Mechanical Characterization of Hand-Layup Carbon Fiber Reinforced Epoxy Composites for Automotive Applications

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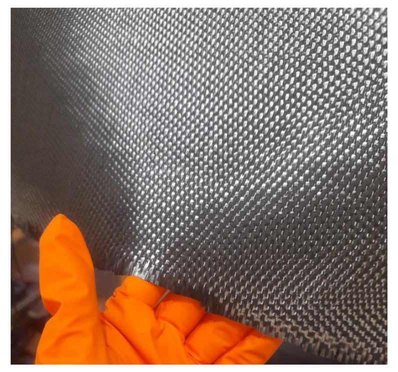
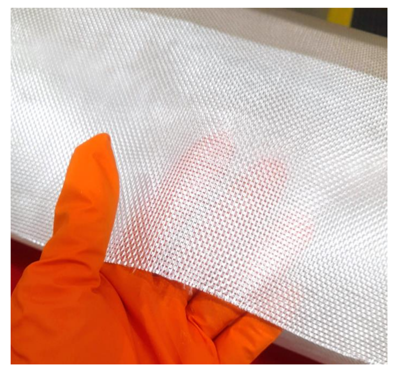
Introduction

The automotive industry is continually seeking to enhance performance, driving the demand for lightweight advanced composite materials.

Carbon fiber composites emerge as a promising solution due to their exceptional lightweight and mechanical properties. However, carbon fiber is expensive and presents a costly challenge in terms of scaling up.

This is where hybrid composites, composed of a blend of carbon fiber and glass fiber, a more cost-effective material, come into play.

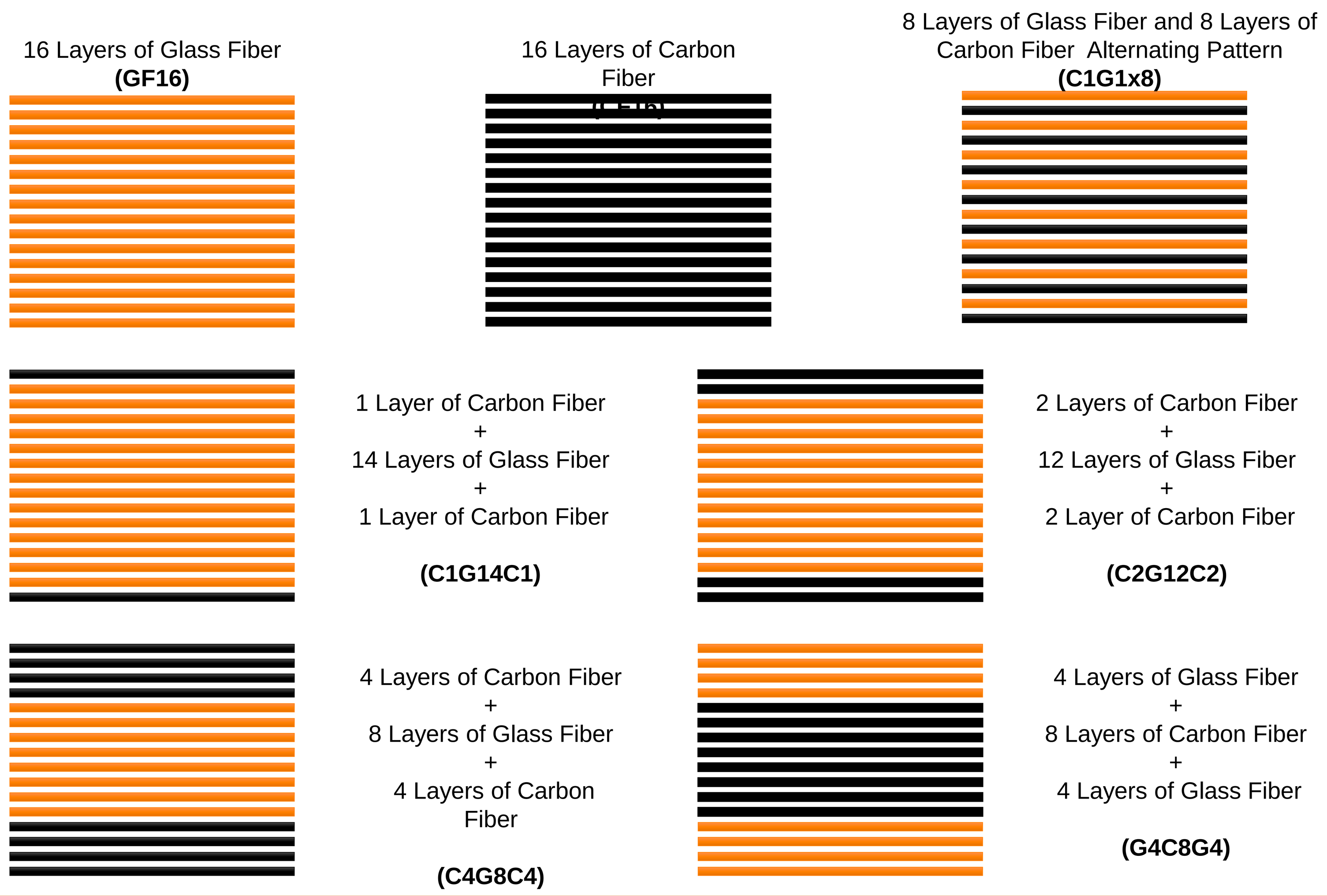

Dry Carbon Fiber


Dry Glass Fiber

Methods

Materials: E-Glass Fiber, IM7 Carbon Fiber, SC-15 Epoxy
Composite Manufacturing: Composites are prepared using the vacuum bag hand lay-up technique. Composites are cured twice or post-cured for best mechanical properties for this specific epoxy.
C-Scan: Composites are inspected for voids and defects using c-scan.
Sample Prep: Composites are cut using Extec Labcut composite cutter to ASTM standards.
Mechanical Testing: Samples are tested using Short Beam Shear Testing ASTM D2344 and Three Point Flexure Test ASTM D7264

Carbon Fiber and Glass Fiber Lay-Up Patterns



Results

Shear Strength
- Maximum stress a material can endure before experiencing shear failure

$$\tau_f = \frac{3F}{4bd}$$

Flexure Strain
- Max deformation experienced by a material subjected to bending forces

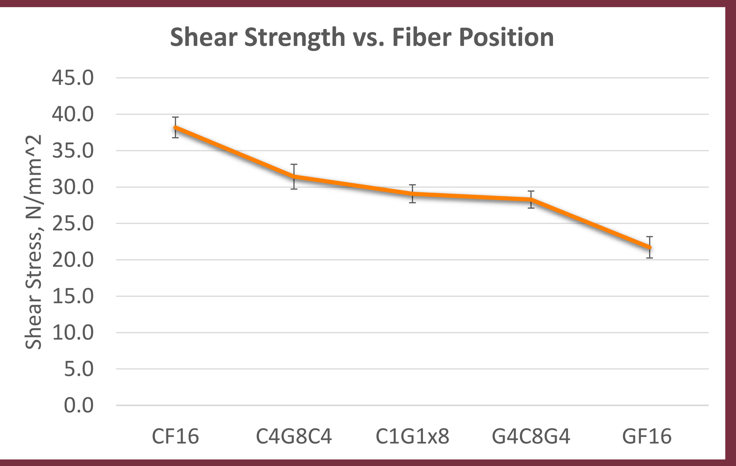
$$\epsilon_f = \frac{6Dd}{L^2}$$

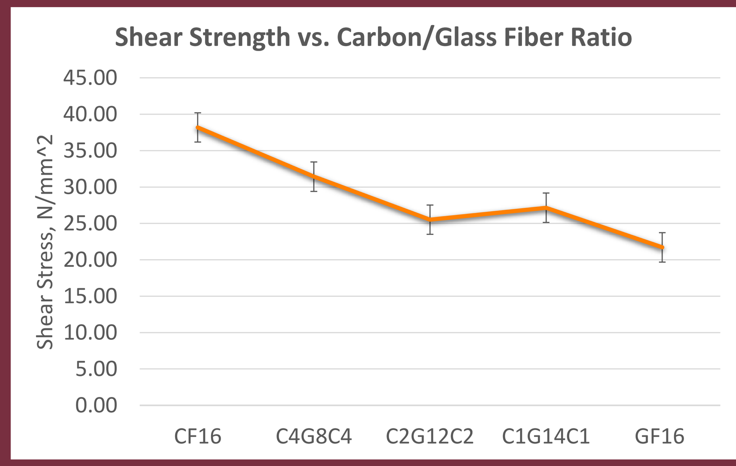
Flexure Elastic
- Material's ability to return to its original shape after being subjected to bending forces

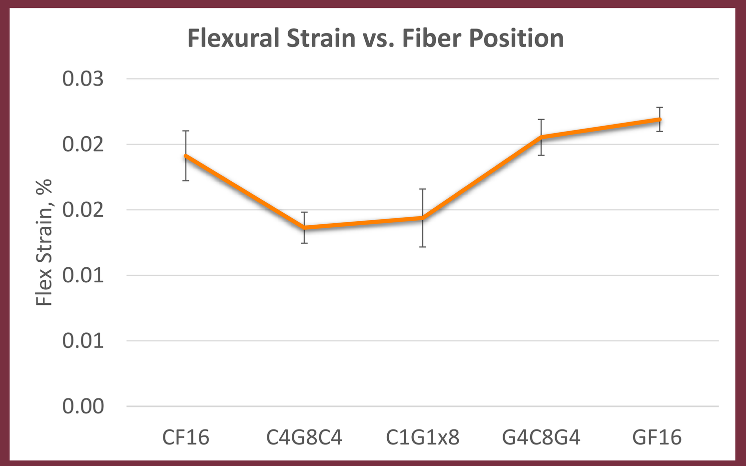
$$E_f = \frac{L^3 m}{4bd^3}$$

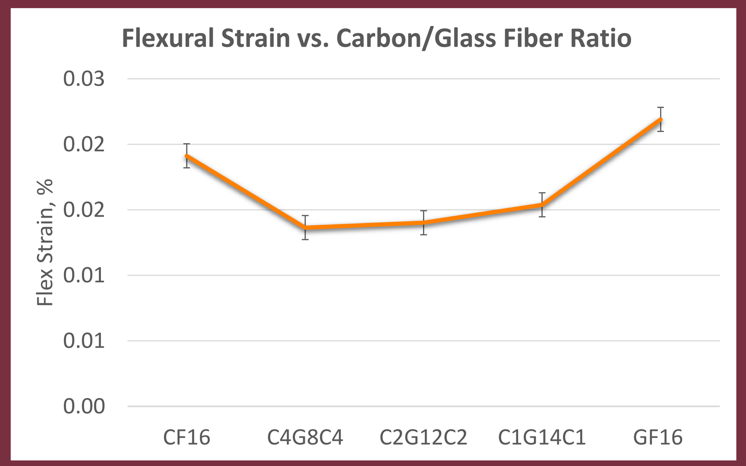
F = Max Force, (N)
D= Maximum Deflection, (mm)
m = Initial Slope of Force, (N/mm)

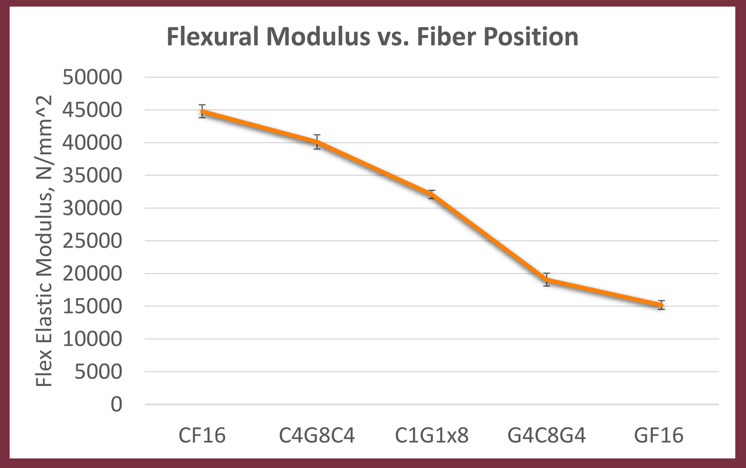
L = Support Span, (mm)
b = Width of Sample, (mm)
d = Thickness of Sample, (mm)

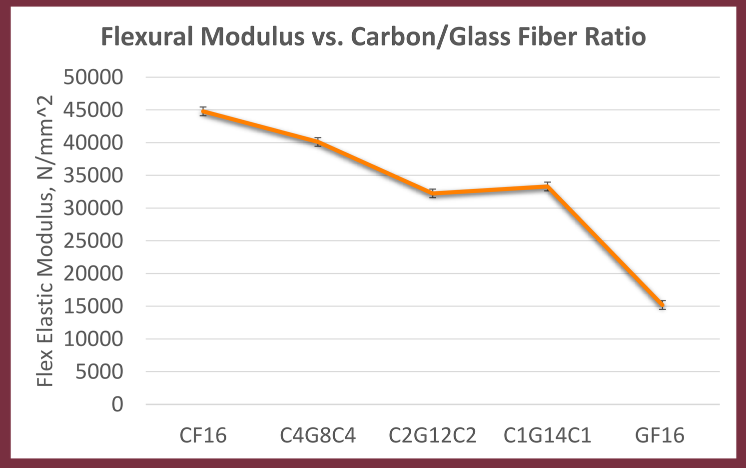








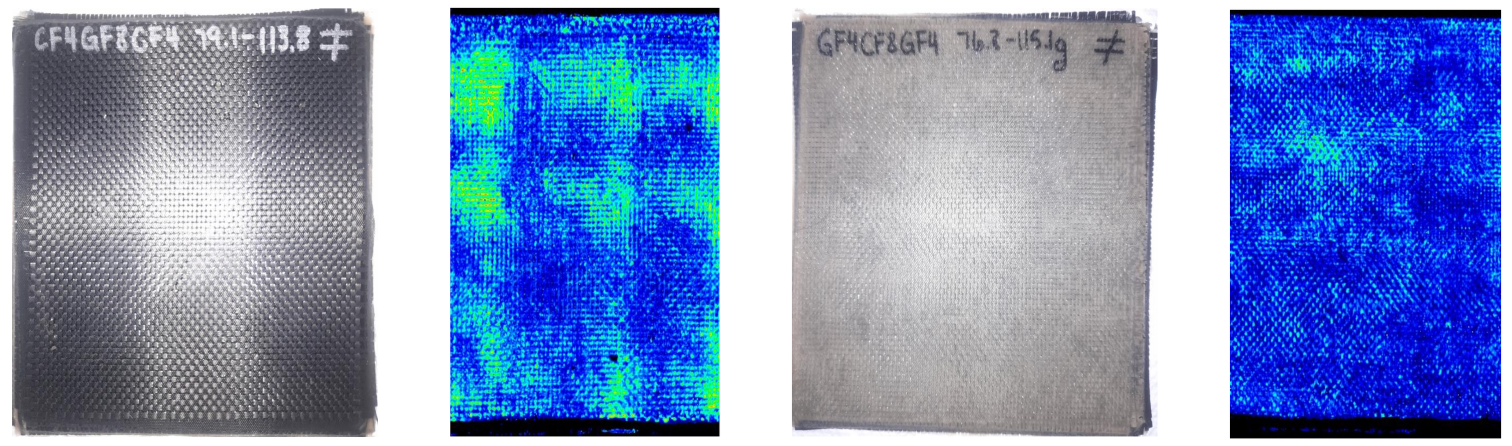




Discussion

C-scan
- An ultrasonic imaging technique used to inspect and visualize internal structures material for defects

Poor Quality Composite | **High Quality Composite**



Factors Which Impact Composite Mechanical Performance
- Quality of composite interface
- Uniformity of the composite interface will impact the variability of samples taken for testing and lead to higher margins of error
- Variations in the surface finish of composite
- Ununiform thickness of composite panel as samples are cut to size based on the average thickness of the panel
- Directionality of woven fiber layers

Conclusion & Future Work

- Hybrid composites can be tuned to enhance their properties
- Arrangement of fibers influences mechanical characteristics
- Positioning carbon fiber farthest from the neutral axis maximizes mechanical properties
- Incorporating only an outer layer of carbon composite leads to substantial property enhancements
- Additional research is required to comprehensively characterize properties across various orientations

Reference

[1] Bergant, Z., Janez, J., & Grum, J. (2018). Ultrasonic C-Scan Testing of Epoxy/glass Fiber Composite. 14th International Conference of the Slovenian Society for Non-Destructive Testing, Sep 4-6, 2017, Bernardin, Slovenia. https://www.ndt.net/?id=22547
[2] Nayak, Suhas & Heckadka, Srinivas & Rao, Sathish & Narang, Karan & Kirti, Vardhan & Pant,. (2015). Mechanical Properties of Multi Layer Plain Weave and 3-D Glass Fabric Epoxy Composites. International Journal of Composite Materials. 2015. 30-36. 10.5923/j.cmaterials.20150502.02.

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