DYNAMIC RHEOLOGY OF SHEAR THICKENING FLUIDS FOR STRUCTURAL COMPOSITE ARMOR

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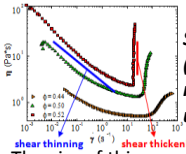
MOTIVATION FOR STRUCTURAL COMPOSITE ARMOR

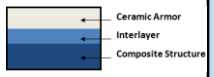
- Armored vehicles typically experience two types of loads that require different structures for protection

Mobility Loads → fully decoupled structure → Interlayer acts as a dampening agent

Ballistic Loads → fully coupled structure → Interlayer acts as a bonding agent



Shear Thickening Fluids (STFs) can change their mechanical properties under different loads.

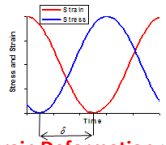


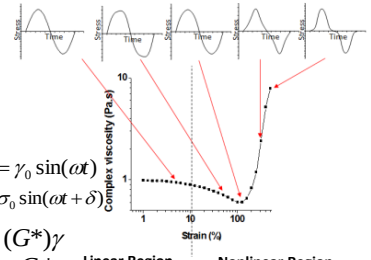
The aim of this research is to couple the material properties unique to STFs with the mechanical properties they exhibit in applications. There are three goals toward meeting this objective:

1. The present research focuses on Large Amplitude Oscillatory Shear (LAOS) tests to understand the material properties of STFs.
2. Flexure testing of STFs in 3-pt beam bending experiments
3. Computer modeling of the flexure tests (#2) using the properties gained from LAOS experiments (#1)

LAOS MEASUREMENTS

- Under LAOS an oscillatory shear deformation is applied to the sample and the stress response of the sample is measured.
- The linear region is well characterized . From the sinusoidal stress response we can determine the complex modulus and viscosity.
- The nonlinear region does not have a sinusoidal stress response therefore we need another means for interpreting responses under LAOS





Strain Deformation $\gamma(t) = \gamma_0 \sin(\omega t)$

Stress Response $\sigma(t) = \sigma_0 \sin(\omega t + \delta)$

Complex Modulus: $\sigma = (G^*)\gamma$

Complex Viscosity: $\eta^* = \dfrac{G^*}{\omega}$

Linear Region ⟵ ⟶ Nonlinear Region

Φ = 0.47 silica spheres in PEG

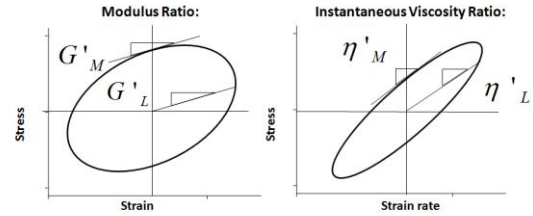
Frequency = 20 radian/sec

NONLINEAR REGION ANALYSIS

Applying the MIT method:

There are two definitions utilized in this analysis:

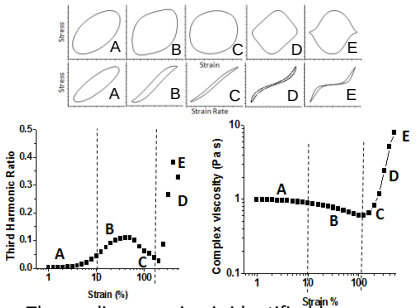
1. Modulus Ratio
2. Viscosity Ratio



$\dfrac{G'_L}{G'_M}$ >1 Strain Stiffening, =1 Linear Elastic, <1 Strain Softening

$\dfrac{\eta'_L}{\eta'_M}$ >1 Shear Thickening, =1 Linear Viscous, <1 Shear Thinning

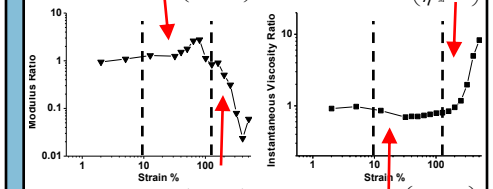
STFs LISSAJOUS BOWDITCH DIAGRAMS UNDER LAOS



The nonlinear region is identified by the existence of the third harmonic

APPLYING THE NONLINEAR REGION ANALYSIS

Strain Stiffening $\left(\dfrac{G'_L}{G'_M} > 1\right)$ Shear Thickening $\left(\dfrac{\eta'_L}{\eta'_M} > 1\right)$



Strain Softening $\left(\dfrac{G'_L}{G'_M} < 1\right)$ Shear Thinning $\left(\dfrac{\eta'_L}{\eta'_M} < 1\right)$

CONCLUSIONS

- Preliminary results indicate that oscillatory tests are one way to understand the mechanical properties of STFs under loads similar to those mobility loads experienced by armored vehicles.
- The MIT method discussed here shows promising results toward analyzing the nonlinear region of LAOS tests in order to understand the material properties and molecular interactions of STFs.

REFERENCES

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FUTURE RESEARCH PLANS

- Perform 3-point beam bending tests using STFs as the interlayer in a sandwich beam structure
- Apply the stress-strain and stress-strain rate Lissajous-Bowditch relationships from LAOS experiments to the computer model of the 3-point beam bending tests

ACKNOWLEDGEMENTS

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