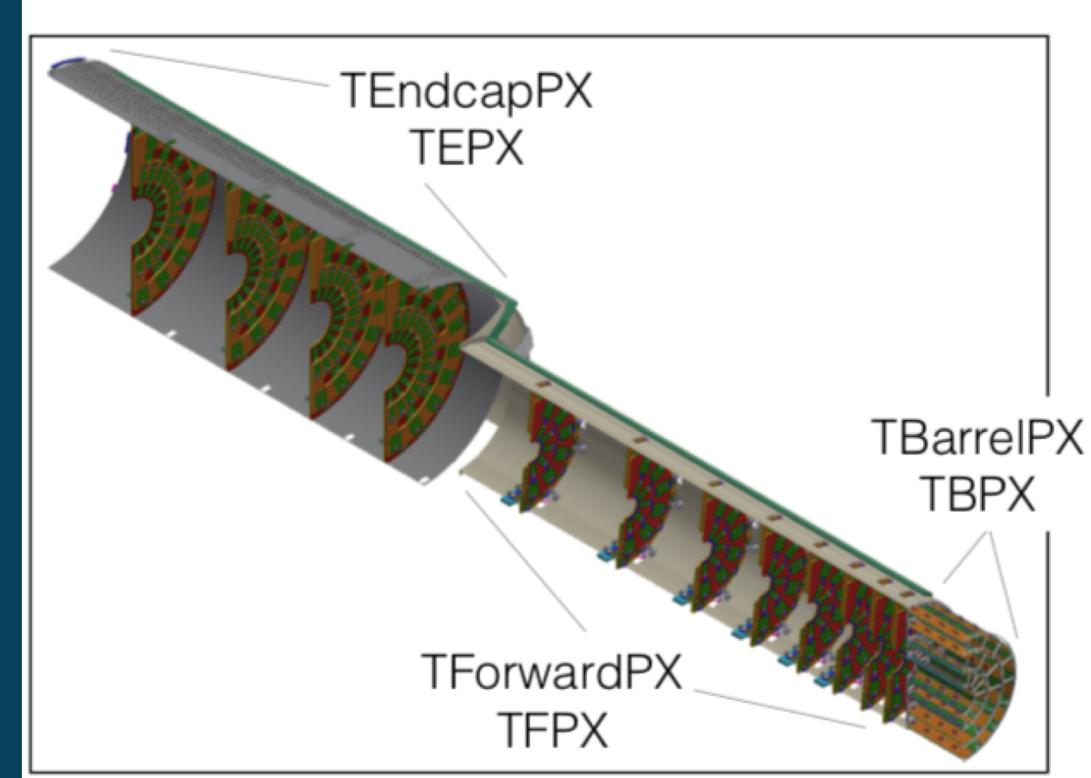
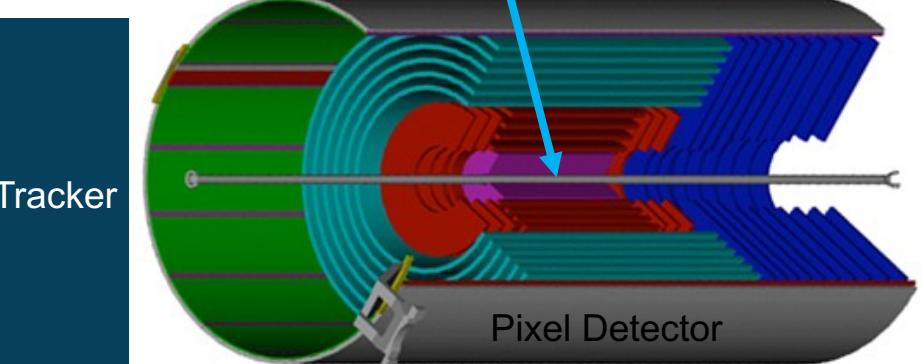
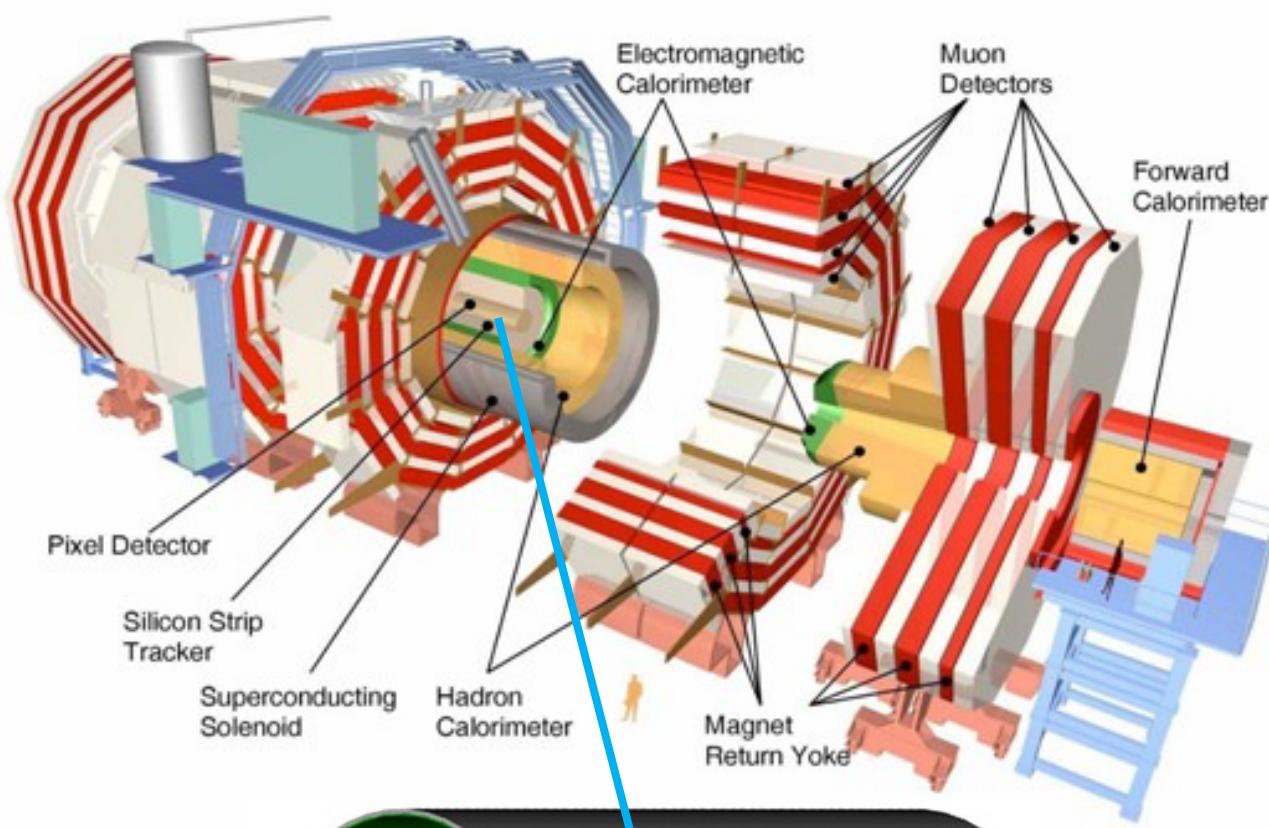


# Strain Gauge Measurements of Carbon Fiber Dee for the CMS Phase-2 Upgrade of the Tracker Forward Pixel Detector

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UPRM CMS Research Group  
September 6, 2019

# CMS Inner Tracker Mechanics



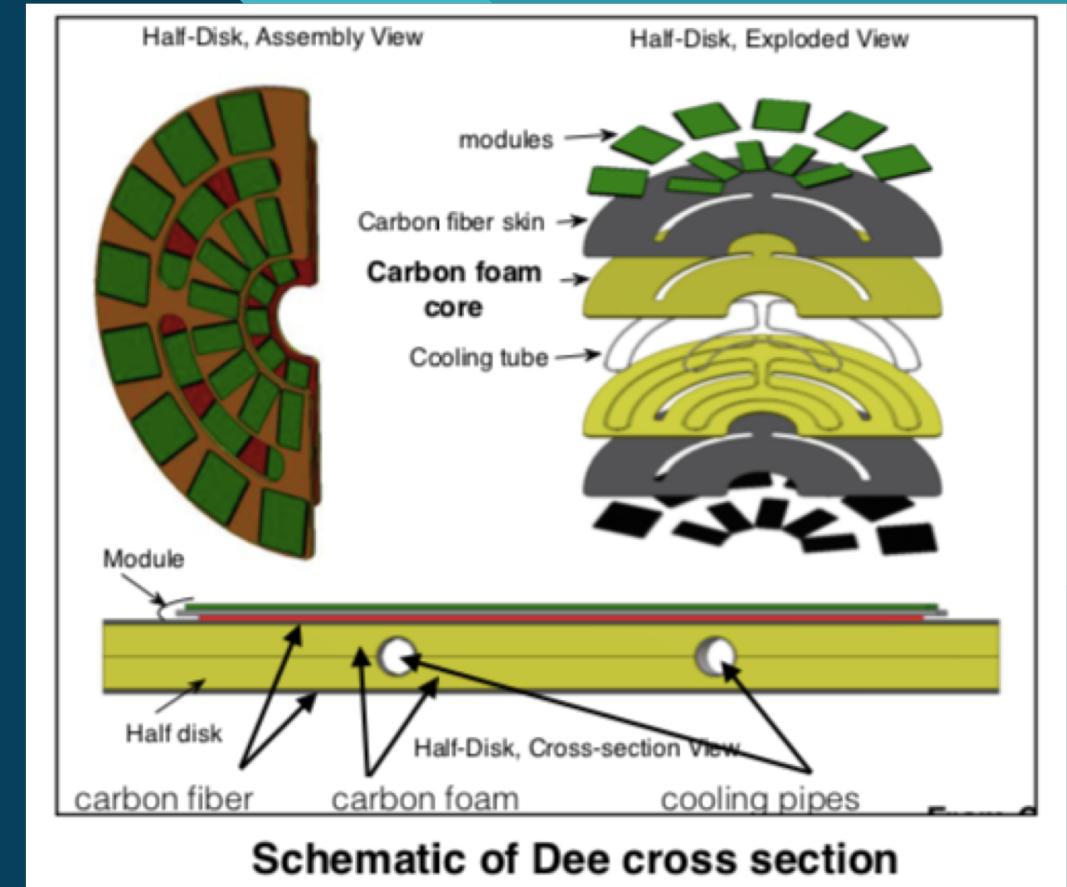
**Phase II Pixel Detector schematic**

- CMS is a general purpose detector at the LHC.
- The Pixel Detector is closest to the LHC beam-pipe.

# Carbon Fiber Dee Structure

The effect of stress on carbon fiber materials changes with the direction which it is applied due to the manufactured direction of carbon fiber tubes in the material.

Carbon fibers themselves are much more brittle than metal, but due to the nature of the material, failure in one of the fibers can be compensated for by the surrounding intact fibers.

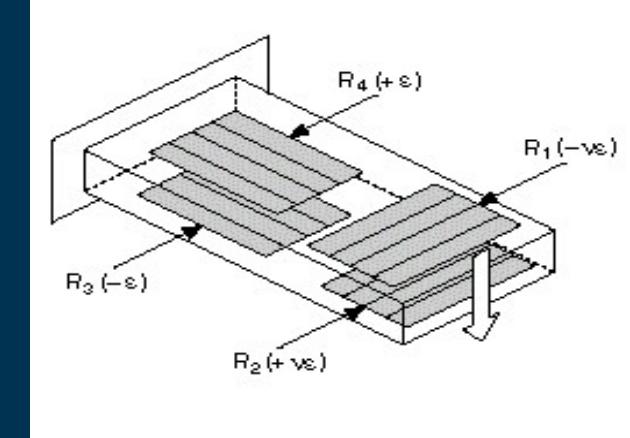
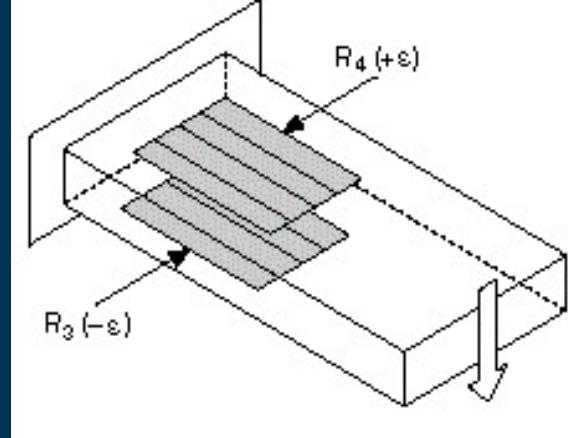


- Carbon fiber is TENCATE K13D2U / TC-275-1, 3 ply
- Carbon foam is AllComp K9 foam (2mm)

# Types of Stress/Strain

## Mechanical Stress

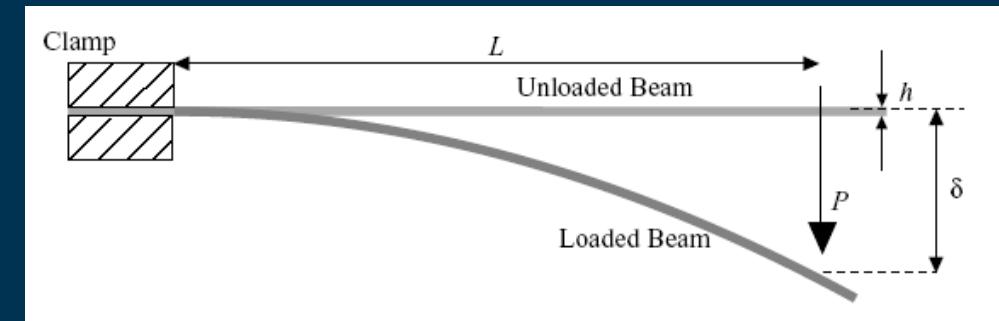
- Axial or Bending Strain
  - Equations for axial and bending strain are different.
- Cantilever Beam Bending Test
  - A piece clamped at one end and on the other end the normal load is applied.



## Thermal Stress

- Deflection Observation
  - Thermal expansion and contraction of the material due to a change in temperature.
  - Experiment under high temperatures (80 °C – 100 °C), looking for delamination due to thermal shock.

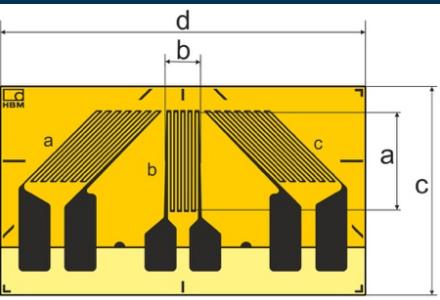
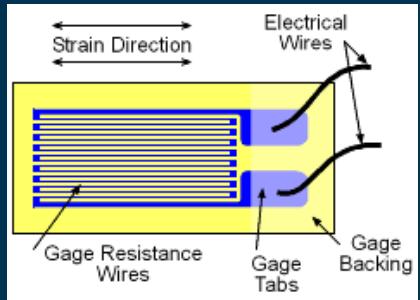
<http://www.ni.com/en-us/innovations/white-papers/07/measuring-strain-with-strain-gages.html>



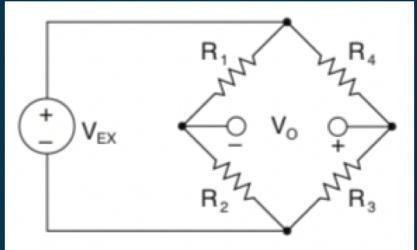
# Stress/Strain Measurements

Based on the acquired data, a material profile for carbon fiber is used as a guideline for the Dee's construction and modeling as part of the Phase-2 Upgrade.

## Strain Gauges



- A tool whose electrical resistance varies in proportion to the amount of strain in the device.
- The Wheatstone bridge is the most used circuit to measure strain of an applied strain gauge, measuring the voltage difference between two ends of a simple bridge.



The equation for strain ( $\epsilon$ ) in the cantilever beam test depends on the configuration of strain gauges being used.

$$\epsilon = \frac{-2V_r}{GF} \cdot \left(1 + \frac{R_L}{R_G}\right)$$

Half Bridge Strain

$$\epsilon = \frac{-2V_r}{GF(\nu + 1)}$$

Full Bridge Strain

$$\sigma = \frac{6Wx}{bt^2}$$

Mechanical Stress

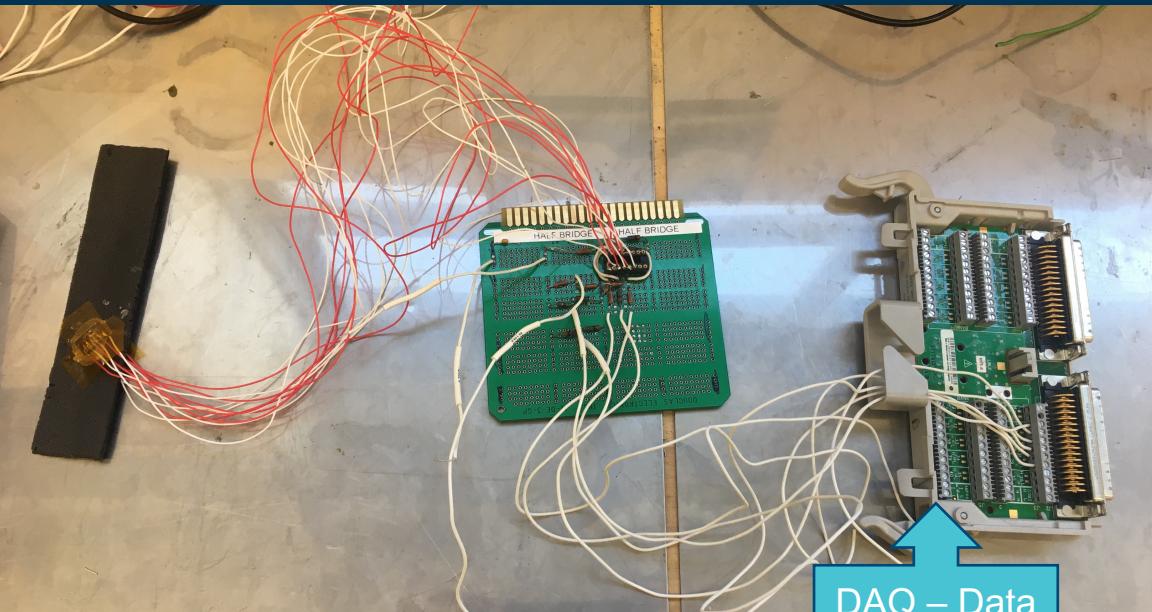
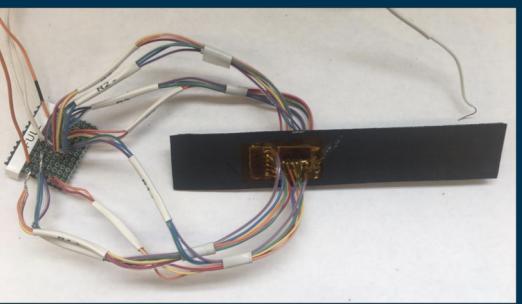
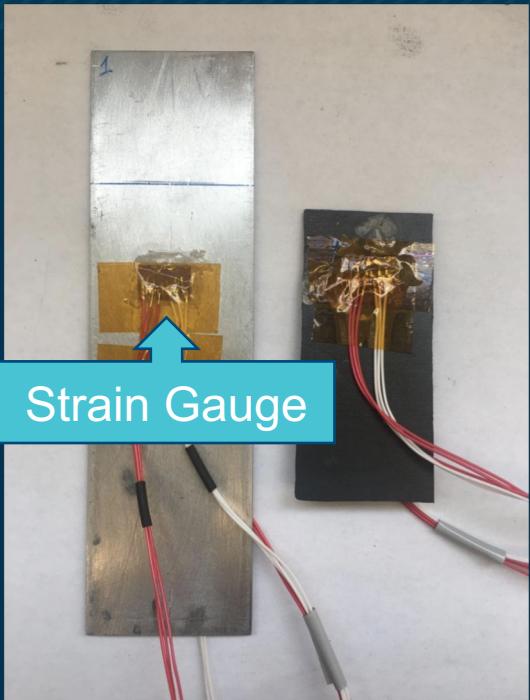
$$E = \frac{\sigma}{\epsilon}$$

Young's Modulus

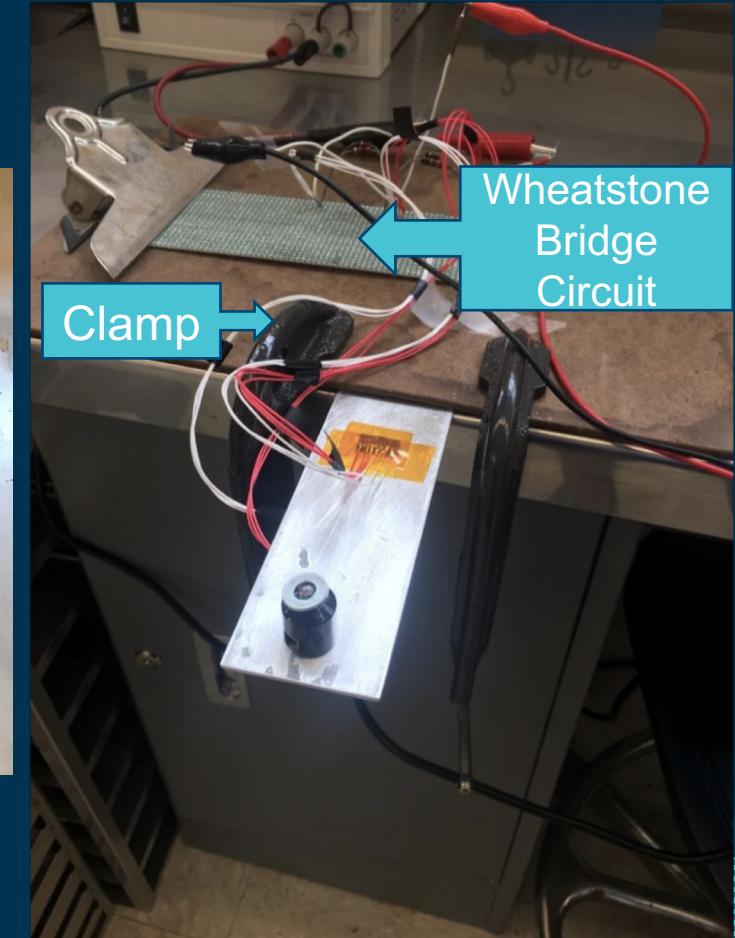
$$\nu = \frac{-2EV_r}{GF(\sigma)} - 1$$

Poisson's Ratio

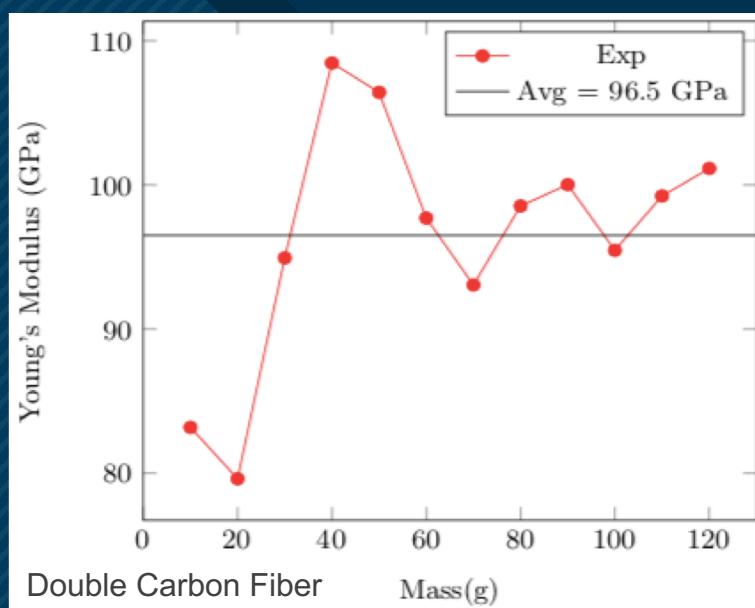
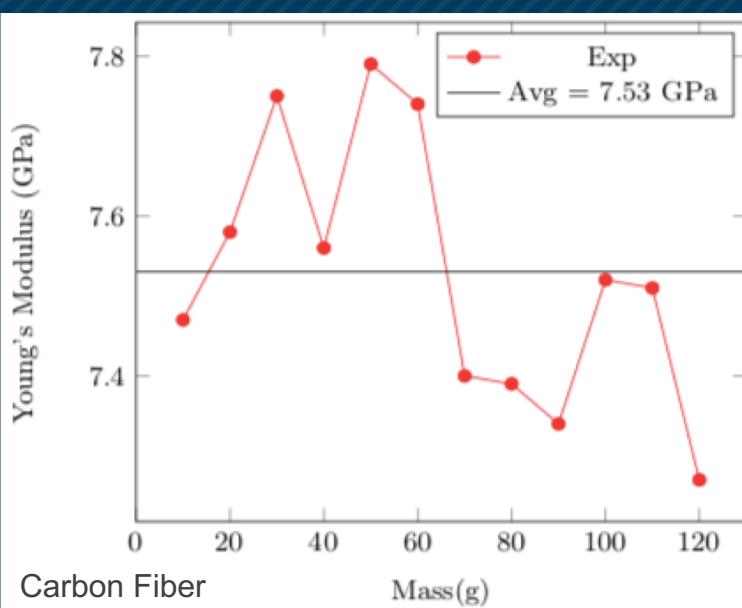
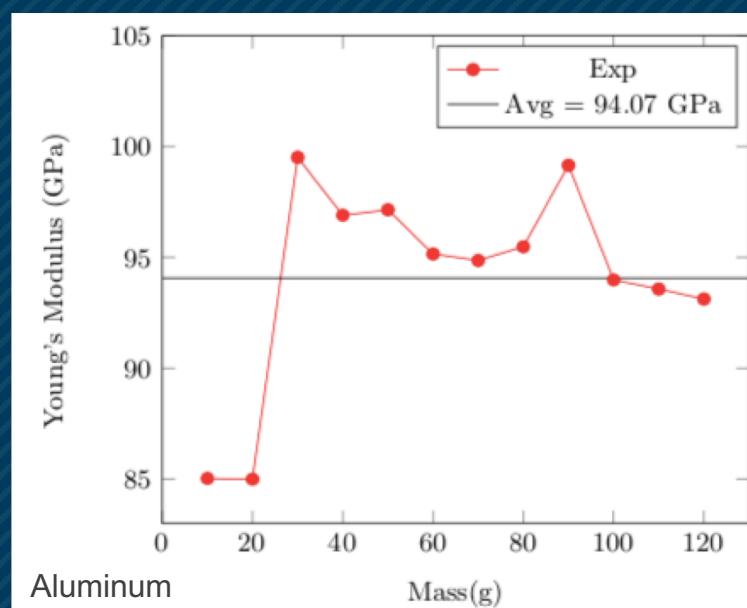
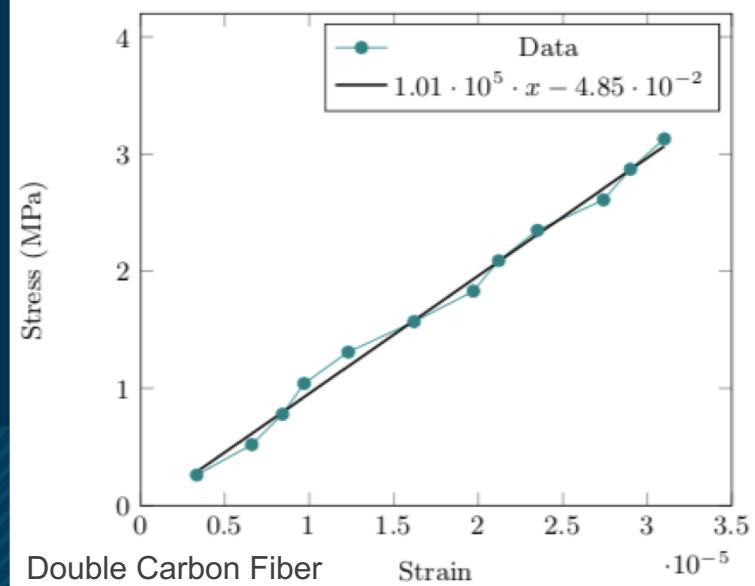
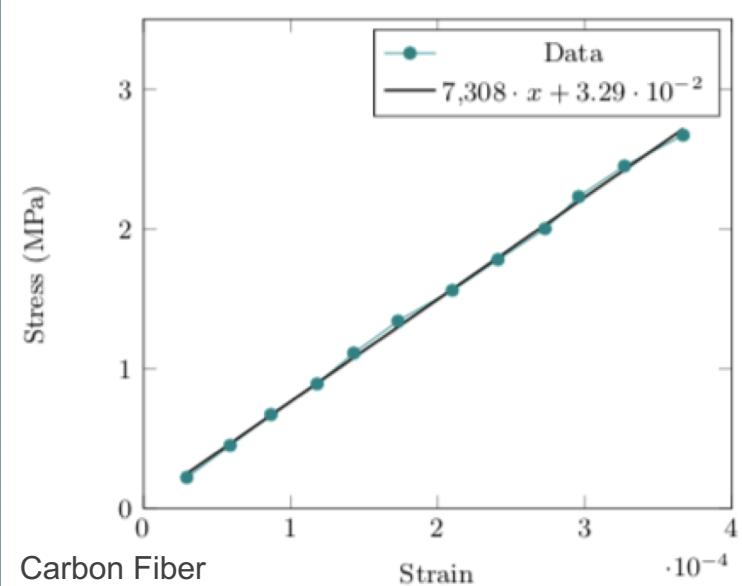
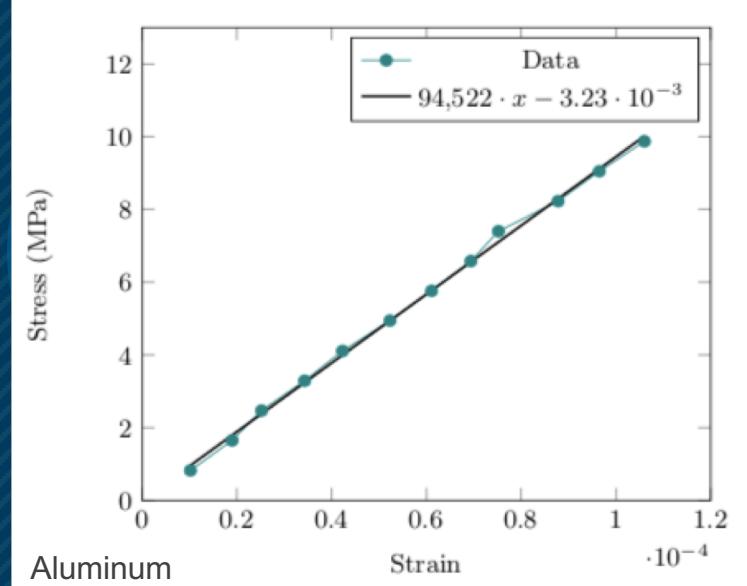
# Cantilever Beam Bending Test



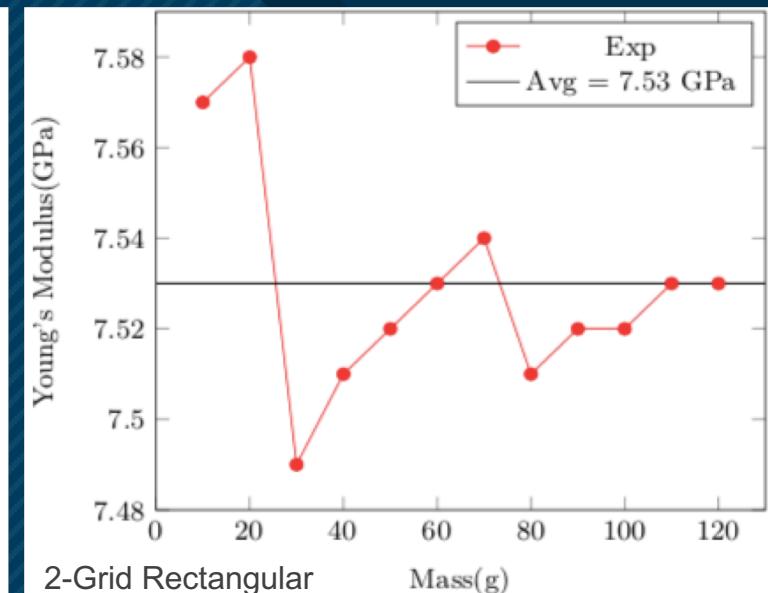
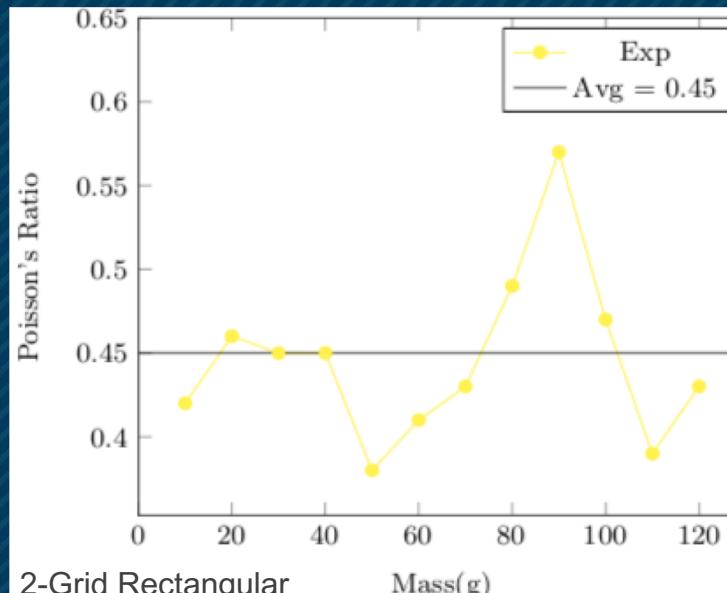
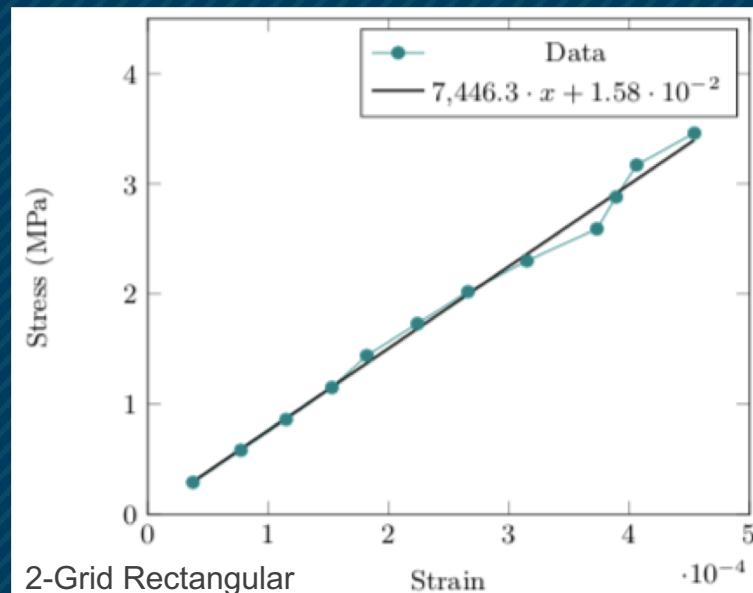
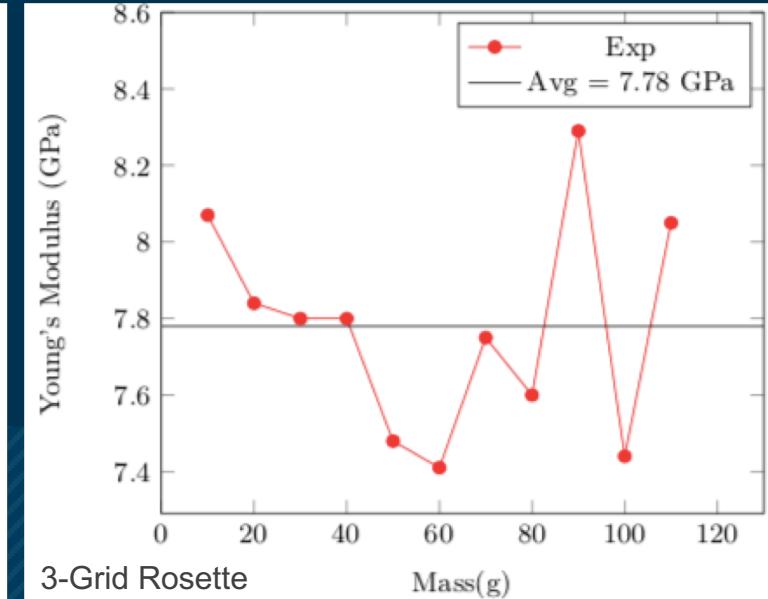
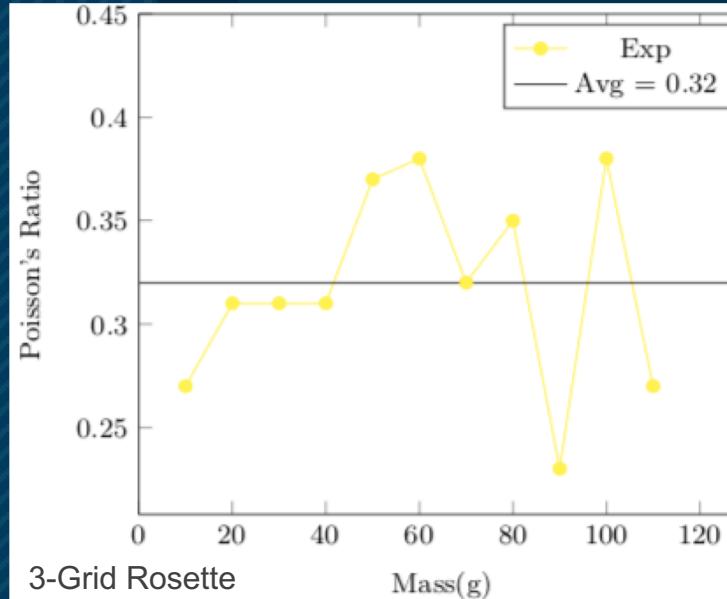
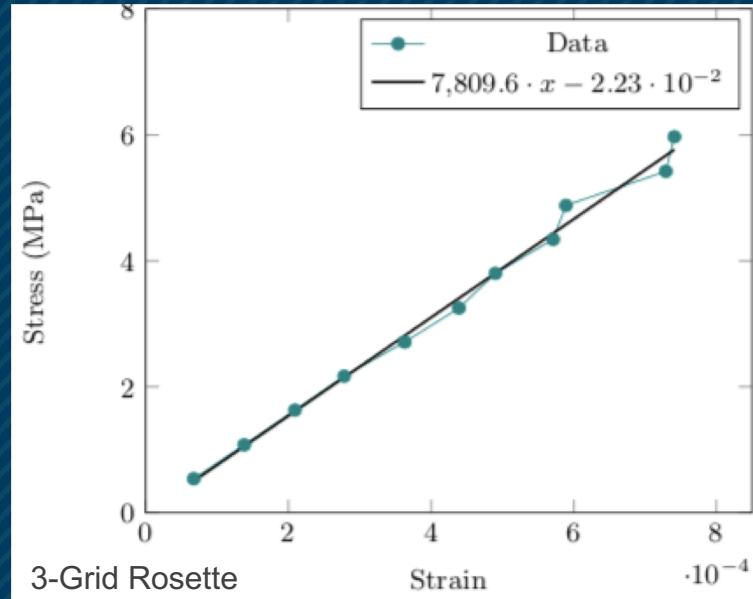
DAQ – Data  
Logger



# Mechanical Stress Results: Half Bridge

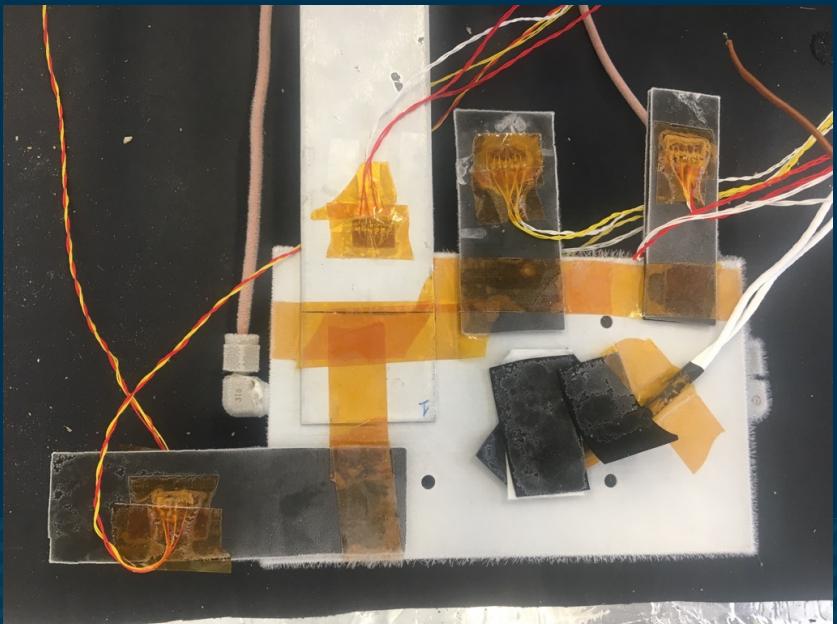
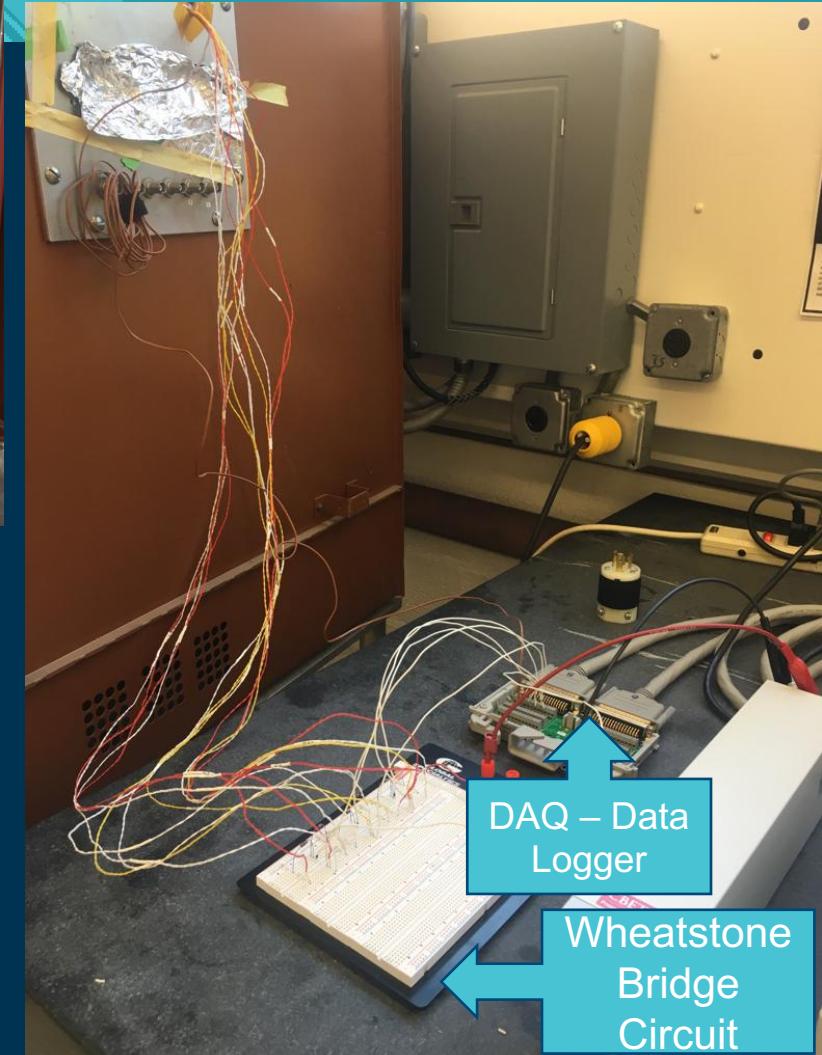
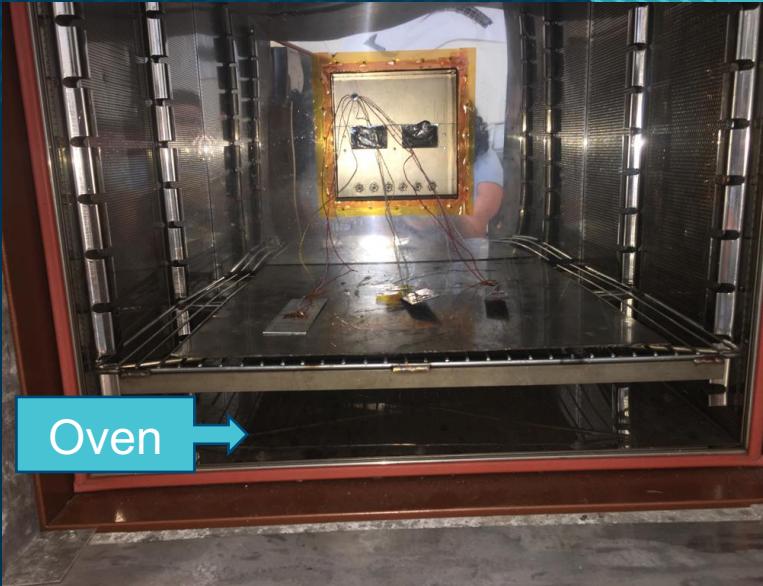
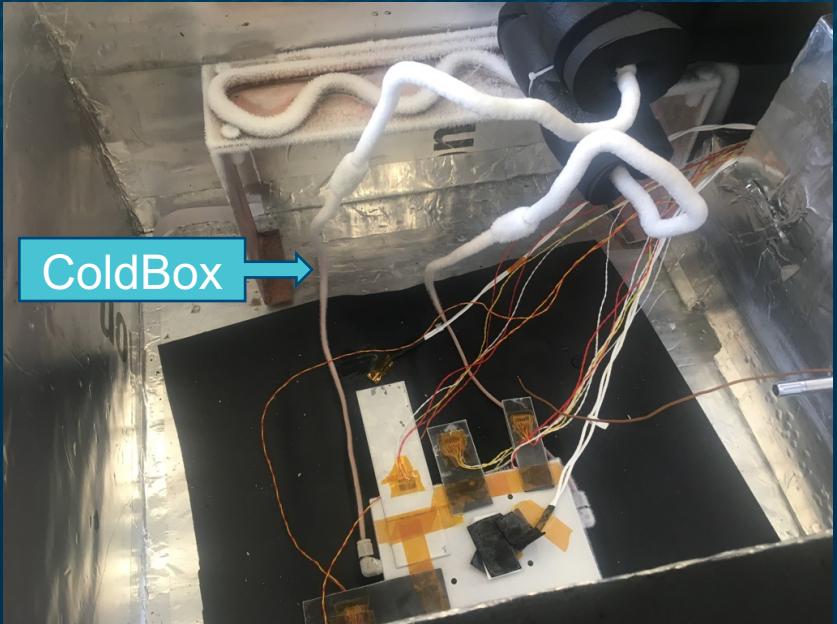


# Mechanical Stress Results: Full Bridge on Carbon Fiber



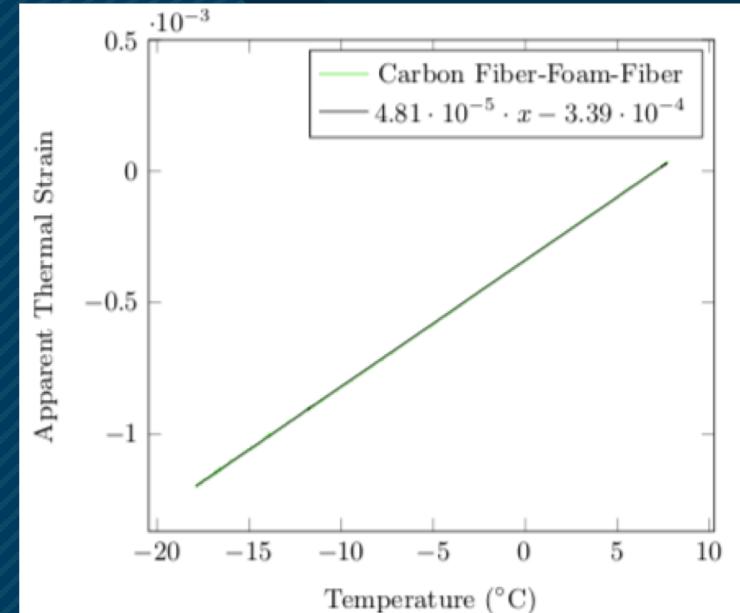
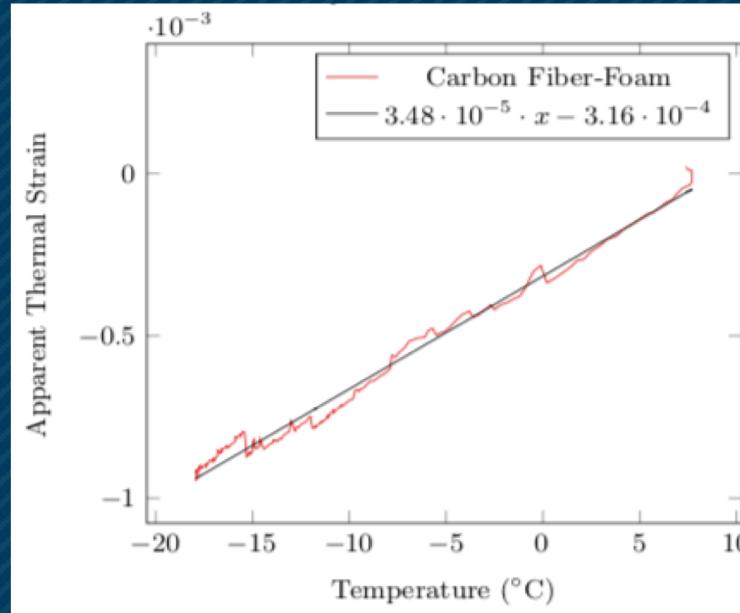
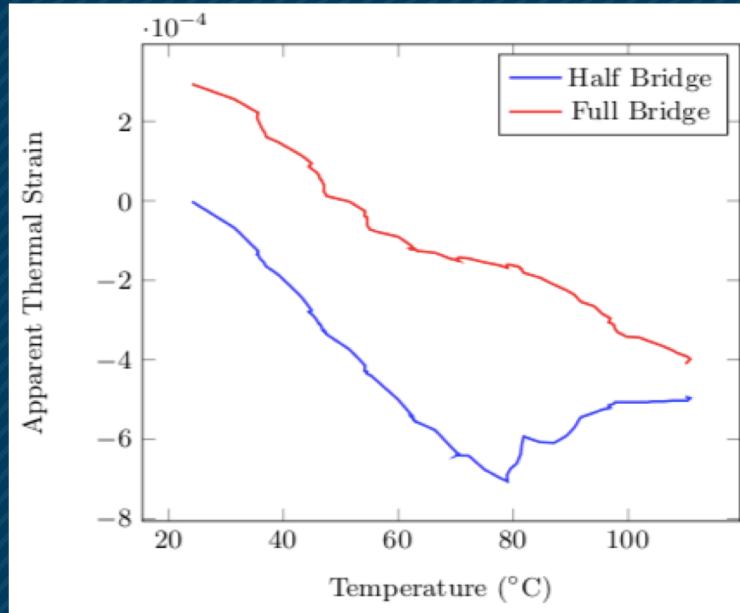
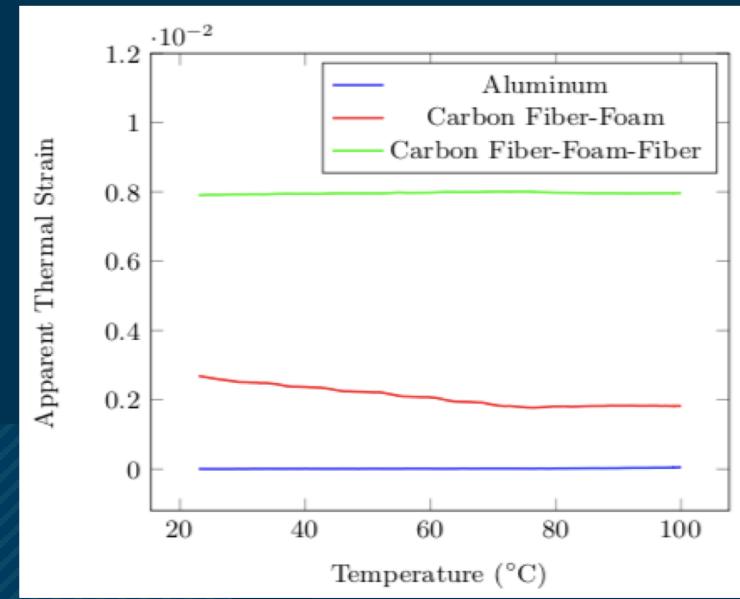
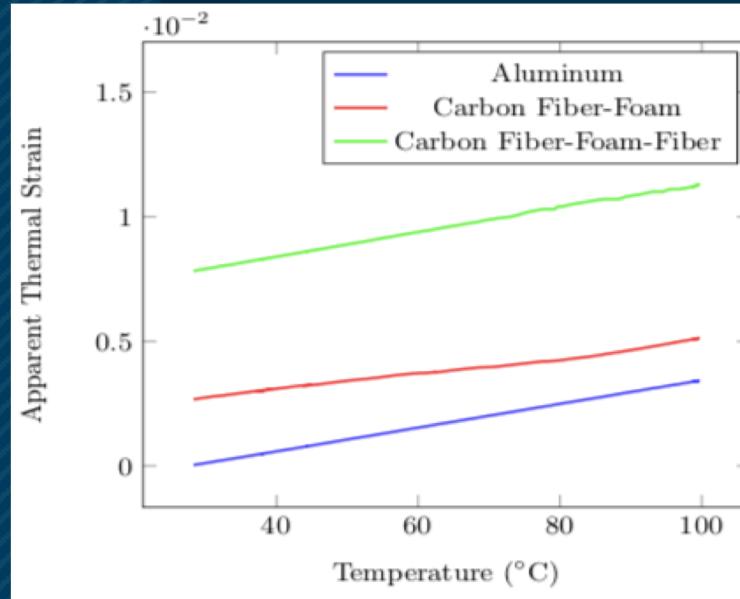
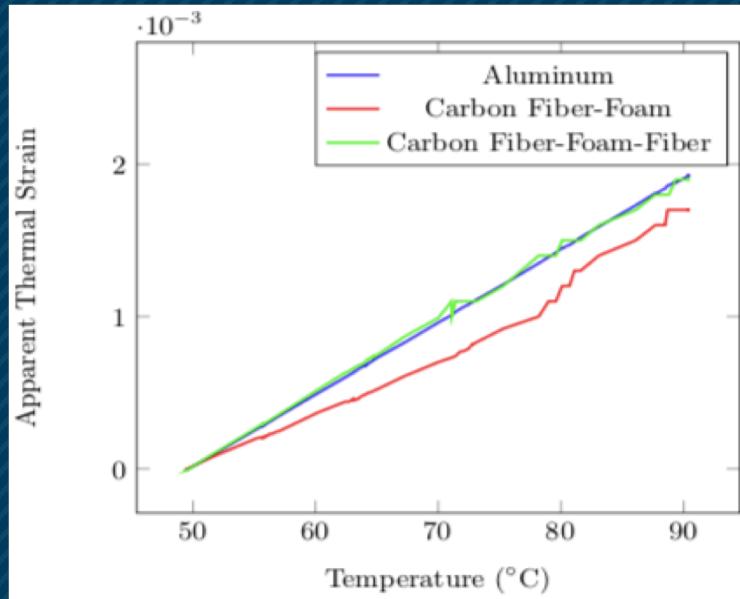
# Thermal Shock Testing

Temperature Range:  
-25 °C – 180 °C

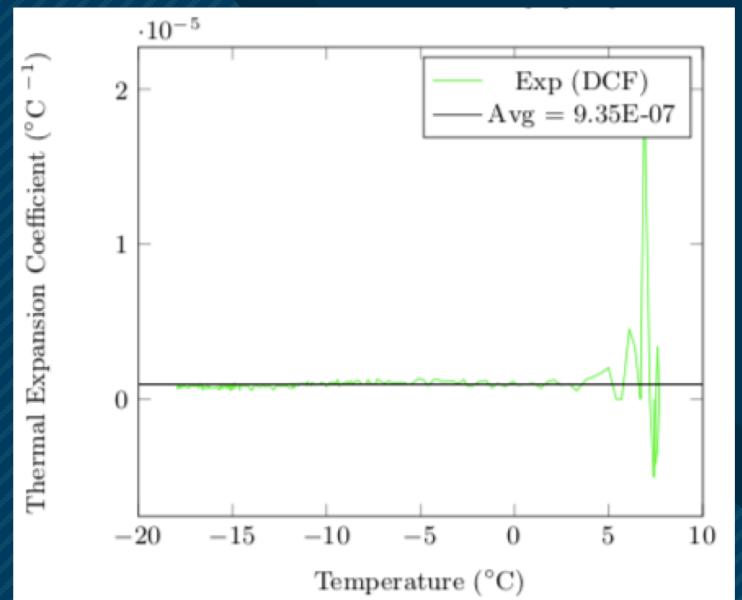
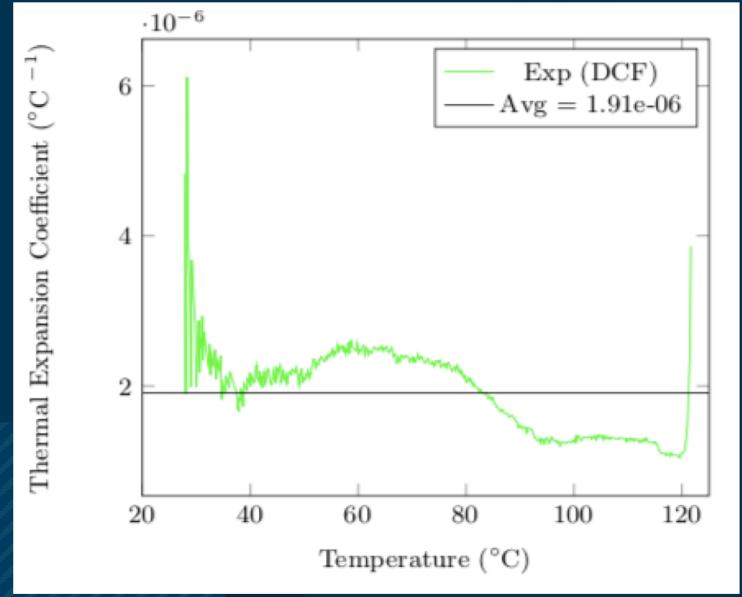
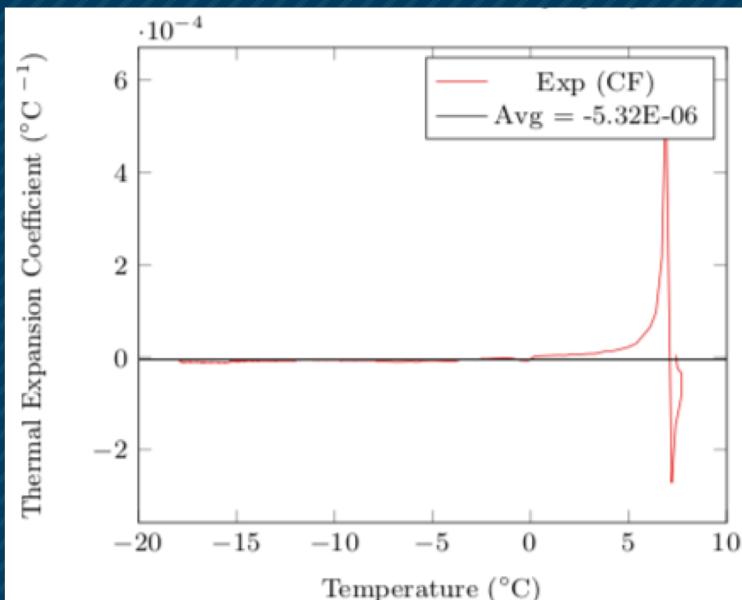
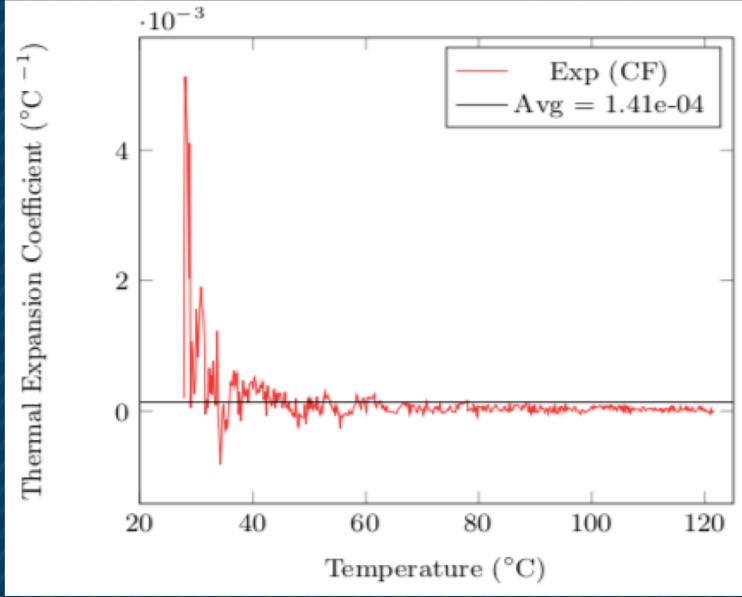
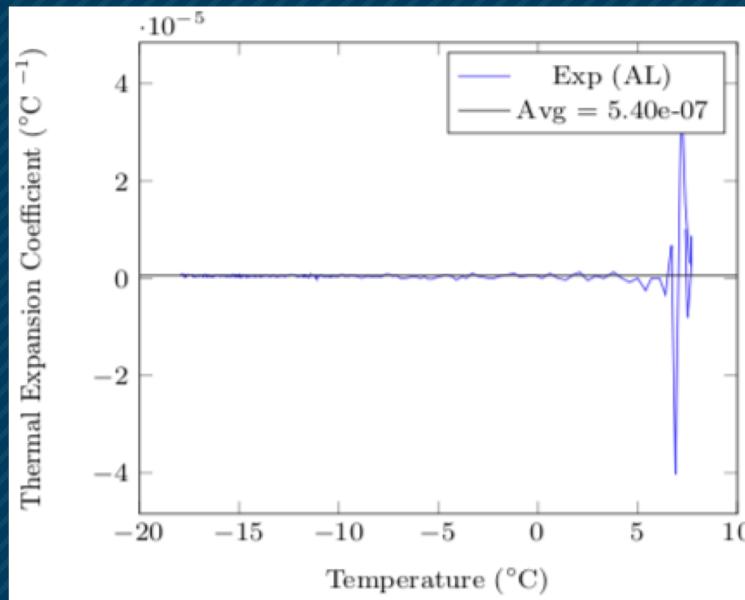
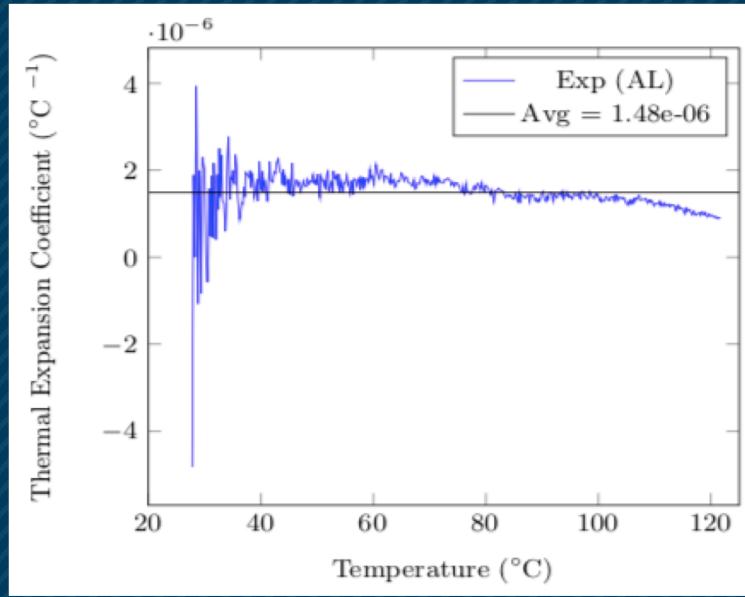


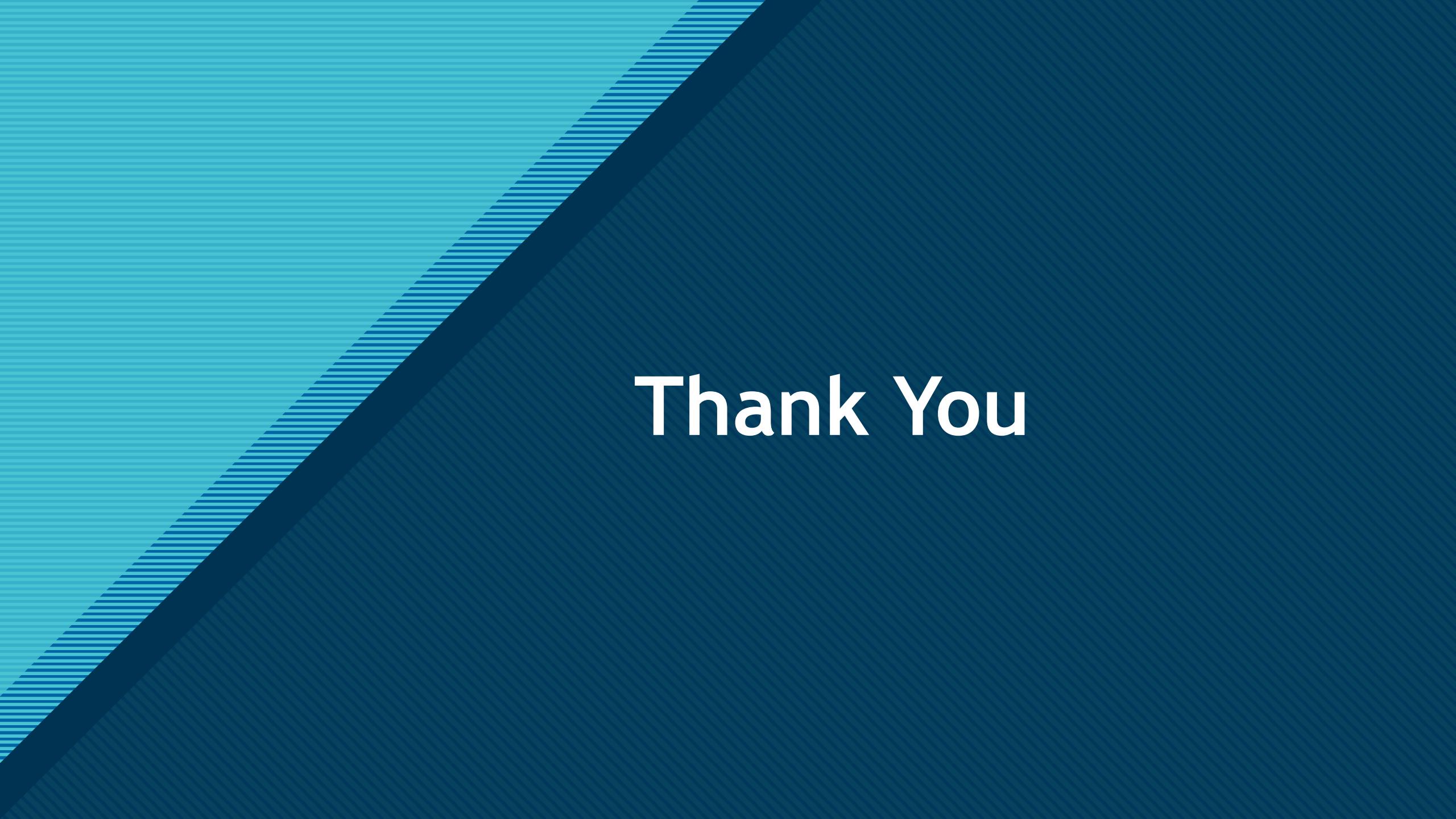
Strain Gauge

# Thermal Stress Results



# Thermal Stress Results



The background features a large, solid teal rectangle on the left and a large, solid dark blue rectangle on the right. Both rectangles have thin, light-colored diagonal stripes running across them. In the center, there is a white rectangular area where the text is placed.

Thank You