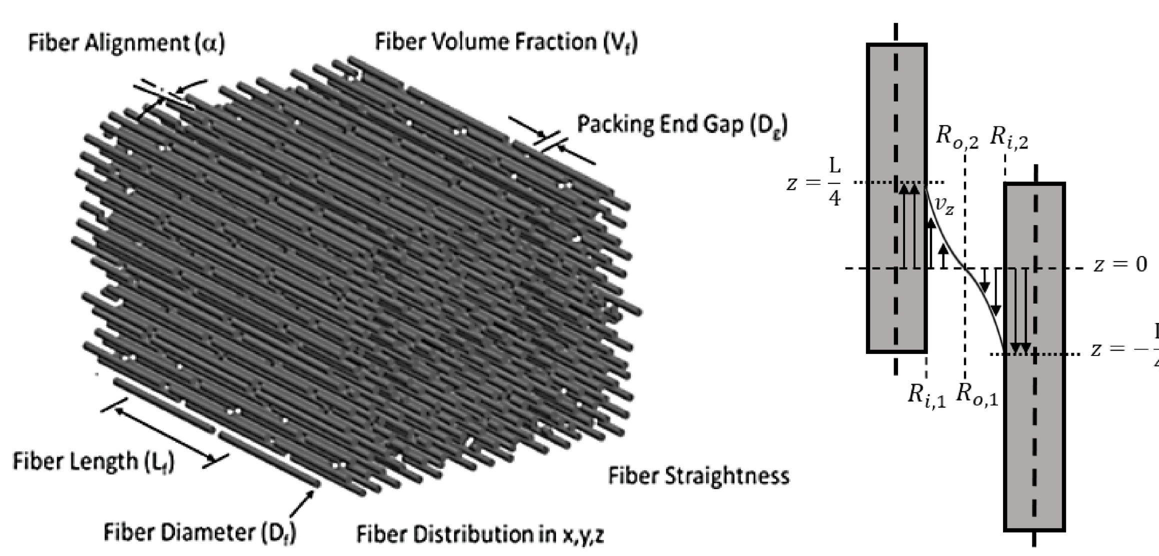
Modulus was near constant at a value of 56 GPa.

Conclusions and Future Work

These results indicate trends for relaxation time and modulus, which can be used to help guide future modeling. Specifically, the power law for λ versus η is a direct result. A caveat is that these results are for transient loading conditions. More work needs to be done to understand the strain softening and stress relaxation behavior.



Future work will correlate these results to the microstructure to gain insight into how the microstructure changes during deformation.



Acknowledgements

This material is based upon work supported by the National Aeronautics and Space Administration under Grant and Cooperative Agreement No. 80NSSC20M0164, issued through the Aeronautics Research Mission Directorate, Transformative Aeronautics Concepts Program, University Leadership Initiative.