Woven Carbon Nanotube Yarn for Aerospace Use

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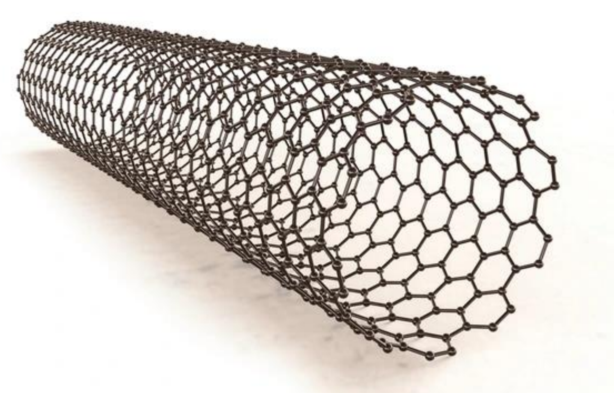
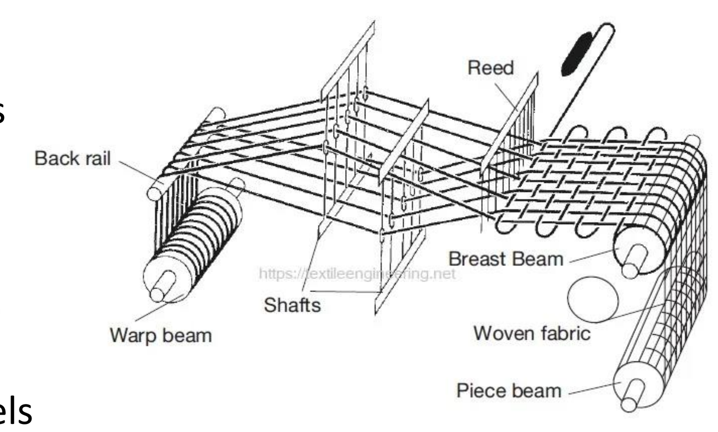
Intro

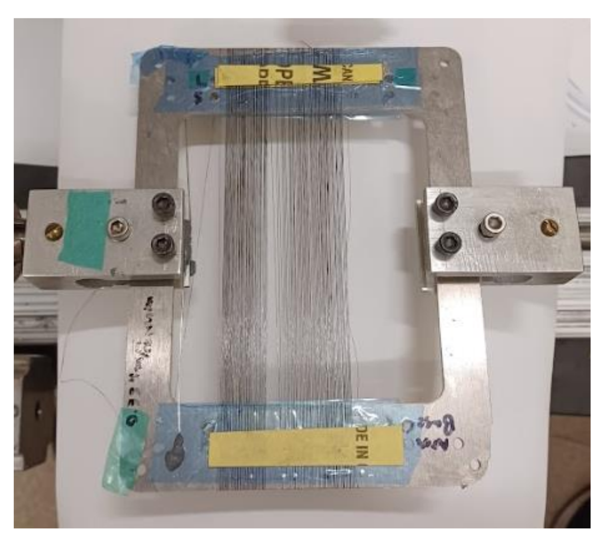
- NASA is investigating Carbon Nanotube Yarns (CNTy's) to replace state-of-the-art carbon fiber in aerospace structures.
- CNTy's are made from Carbon Nanotubes, helical carbon molecules twined into yarn.
- Typical panels are only strong in one direction, the CNTy direction. A woven panel would have strength in two directions
- Each ply was woven in a prototyped vertical loom. A loom works by having two vertical layers of yarn (warp) interlacing as a yarn (weft) is passed through.
- CNTy is ideal for heddle stringers because their graphitic character reduces friction.
- Woven panels are placed under pressure, densifying them, to reduce voids.
- Laminates are multiple panels cured in Resin together. Typically, panels are put in different directions so the laminate has strength in multiple directions.
- Tensile testing applies a pulling force on a specimen to measure the relationship between Stress (Force divided by Area) and Strain (percent elongation)



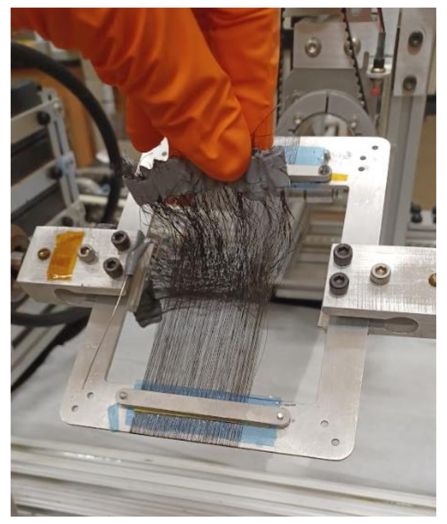


Methods

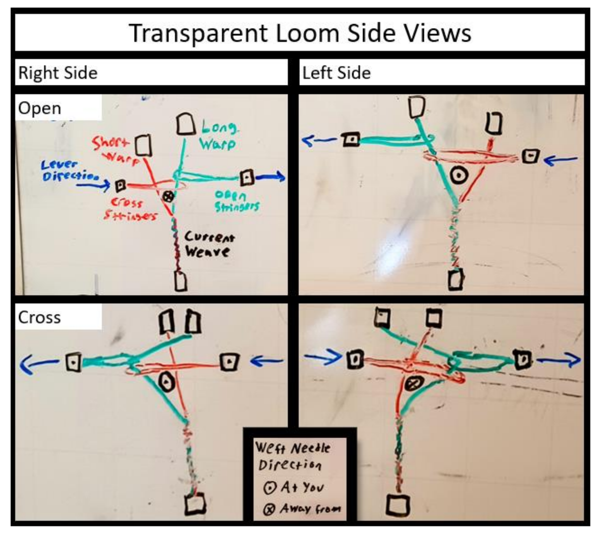
- Heddles were made by winding CNTy on warp plate
- Glued down and cut on edges for consistent length



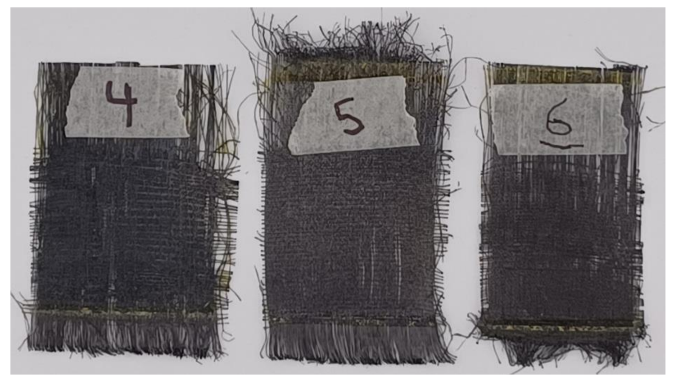
- CNTy is wound on Warp plate with a pause every 180° for Heddle attachment
- Heddle attachment through plate hole during warp assembly tripled production rate
- Without the plate hole, singular heddle attachments were done on the loom



- The CNTy weft was passed through the alternating warp layers, thus looming a panel.
- The layers are referred to as "short" and "long"



- The weaved panel is framed and cut from the loom
- The weave panel is densified at 5000 lbs and prepregged with BMI
- Three weaved panels are pressed and cured to make one laminate.
- Eight cuts were made for multiple trials



Questions/Goals

Find the tensile properties of a woven CNTy laminate.
How does it compare to current CNTy laminates?
How should woven CNTy laminates be manufactured?
Iteratively design a manufacturing process.

Expectations

The woven laminate will have significantly lower tensile properties than current laminates.

Future work

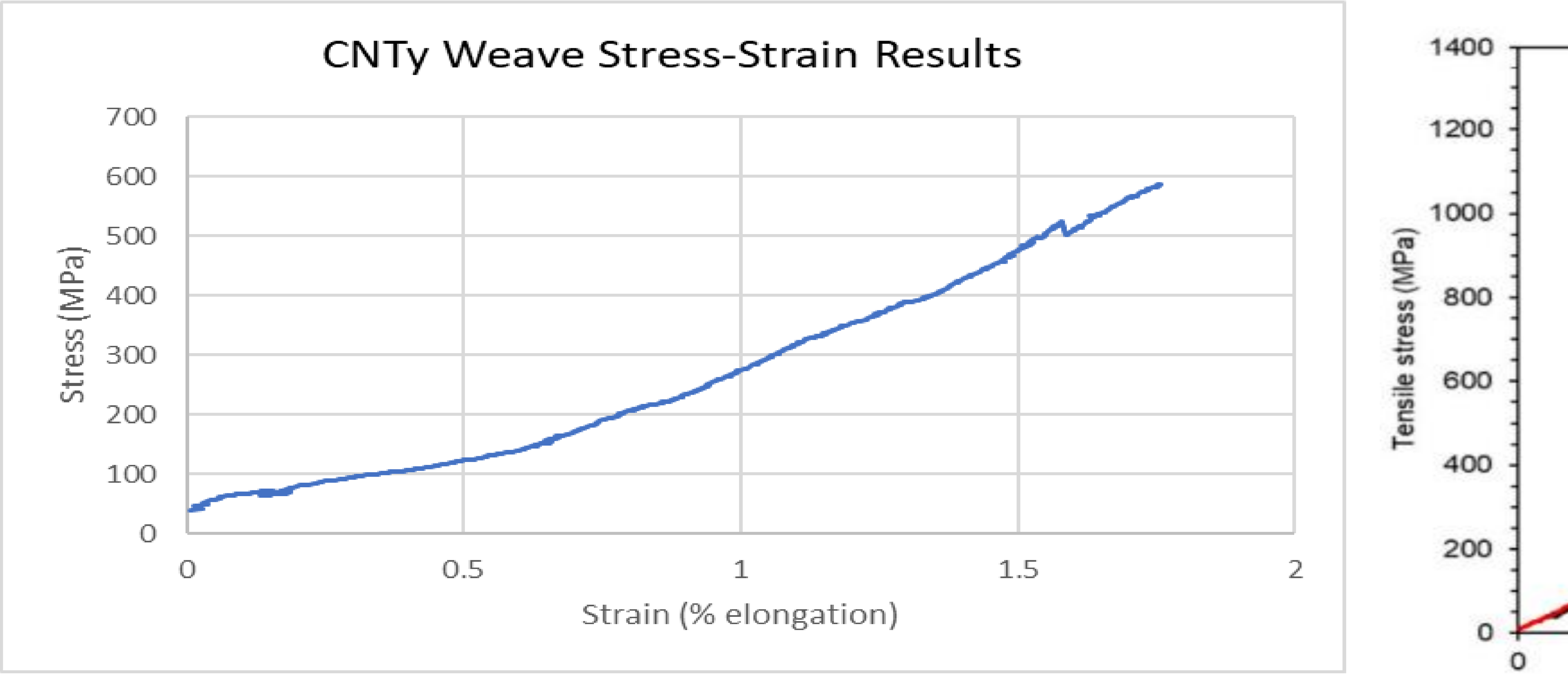
Create a Graphitized Sample; reduce voids and bond the carbon to each other.

Perform the following tests:
SEM - Scanning Electron Microscopy
µCT - Micro-Computed Tomography
TGA - Thermogravimetric Analysis
LFA - Laser Flash Analysis

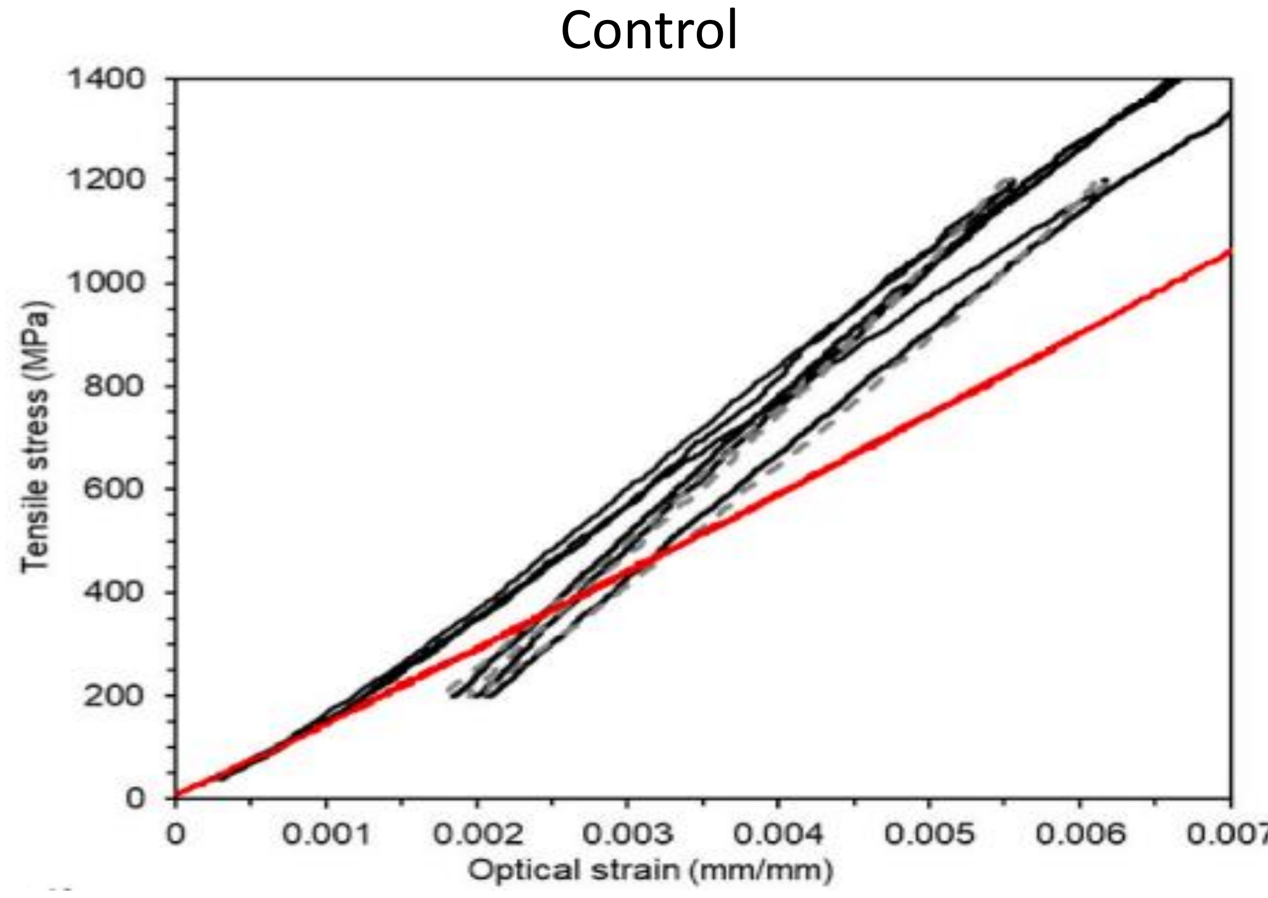
Investigate electrical conductivity potential for diffusing lighting on aircraft.

Explore improvements to manufacturing and alignment with mechanization of looming and warp assembly

Results & Discussion



Control



The Modulus of Elasticity on the woven laminate is 343 MPa; The control Modulus of elasticity is 150000MPa, or, 150GPa.
The Modulus of Elasticity of the control is 437 times greater than that of the woven laminate.
The woven laminate is far more ductile, stretching 2 % in length where the control breaks at 0.007 % elongation.
The woven laminate has a toughness of 1050 J/m^3 where the control laminate has a toughness of 10 J/m^3.

Conclusion

An efficient method for creating woven CNTy laminates was created using human labor, a loom and a filament winder. Initial sample tests showed poor results, as expected with limited precision available in manufacturing.

Acknowledgments

textile-engineering. (2024, October 25). Basic Principles of Weaving Loom - Textile Engineering. Textile Engineering. https://textileengineering.net/basic-principles-of-weaving-loom/

Vondrasek, B., Evers, C., Jolowsky, C., Odegard, G. M., Liang, Z., & Czabaj, M. (2024). Characterization of multidirectional carbon-nanotube-yarn/bismaleimide laminates under tensile loading. Composites Part B: Engineering, 280, 111465. https://doi.org/10.1016/j.compositesb.2024.111465