Polymer Composite Material Testing for a Cryotank Application

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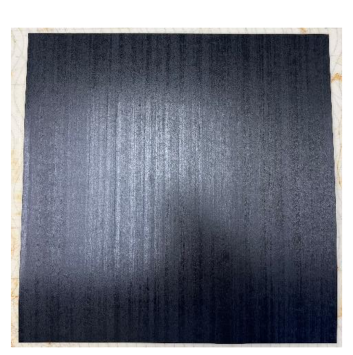
Background and Objective

- **Problem:** To develop more fuel-efficient and lower carbon emission Advanced Air Mobility (AAM) technologies, challenges must be overcome to store and operate alternative fuels at cryogenic temperatures
- Liquid hydrogen (LH2, 20 K) has a higher energy density and fewer carbon-based emissions than jet fuel [1], and liquid natural gas (LNG, 111 K) has an abundant domestic source with established supply chain [2]
- **Objective:** Investigate carbon fiber reinforced polymer (CFRP) composite materials for their mechanical performance and viability at cryogenic temperatures to inform modeling, design, and manufacturing efforts
- **Solution:** Leverage CFRP composites to develop an all-composite cryotank to increase efficiency of aircraft
- Minimize microcracking and establish a public database

Methods and Materials

Material Screening:

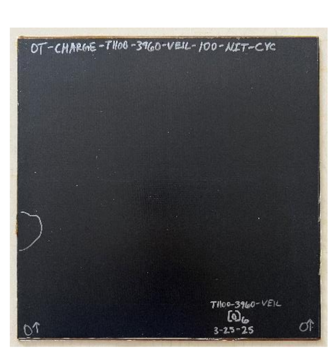
- T1100/TC1225 (LM-PAEK) thermoplastic (TP) composite
- T1100/3960 thermoset (TS) composite
- T1100/3960/TPU Veil Hybrid (TS/Veil) composite
- Determine effect of thermal cycling on mechanical properties
- Liquid Nitrogen (LN2, -196C/ 77K) was used to thermally cycle coupons due to project cost and time constraints



One ply T1100/3960 prepreg.

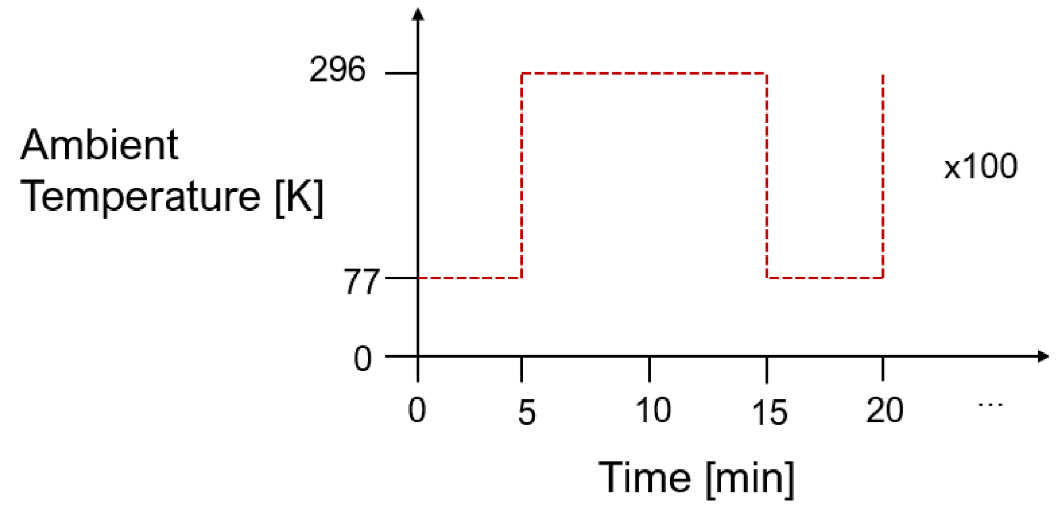
TPU veil in between each ply.

Repeat x15



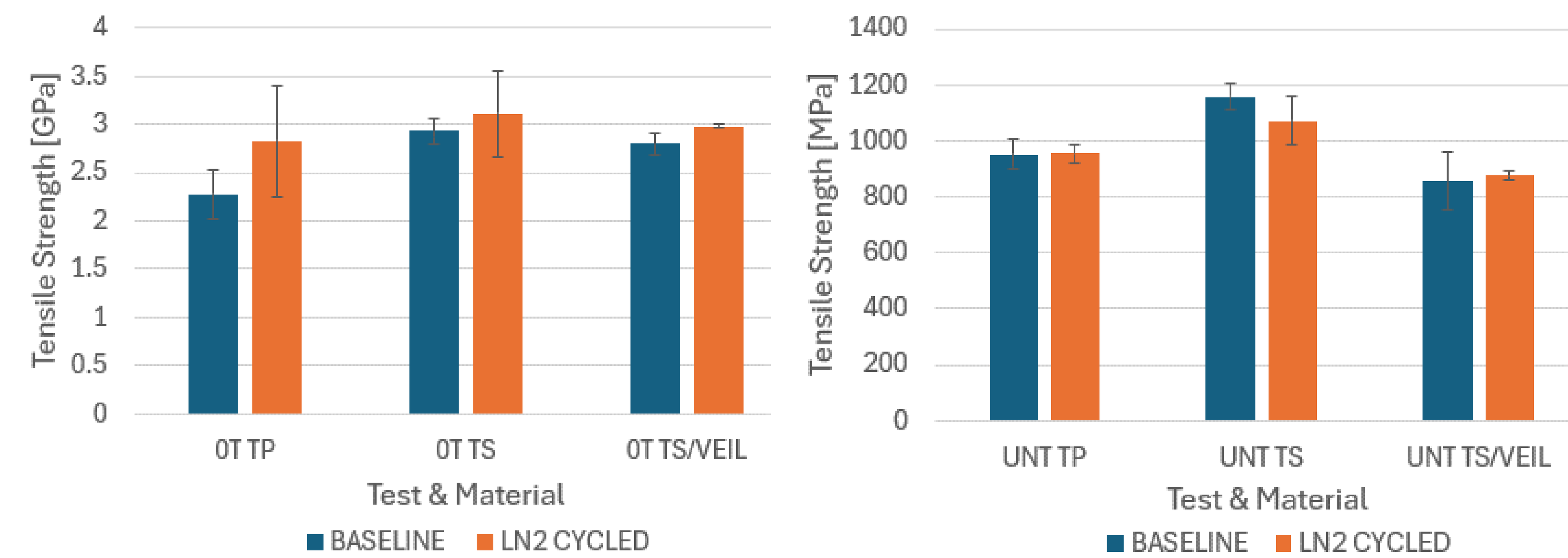
Hybrid TS/TPU veil composite.

Cryogenic Thermal Cycling in LN2:

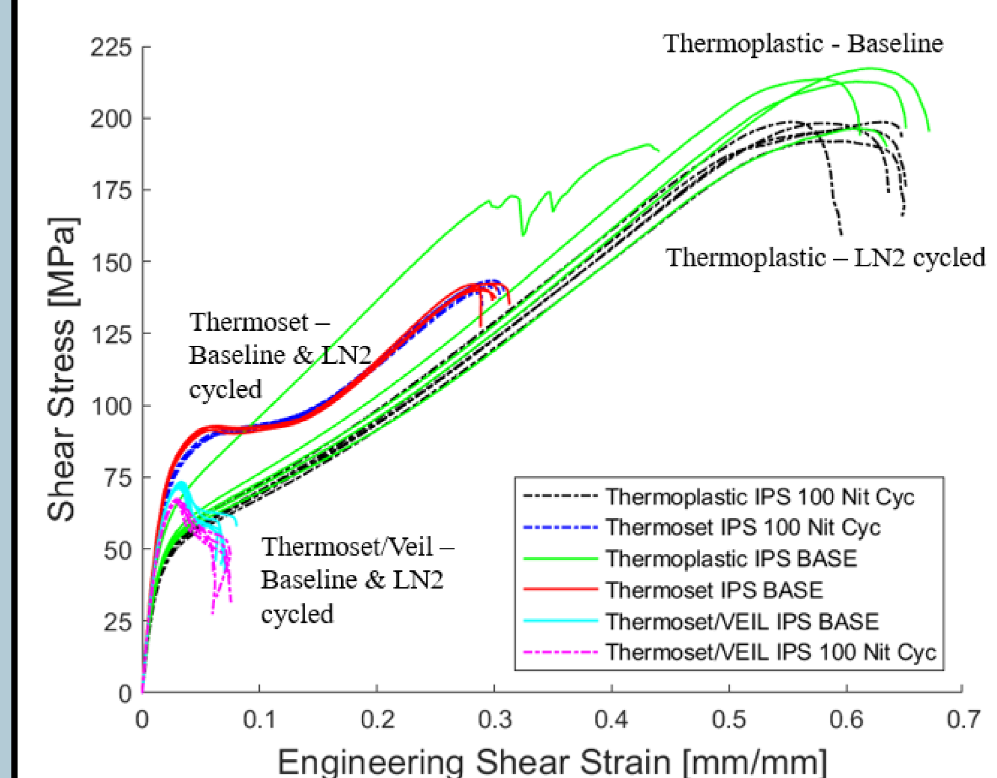


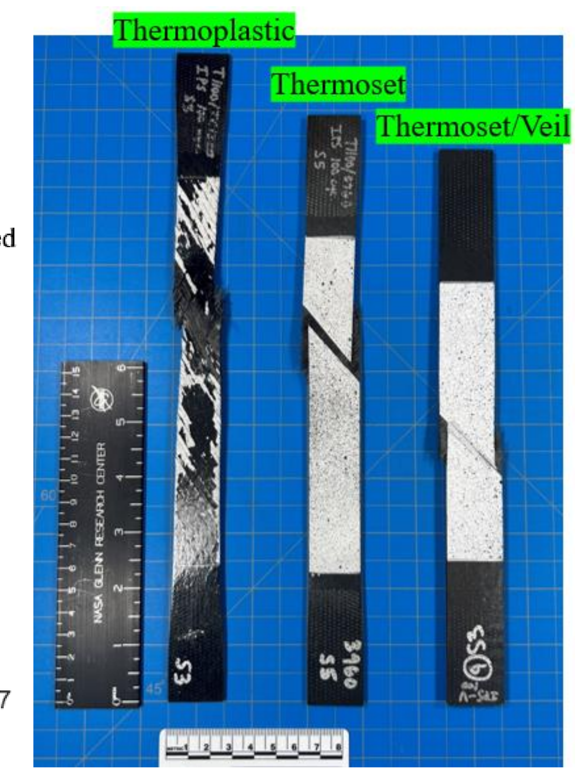
Current Progress

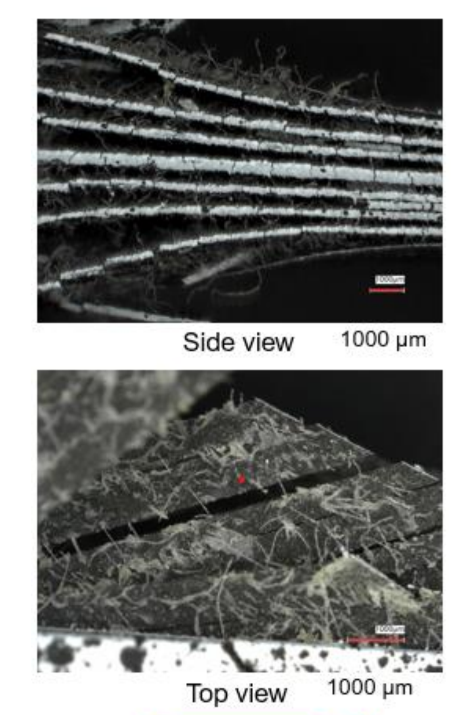
Tension:



In-Plane Shear:



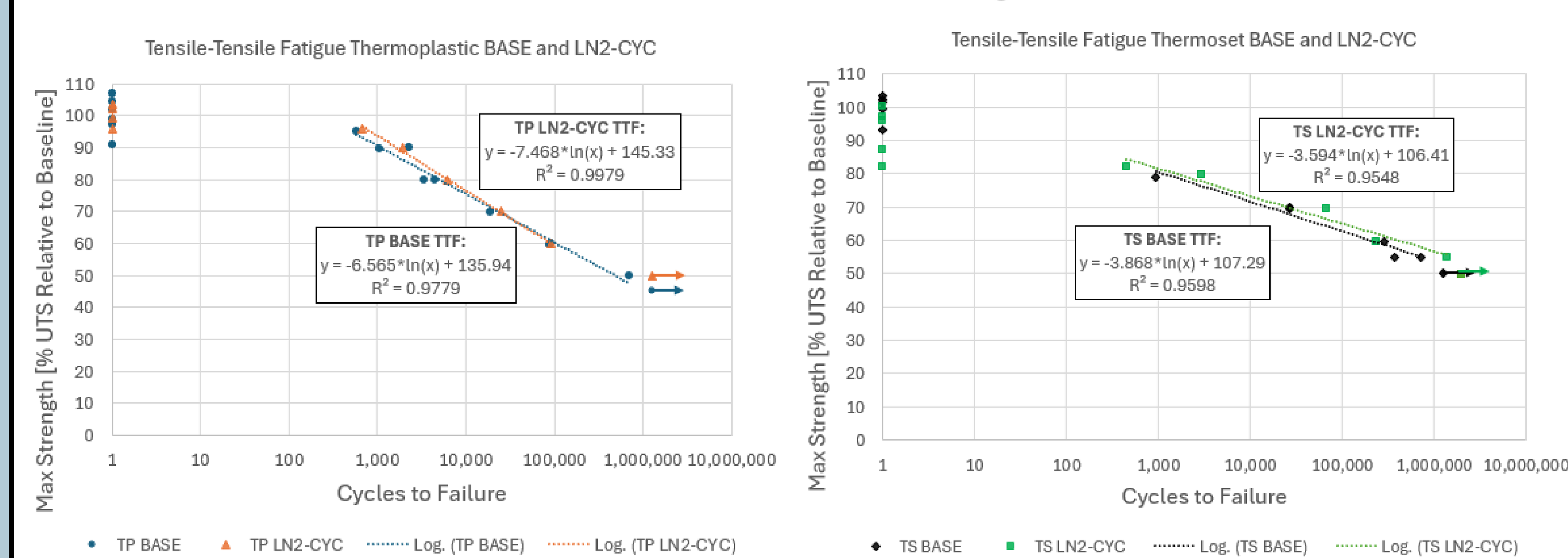




Thermoset/Veil

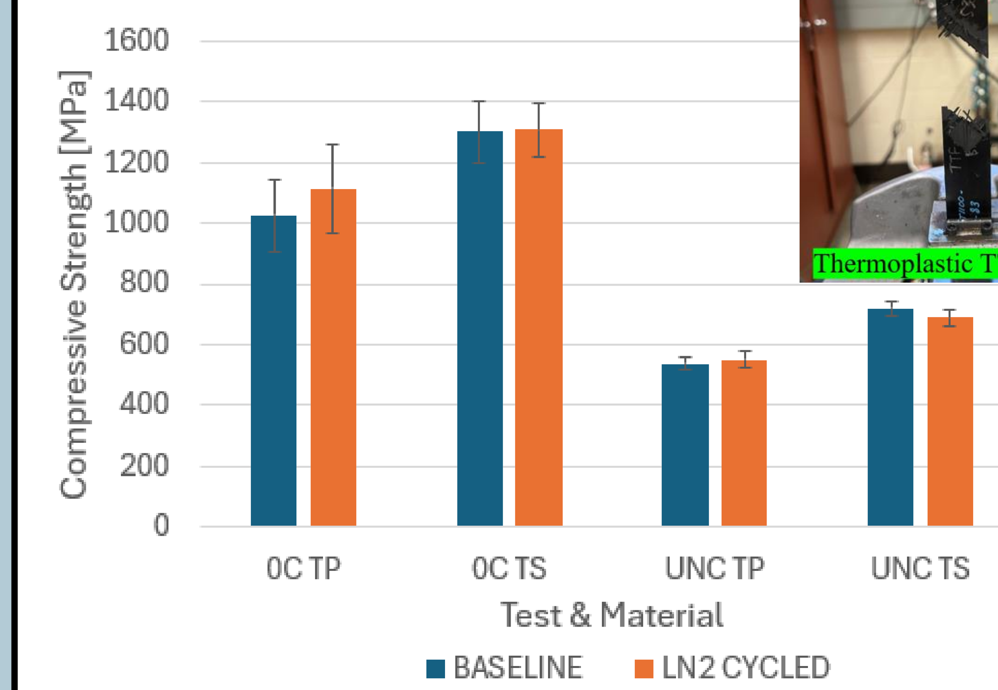
- Poor TS/Veil hybrid composite IPS performance

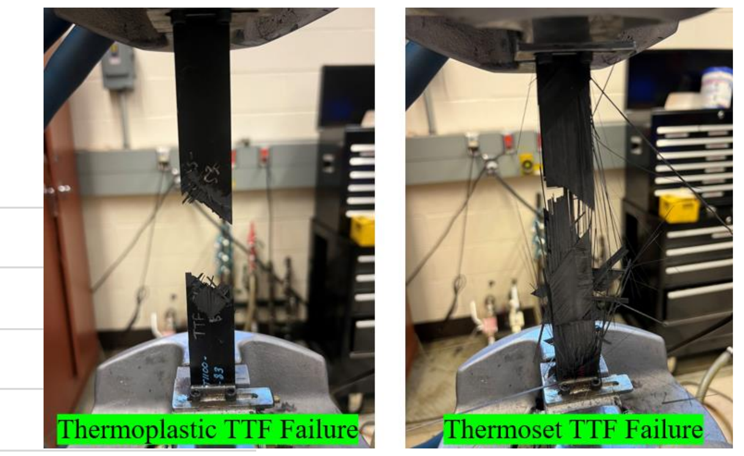
Tension-Tension Fatigue:



- Frequency = 5 Hz, Load ratio = 0.1

Compression:

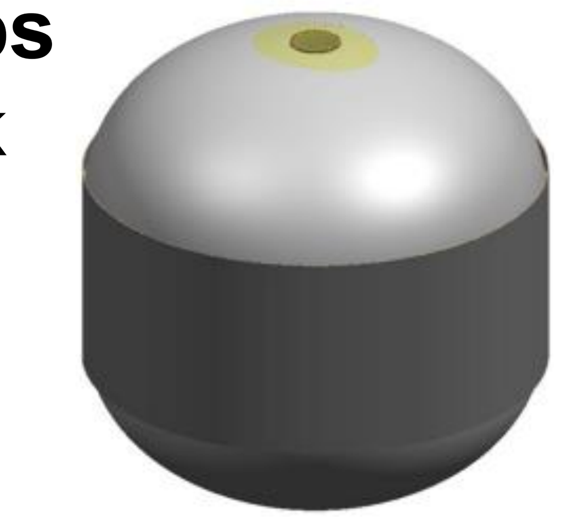




- Failed fatigue coupons

Next Steps

- Mechanically test the LM-PAEK and 3960 composites at 20 K and 111 K
- Toughness, tension, and thermal expansion
- Build a database of TP and TS material properties at cryogenic temperatures
- Manufacture sub-scale cryotank



Composite cryotank reference design [3]

Benefit to NASA

- Inform modeling, design, and material selection for cryotank development in future aerospace work
- Public database allows NASA and private sector to have a starting point for next-gen fuel storage R&D
- Investigate the manufacturing technology for both TS and TP cryotanks and understand areas of improvement
- Lays the groundwork for increased fuel efficiency and lower carbon emission AAM vehicles

References

1. Diaconu, T. M., "Integration and design of cryogenic hydrogen fuel systems for sustainable commercial aviation." *INCAS Bulletin*, *16*(4), (2024), pp. 11-27.
2. Roberts, R. A., Nuzum, S. R., & Wolff, M. (2015). Liquefied natural gas as the next aviation fuel. In *13th International Energy Conversion Engineering Conference* (p. 4247).
3. McCarville, D. A., Guzman, J. C., Jackson, J. R., & Birkland, J. O. (2017). Design, manufacture and test of cryotank components. *Comprehensive composite materials II*, *3*(M17-6280).

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