INVESTIGATING THE HIGH STRAIN RATE COMPRESSION-SHEAR BEHAVIOR OF A DISCONTINUOUS SHEAR-THICKENING FLUID (STF)

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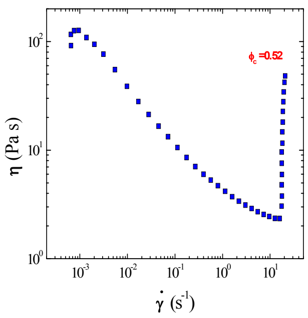
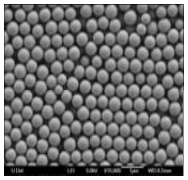
SHEAR THICKENING FLUID

- **A shear-thickening fluid (STF) experiences an increase in viscosity with shear rate.**
  - Repulsively charged silica particles
  - Polyethylene glycol (PEG, 200 MW)

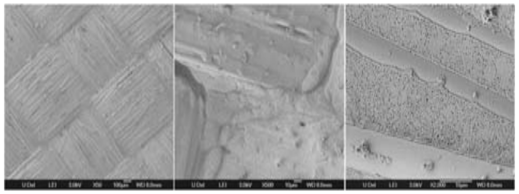




- Low shear rate rheology for a discontinuous STF, courtesy of M.J. Decker et al. from "Low Velocity Ballistic Properties of Shear-Thickening Fluid (STF)-Fabric Composites."

MOTIVATION

- **STF-infused fabrics outperform neat fabrics under spike, stab and low velocity projectile threats.**
  - A fundamental understanding of STF behavior within a fabric during ballistic impact has not yet been achieved.
- **During a ballistic event, the STF is subjected to high stresses resulting in transition.**

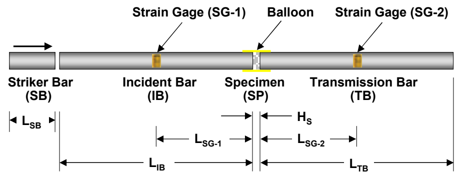


STF–infused Kevlar at increasing magnifications.

- **To understand the role of STF in fabric during impact, it is necessary to determine two things:**
  - The time required for the STF to thicken.
  - The post-transition behavior of the STF.
- **Standard rheometers can achieve strain rates up to 300 s^{-1}.**
  - Strain rates which occur during fabric impact events can be an order of magnitude greater.

EXPERIMENTAL

- **Compression-shear split-Hopkinson pressure bar (CS-SHPB) was used to investigate the high strain rate behavior of the STF.**



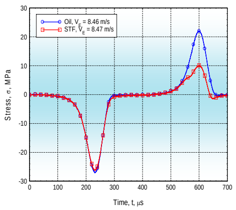
- **Test parameters were adjusted as necessary to achieve a thickening response within the material.**
  - bar material, striker bar velocity, pulse shaper, specimen thickness

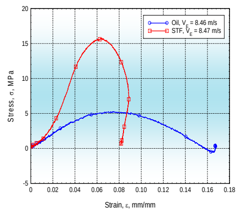
Table 1. CS-SHPB Experimental Parameters.

L_{IB}	1.83 m (6')	L_{TB}	1.83 m (6')
D_{IB}	0.0254 m (1")	D_{TB}	0.0254 m (1")
L_{SG-1}	0.92 m (3')	L_{SG-2}	0.92 m (3')
E	68.9 GPa	ρ	2700 kg/m^3
D_{SB}	0.0191 m (3/4")	L_{SB}	0.102 m (4")

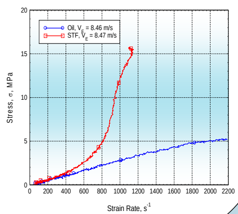
PROOF OF CONCEPT

- **STF and viscosity standard tested via CS-SHPB.**
  - (CANNON S8000, μ = 35.4 Pa.s)





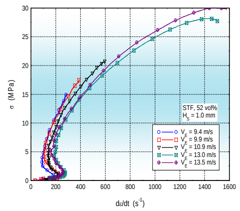
- **STF loads nonlinearly, indicating a change in modulus.**

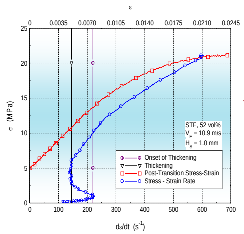


- **Similar behavior up to 400 s^{-1}.**
  - Clear evidence of thickening above 600 s^{-1}.

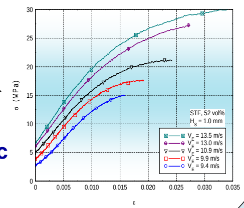
POST-TRANSITION STATE

- **The transition region is identified as the area between the first strain rate maximum and minimum.**





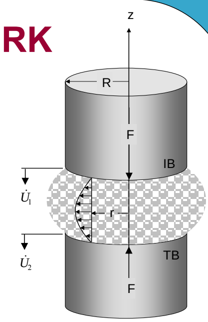
- **Post transition data is integrated to obtain σ–ε information.**



- **This is plotted for each specimen, yielding the plastic deformation of the post-transition STF.**

FUTURE WORK

- **Test the post-transition STF at higher strain rates to achieve failure.**
- **Determine the viscosity of STF during transition using a conservation law model to predict the dynamic squeeze flow behavior of a Newtonian fluid.**



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