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Dynamic response of an anisotropic carbon fiber reinforced epoxy

C. Scott Alexander

Sandia National Laboratories

Air Force Research Lab
Eglin AFB, FL

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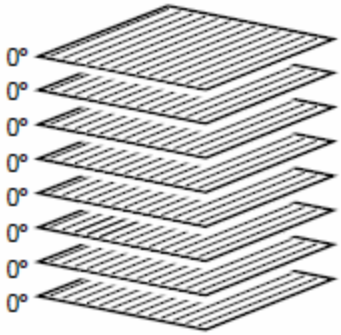
Dynamic Behavior of Composite Materials

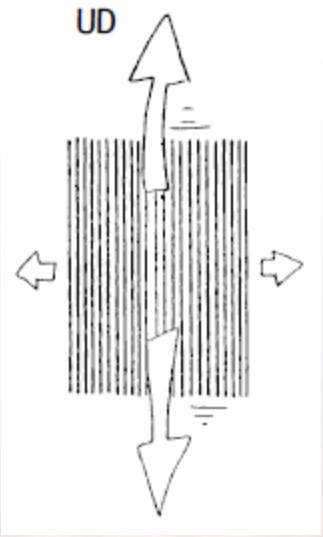
Goal:

Obtain shock data to characterize the anisotropic response of fiber composite materials for development of advanced EOS and constitutive models

Test Material:

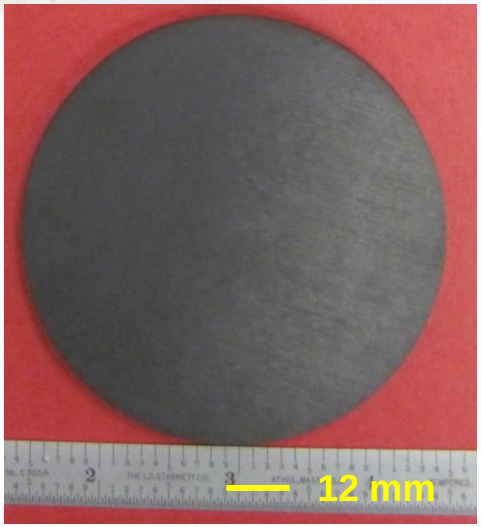
Hexcel IM7/8552
unidirectional / laminate
vary volume fraction (62, 65, 68%)

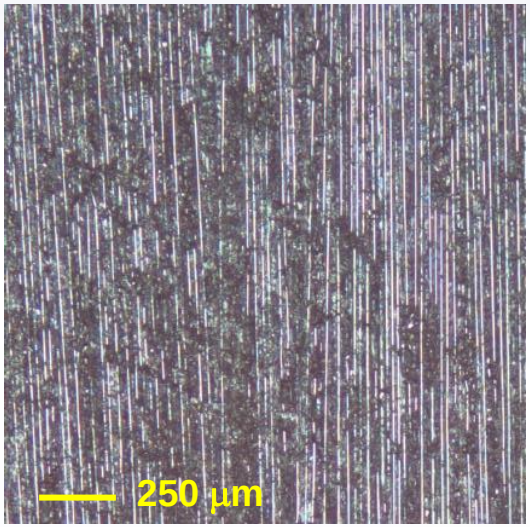


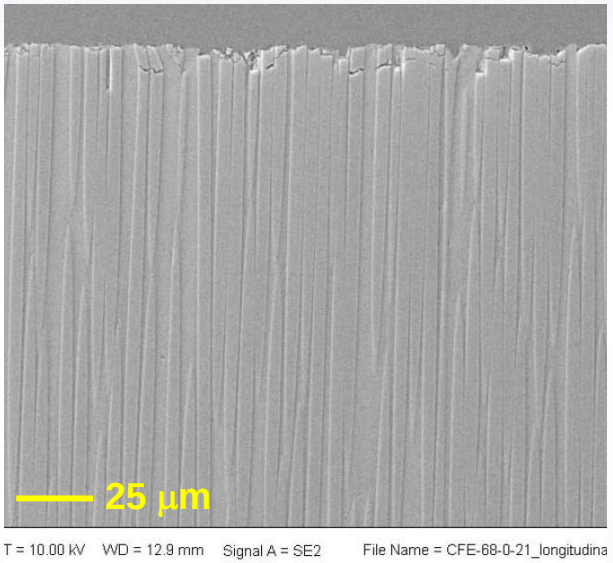


Hexcel Prepreg Technology Guide
Publication No. FGU 017b
March 2005

Material is engineered to exhibit anisotropic response

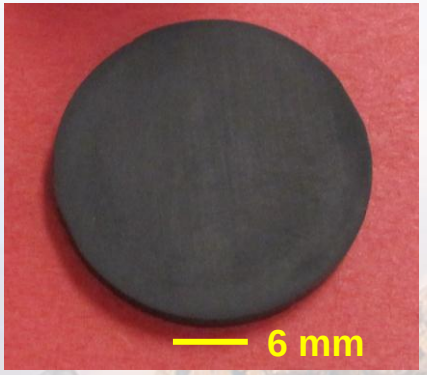




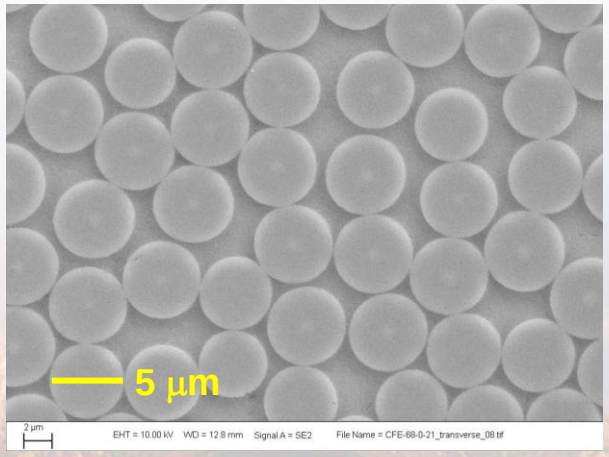


Cross-fiber orientation (90°)

On-fiber orientation (0°)



Ultrasonic Wave Speeds	
0°	10.763 km/s
90°	3.042 km/s



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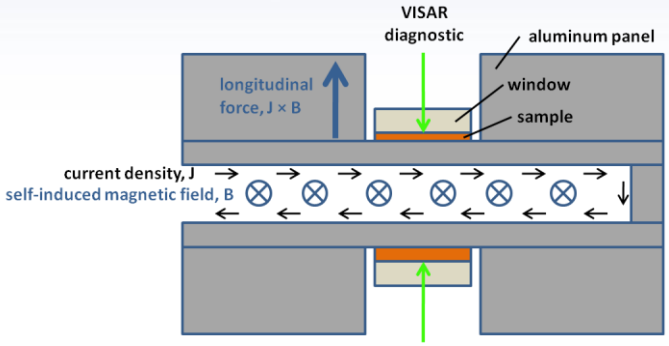
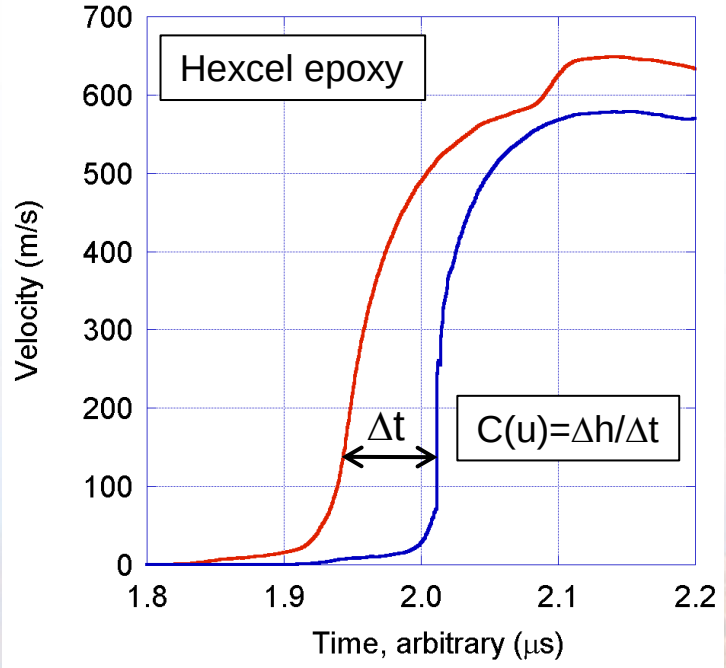
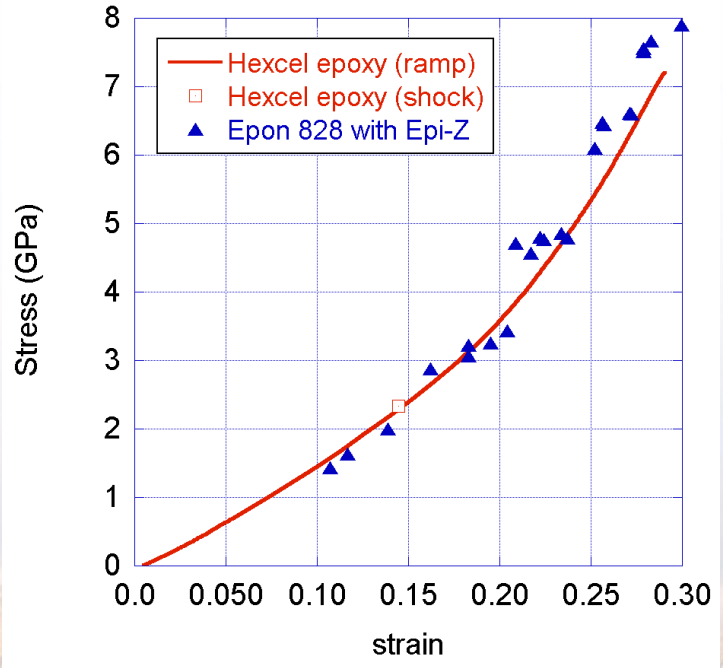
Unreinforced epoxy was characterized using both shock and ramp loading

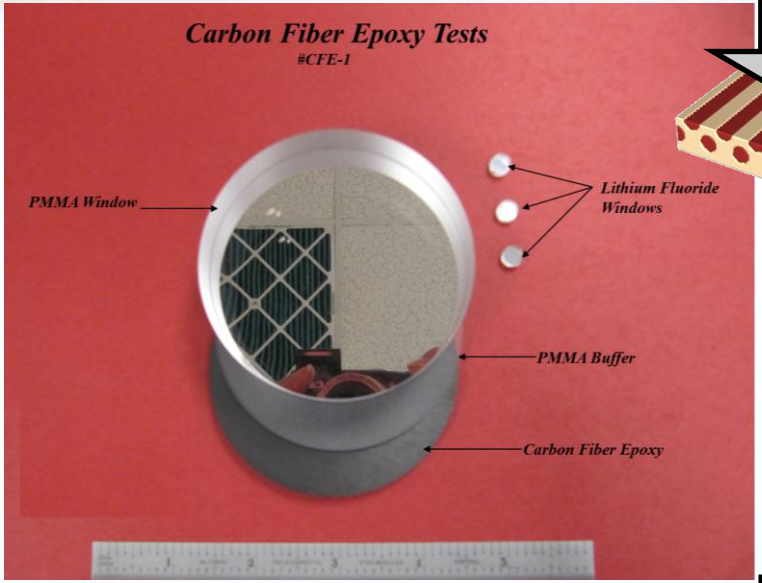


- Epoxy response is needed by model development effort
- Response measured via shock and ramp loading techniques
- Data similar to another common (well characterized) epoxy

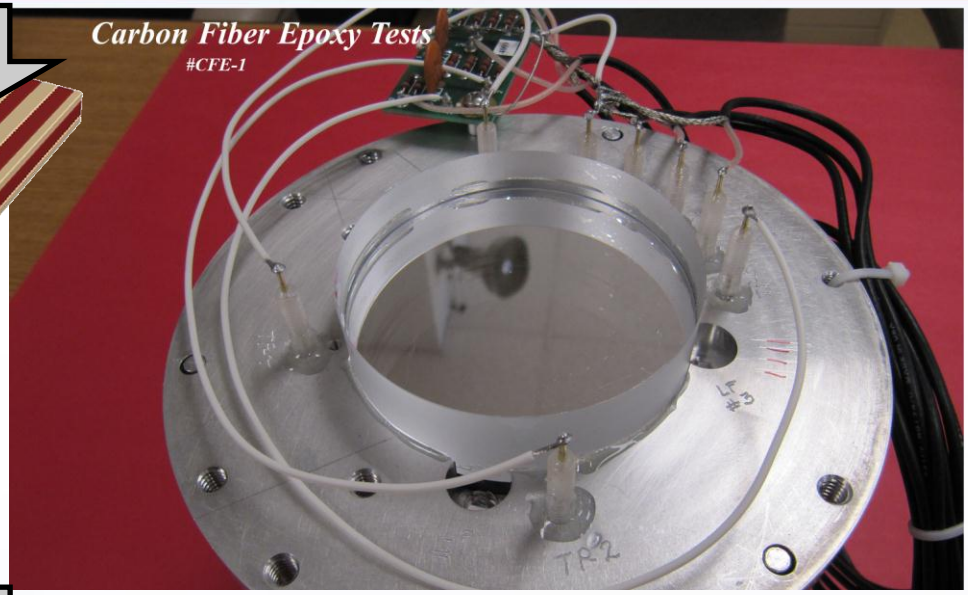




Experimental designs vary slightly depending on fiber orientation



load



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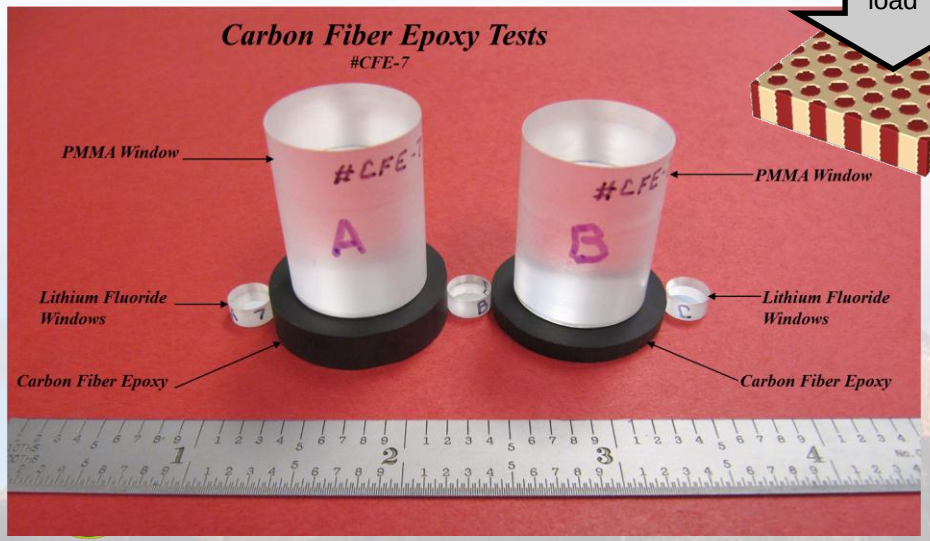
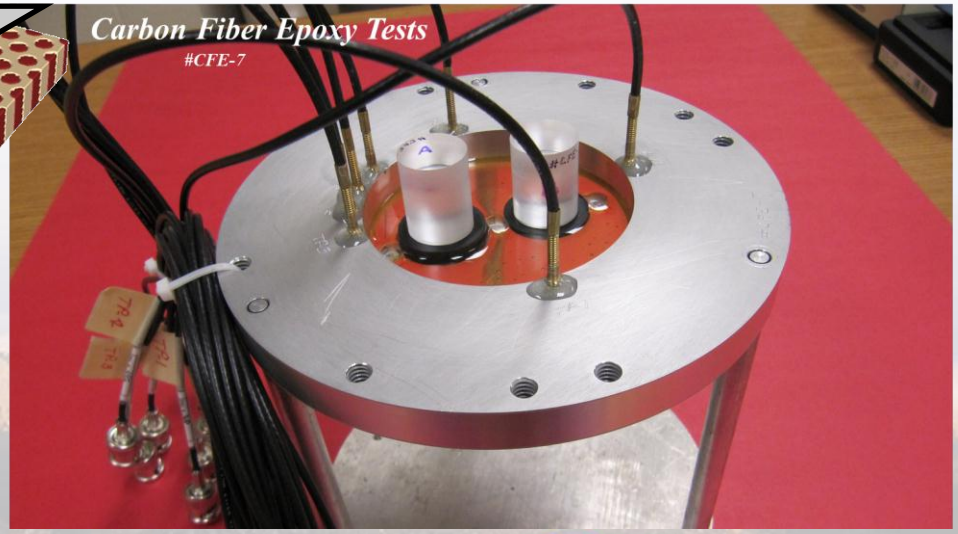
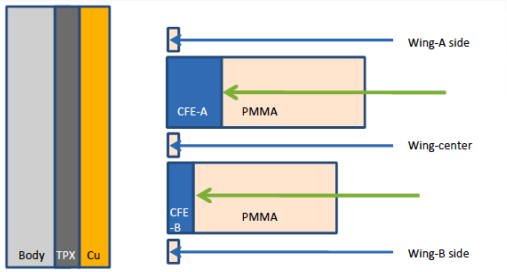
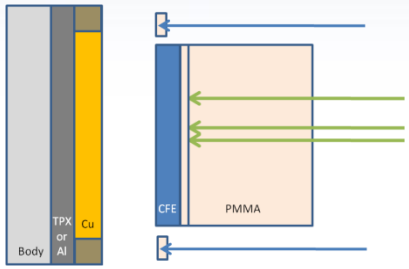


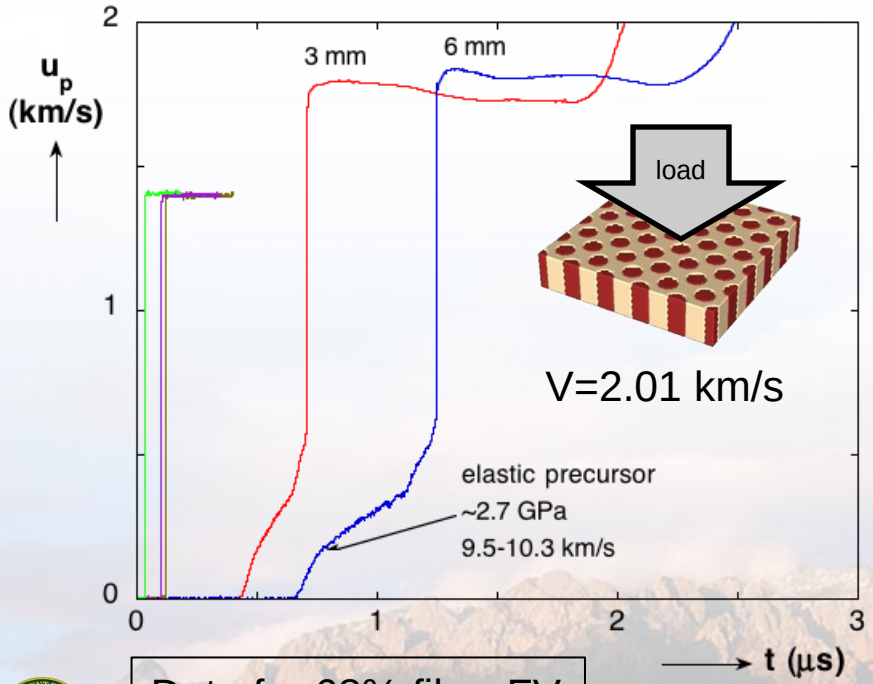


Fiber orientation affects material response

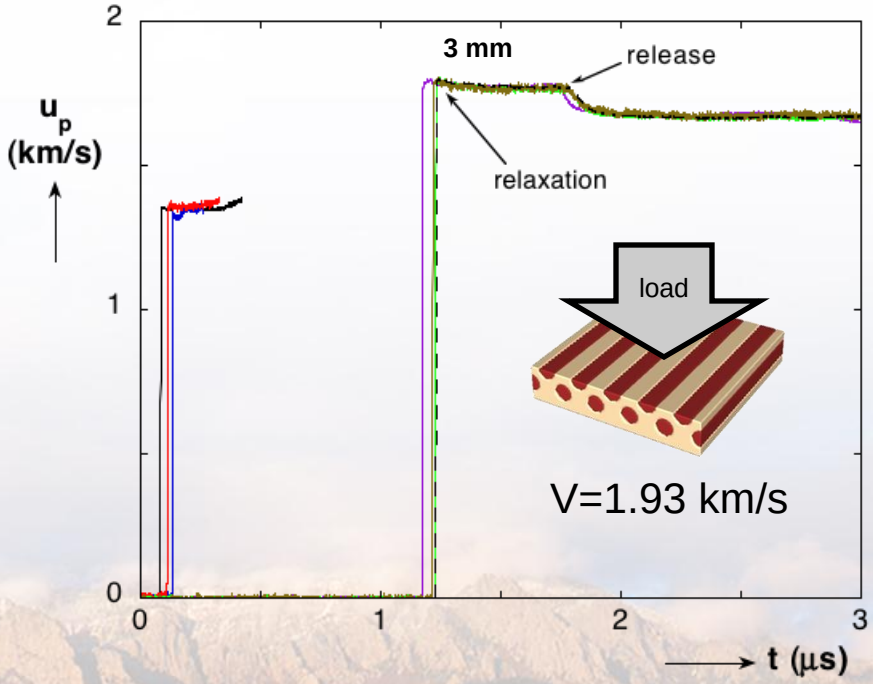




0° (shock along fiber direction)



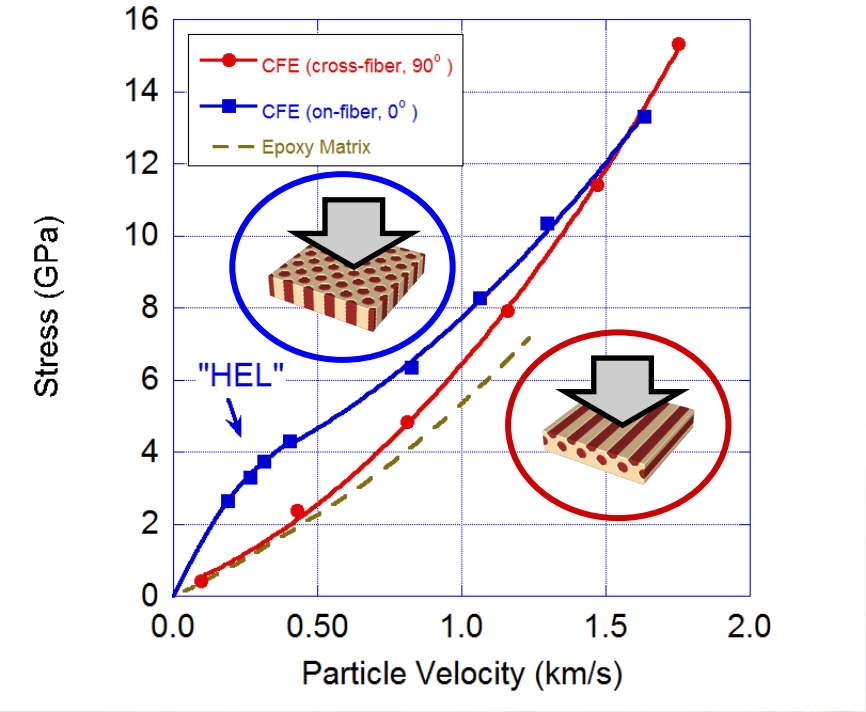
90° (shock normal to fiber direction)



Data for 68% fiber FV

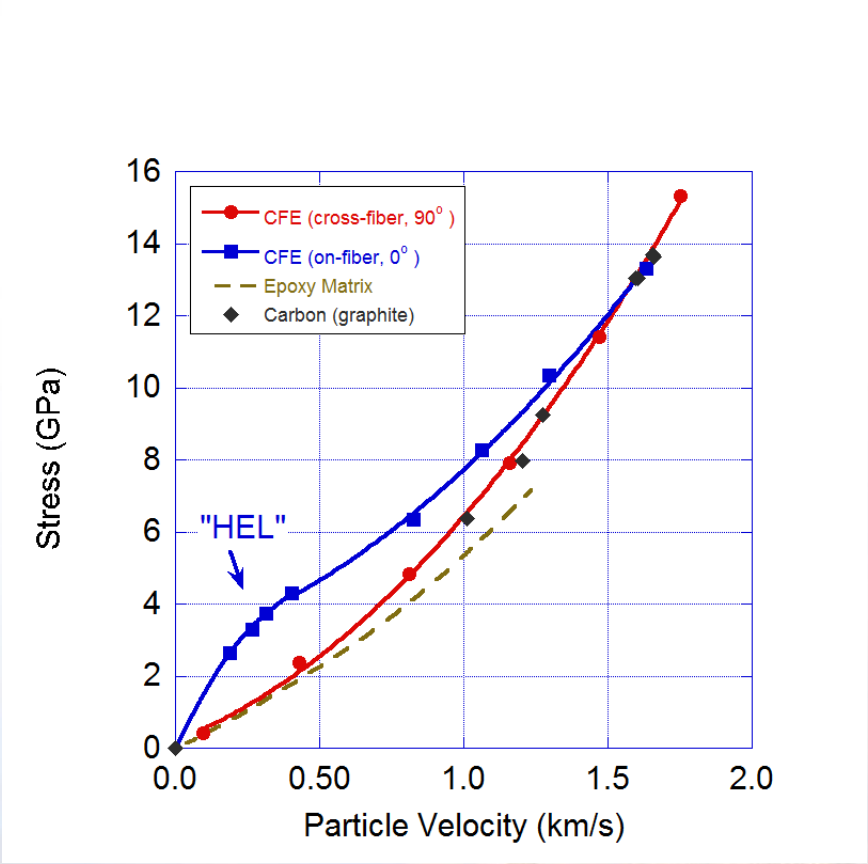
Shock response of CFE is anisotropic up to ~10 GPa

The vast majority of models in the dynamic regime assume **isotropic behavior**, especially for shock behavior



- Fiber stiffens matrix at low-intermediate pressures (up to ~10 GPa)
- Response appears to become isotropic at higher pressures
- Data suggests that the cross-fiber response follows a mixture rule

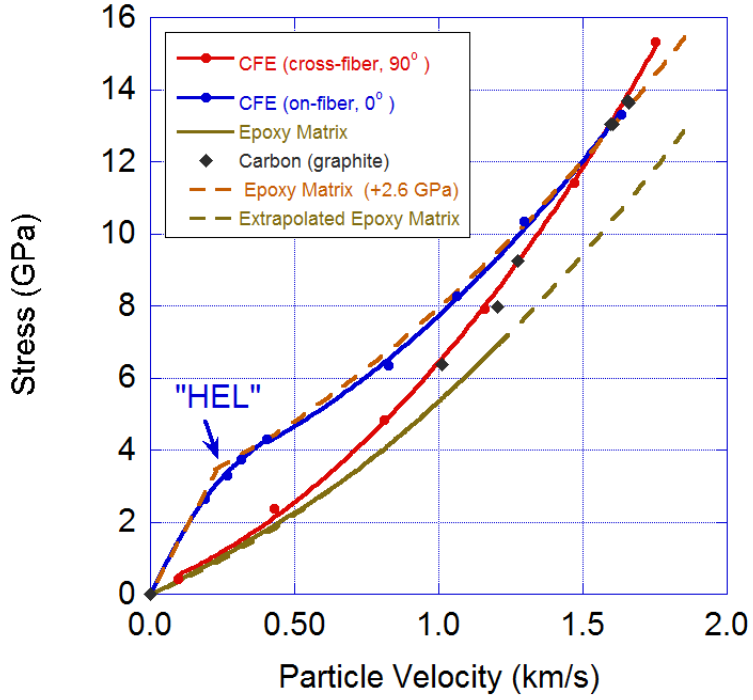
Cross-fiber material response is similar to pressed graphite



Pressed graphite ρ_o = 1.77 g/cm^3
CFE ρ_o = 1.58 g/cm^3

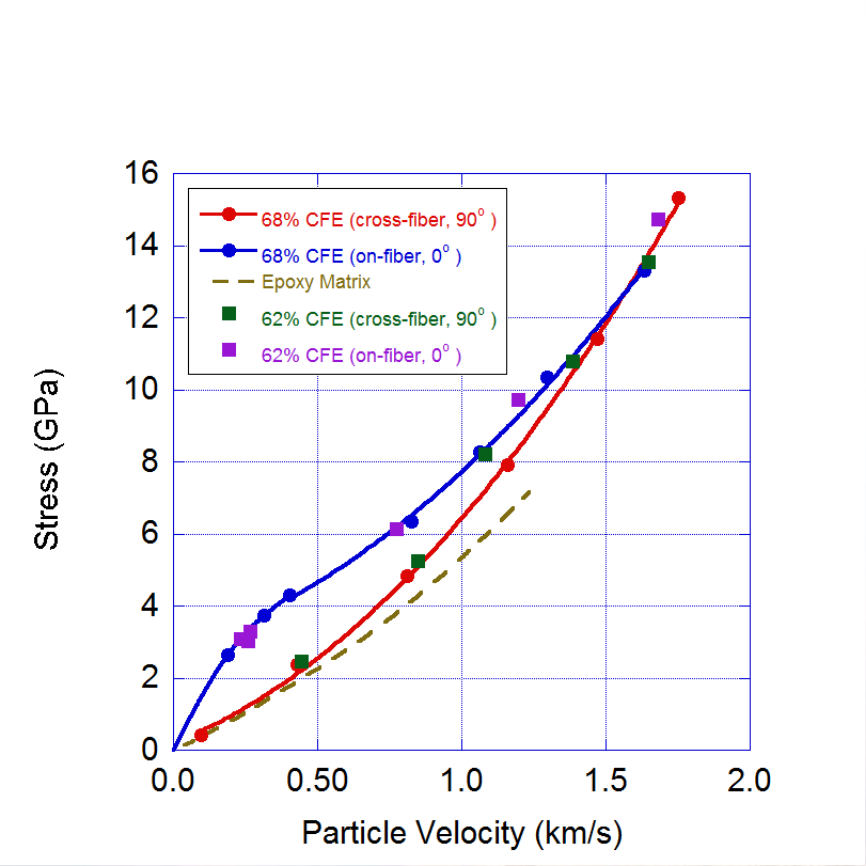
- Fiber stiffens matrix at low-intermediate pressures (up to ~10 GPa)
- Response appears to become isotropic at higher pressures
- Data suggests that the cross-fiber response follows a mixture rule
- However, comparison with pressed carbon of similar density shows like response

Fibers provide an elastic component to the epoxy response (HEL = 2.6 GPa) on-fiber



- Fiber stiffens matrix at low-intermediate pressures (up to ~10 GPa)
- Response appears to become isotropic at higher pressures
- Data suggests that the cross-fiber response follows a mixture rule
- However, comparison with pressed carbon of similar density shows like response
- Further, on-fiber response shows a stiffening of the epoxy matrix with an HEL of 2.6 GPa
- Response is anisotropic with differing fundamental mechanisms in play

62% fill volume shows similar response to 68% material



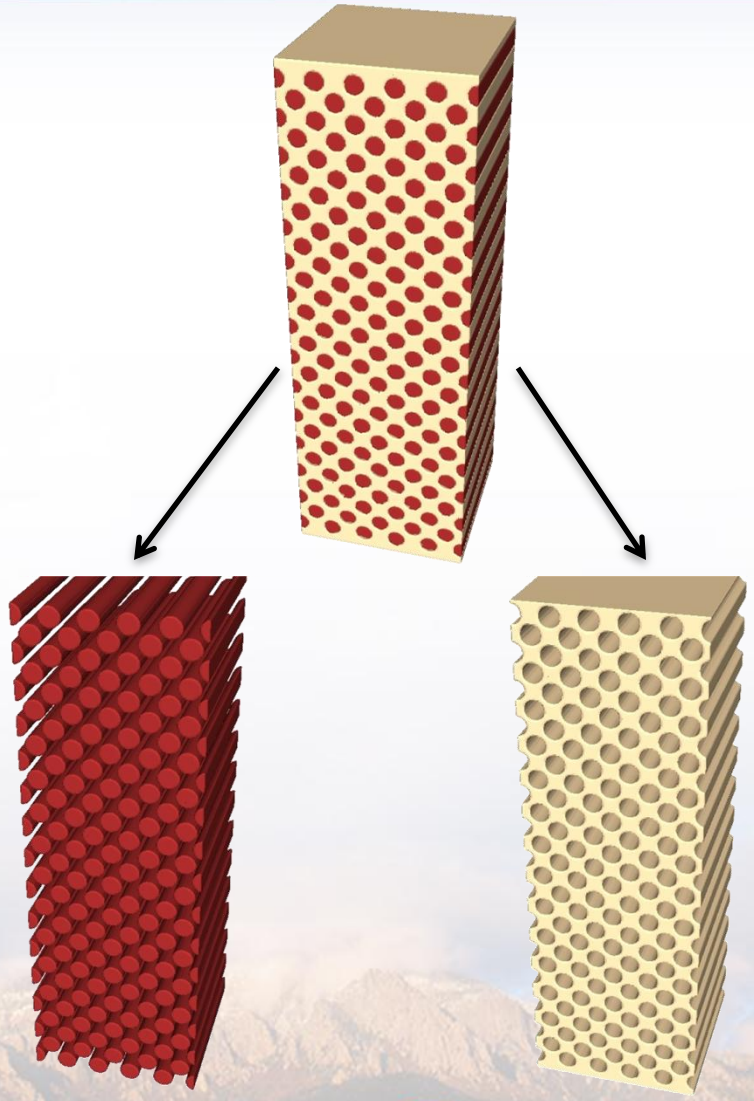
- 62% fill material shows similar dynamic response
- Samples tested are maximum and minimum possible fill volumes for this composite
- Testing will not be performed on 65% fill material

Summary of experimental results

- **Dynamic response of composite is anisotropic**
  - Highlights need for advanced models
- **Compression across fibers shows:**
  - no elastic precursor
  - bulk response similar to pressed carbon
- **Compression along fibers shows:**
  - an elastic precursor traveling along fibers
  - a bulk response similar to the epoxy binder
- **Fiber fill volumes between 62% and 68% exhibit similar response**

Anisotropic EOS Model Development

- **Developed microscopic models for unidirectional materials**
  - 62%, 65% and 68% FV
- **Uniform fiber arrangement in matrix**
- **Generate composite response using matrix and fiber material properties**
- **Validation performed by comparing model results to experiments**



Future work

- **Test off-principle axis response**
  - 10, 20, 45, 70, 80 degrees
- **Penetration tests for model validation**
  - Sphere impact
  - .762 rounds
- **Oblique impact to investigate the effect of combined pressure-shear loading**
- **Woven glass fiber composites**