VISCOELASTIC BEHAVIOR OF HIGHLY ALIGNED DISCONTINUOUS FIBER THERMOPLASTIC MELTS

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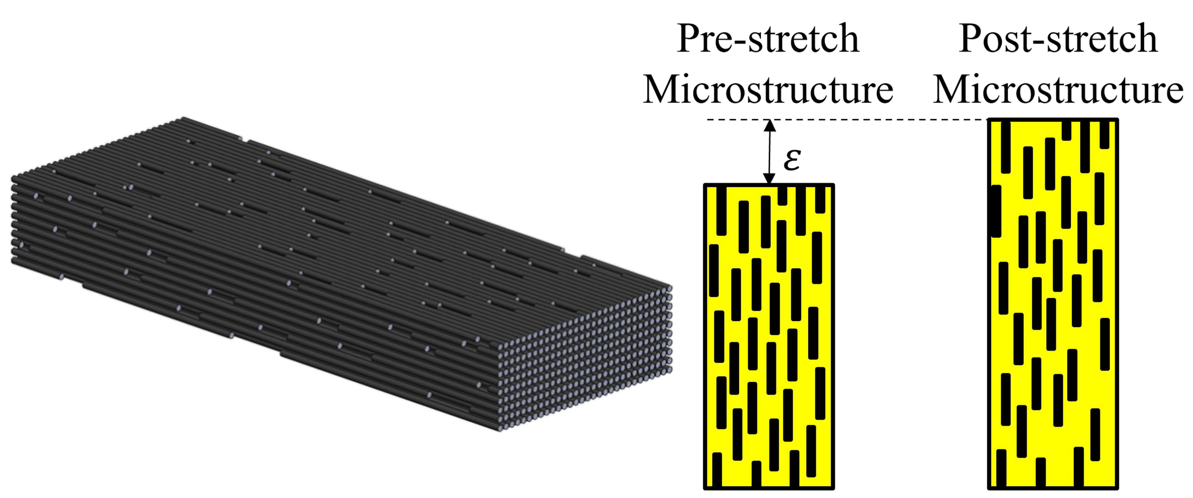
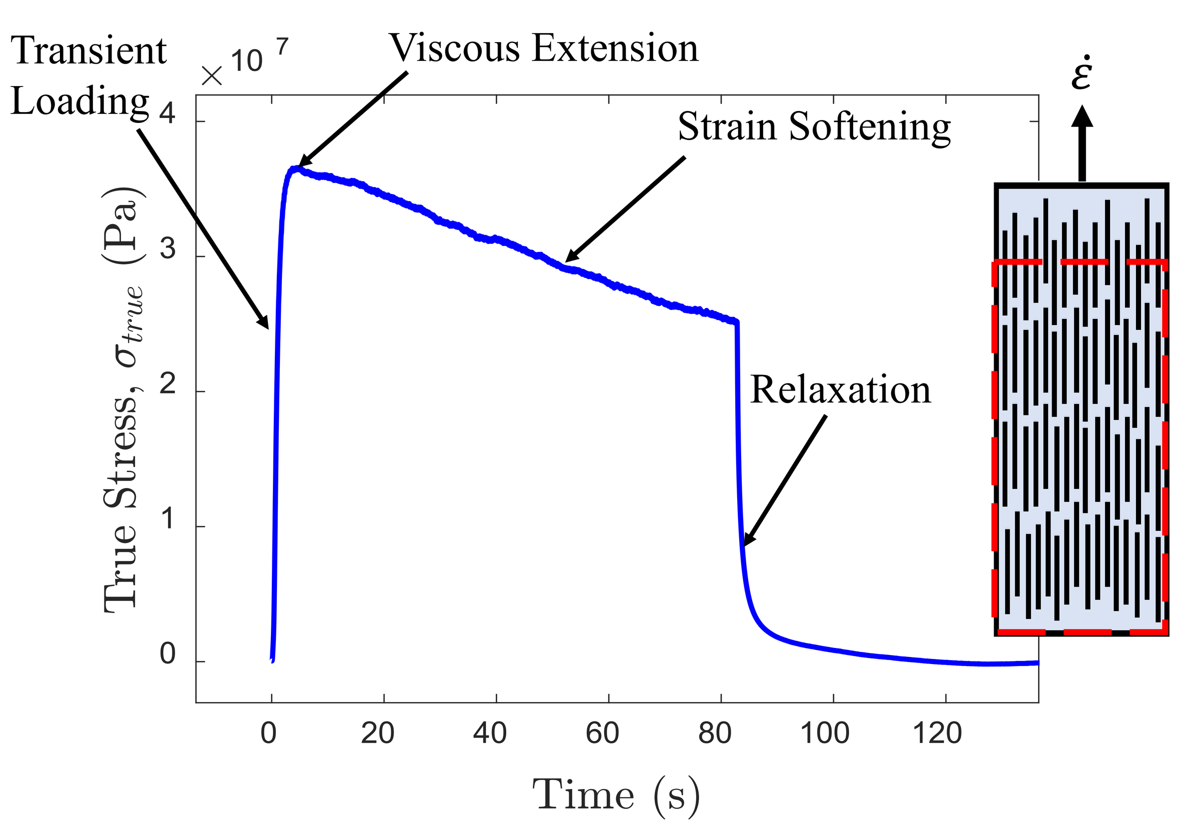
Introduction

Tailored *universal* Feedstock for Forming (T*u*FF) is an aligned discontinuous fiber composite which enables high property retention relative to continuous fibers, while being able to be formed like sheet metals.



Forming consists of multiple phases. This research focuses on stress relaxation at small strains, which gives information about residual stresses during forming.

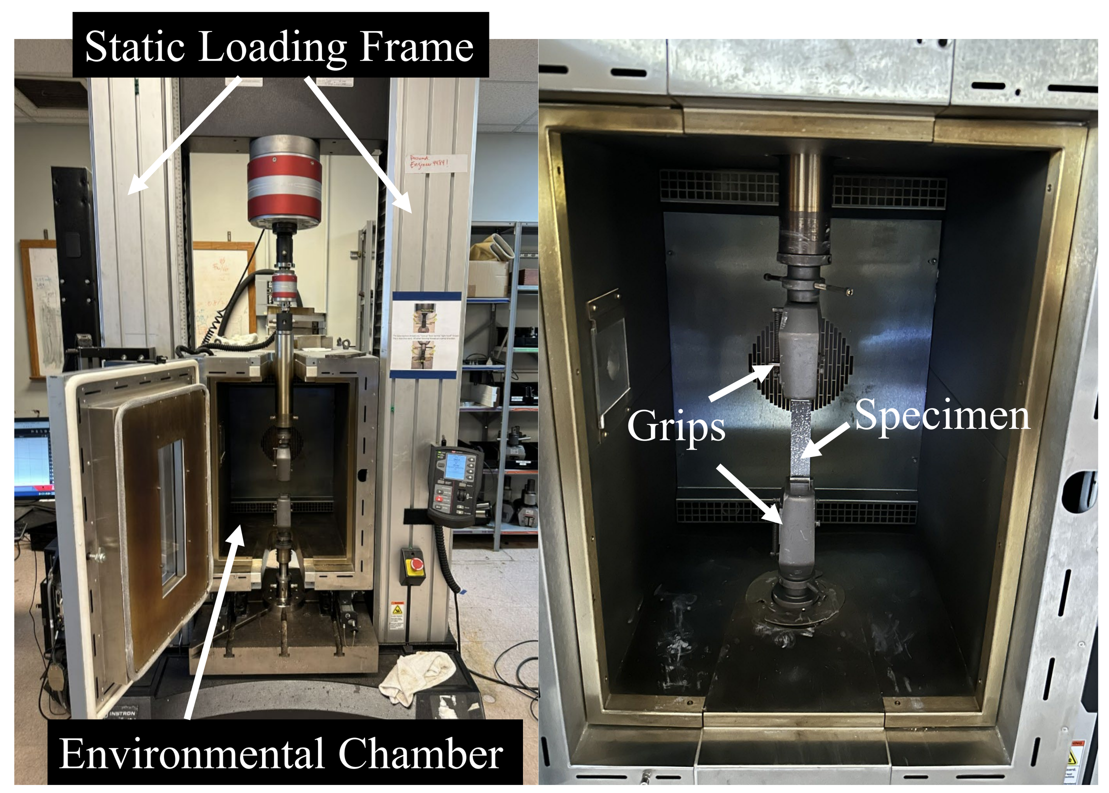


Conducting stress relaxation experiments at small strains provides some advantages:

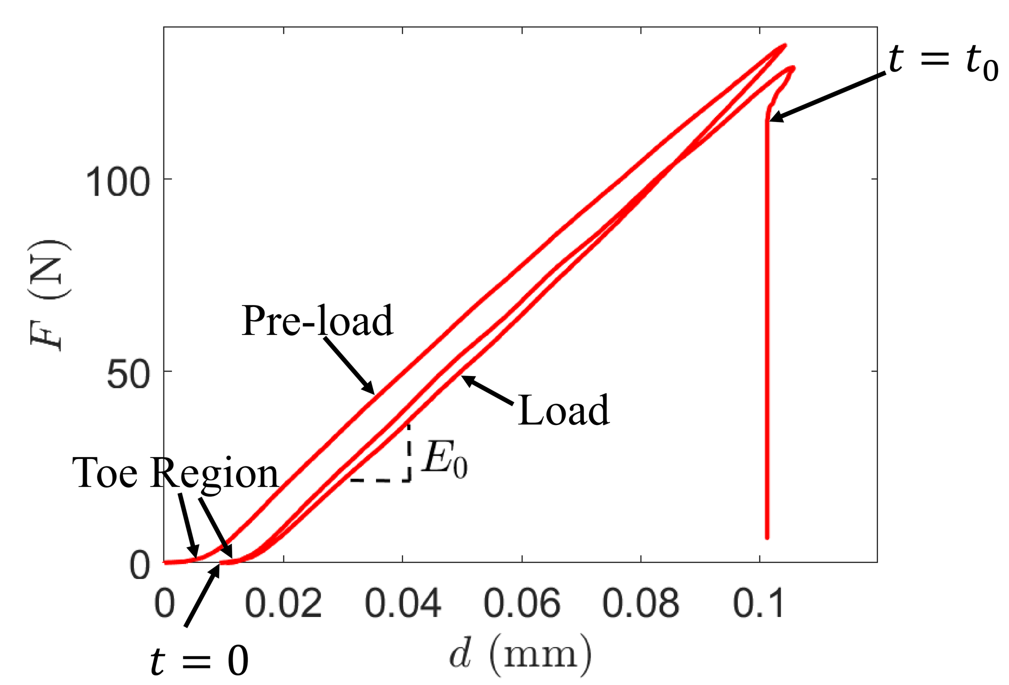
- Relatively undamaged microstructure; ignore effects of strain softening
- Closer to the linear viscoelastic region, which allows data to be transformed into:
  - Creep compliance
  - Dynamic moduli (loss/storage; viscosity)
  - Stress response for any strain history

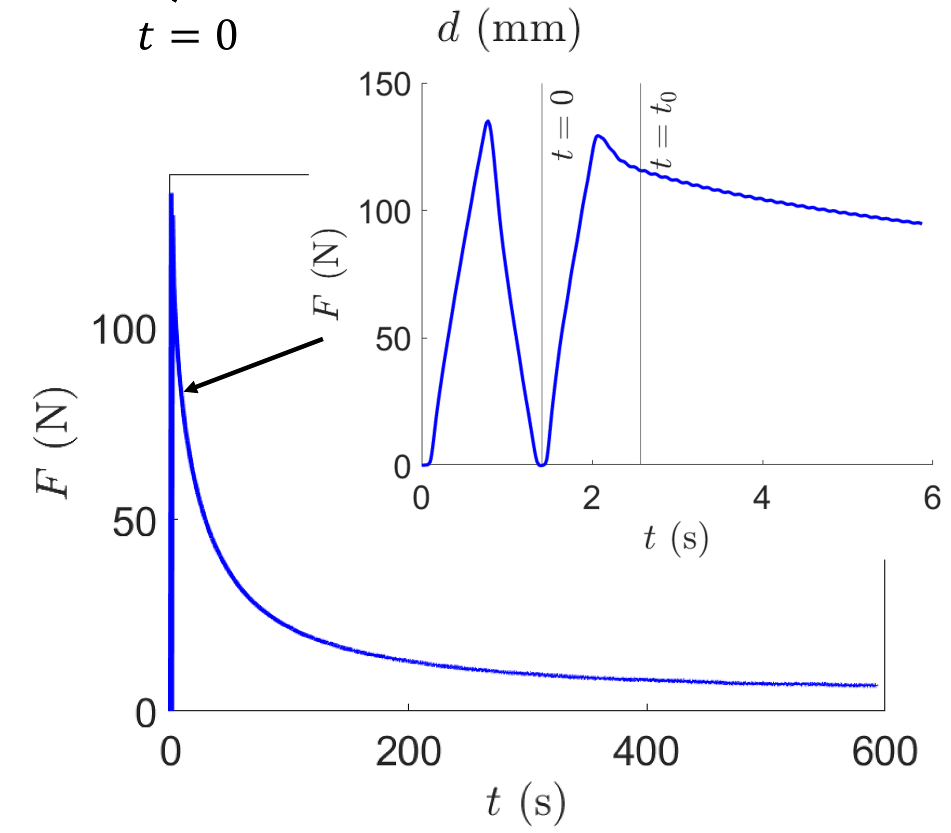
Method

T*u*FF PEI-CF samples were used for this research. Samples contained 57% fiber volume fraction of an aspect ratio of 600 (5μm diameter). Samples were tested in a temperature controlled static loading frame.



Stress relaxation tests consisted of a pre-load and unload cycle preceding the loading and hold/relax. Tests were done at loads doubling from 30N to 480N and at temperatures of 250ºC, 260ºC, and 270ºC.





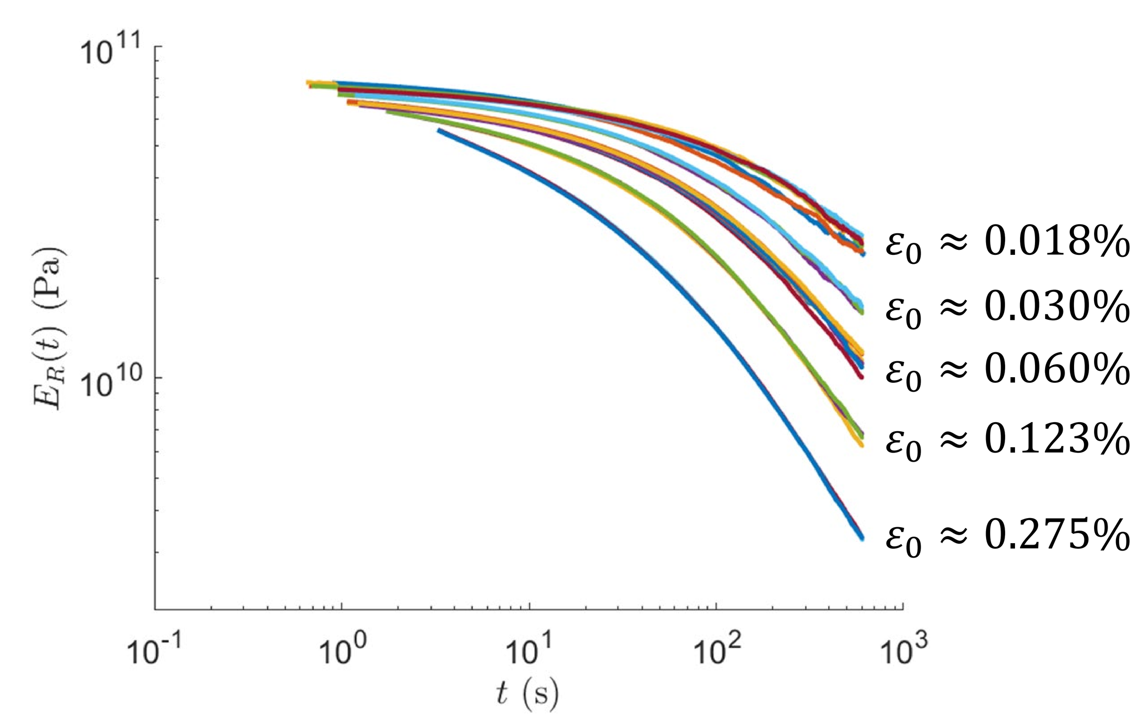
Results

Assessments were made using relaxation modulus $E_R(t)$

$$E_R(t) \equiv \frac{\sigma(t)}{\varepsilon_0} = \frac{F}{A\varepsilon_0}$$

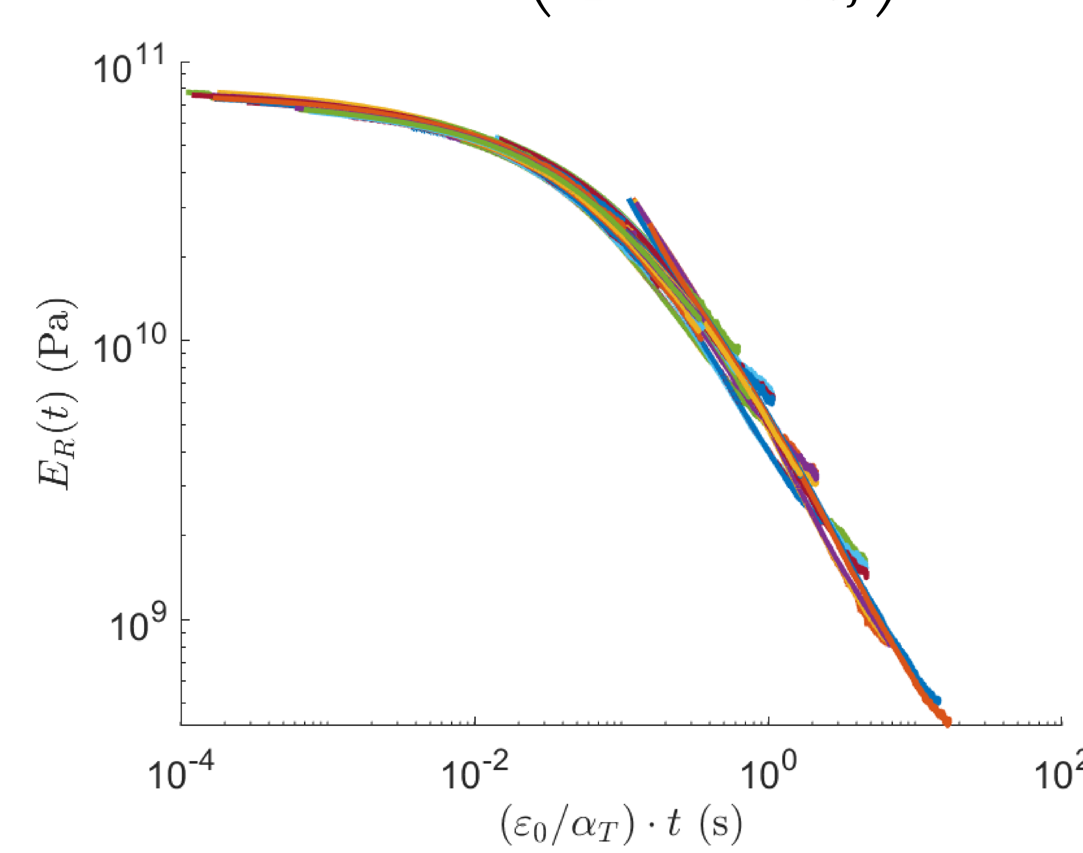
Where ε_0 is the strain during the hold. Relaxation modulus results indicated that:

- The method is highly repeatable at any given strain
- The sample microstructure is not damaged or altered during testing
- Relaxation behavior is non-linear
  - Scales with applied strain ε_0
  - Linearity between different strains

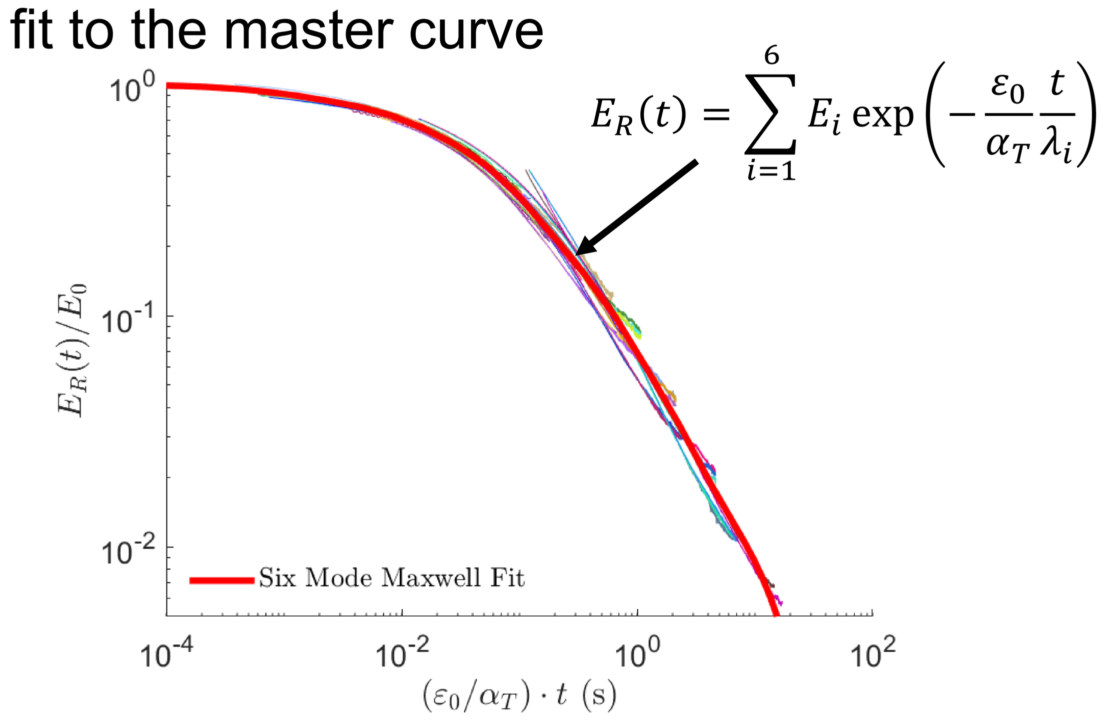


Empirically, a horizontal shift by strain was found to result in a continuous curve. Time-temperature superposition (TTS) factors can be applied to generate a master curve.

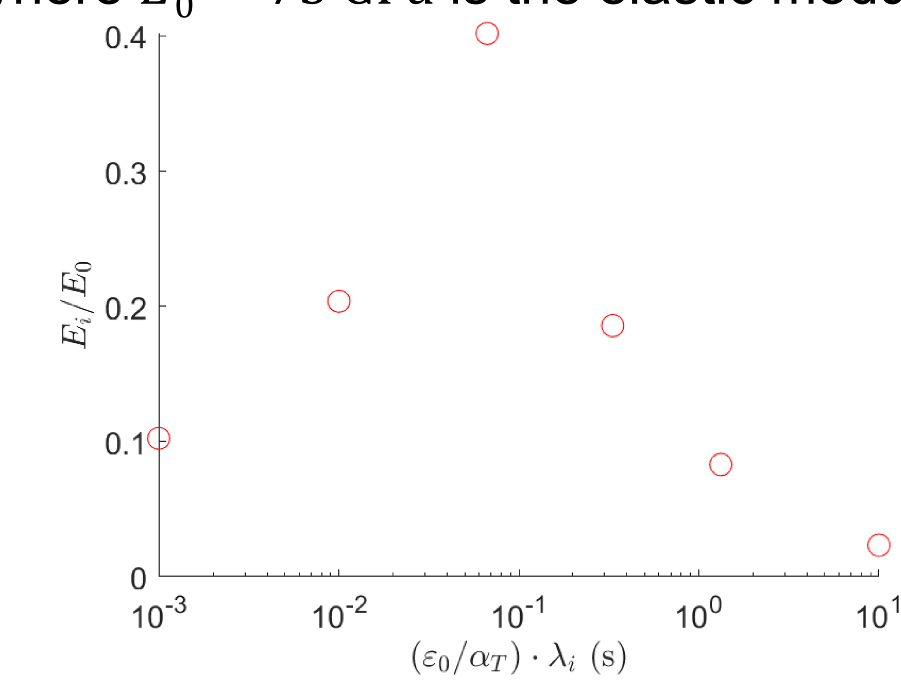
$$\alpha_T = \exp\left(\frac{C_1(T - T_{ref})}{C_2 + T - T_{ref}}\right)$$



A six mode parallel Maxwell model can be fit to the master curve



Where $E_0 = 75$ GPa is the elastic modulus.



The relaxation spectrum (model-derived) is a log-normal distribution. This material property can be used to predict the material response for any processing history.

Conclusions

- A repeatable stress relaxation method was created for an ADF composite
- The relaxation behavior was non-linear, but horizontally scalable by strain
- The master curve can be fit to a six mode parallel Maxwell Model
- The material model can be used to predict any history-dependent response

Acknowledgements

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