Bio-Based Resin Composite Material Testing

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BACKGROUND

Polyfurfuryl-alcohol resin (PFA) is a promising *more* sustainable alternative to the **petroleum derived resins** used in the aerospace industry for **interior cabin** composites.

PFA is sourced from sugarcane by-processing waste products!

MOTIVATION: Materials not fully characterized due to vast variety of different conditions of preparation and this being a relatively new bio-based alternative.

OBJECTIVE: Characterize the *mechanical*, *thermal*, *compositional*, and *chemical* properties using industry standards for prepreg materials provided by the sponsoring company:

- **Company 1:** PFA & fiberglass reinforcement
- **Company 2:** PFA & fiberglass reinforcement
- **Company 2:** PFA & recycled carbon fiber reinforcement (rCF)

METHODS

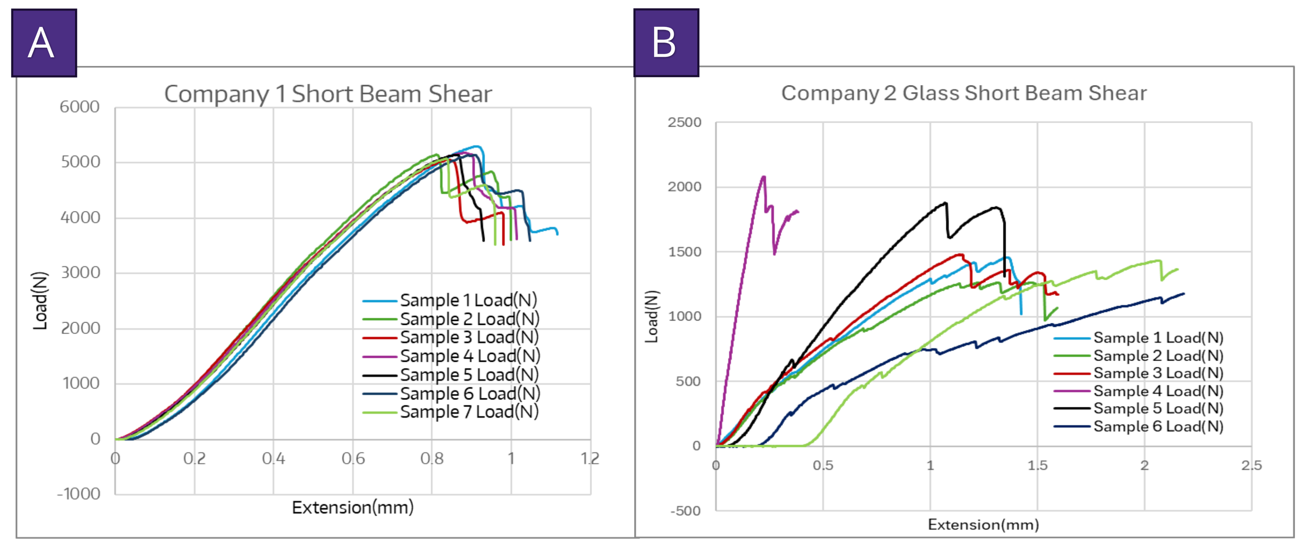
Mechanical	Short beam strength via ASTM D2344, Tensile via ASTM D3039
Thermal	modulated Differential scanning calorimetry (mDSC), thermogravimetric analysis (TGA), Dynamic Mechanical Analysis (DMA)
Compositional	Fourier transform infrared spectroscopy (FTIR) via ASTM E168
Chemical Degradation	Seven-day immersion exposure to consumables (OJ with Coke mixture) and acetone via 20 g of liquid for each sample in sealed container

Curing Technique: HOT PRESS

RESULTS

Mechanical

Short Beam Shear



C $$F^{Abs} = .75 * \frac{P_m}{b * h}$$

Figure 1. Short beam shear graphs for Company 1 (A) and Company 2 (B) PFA/Glass samples. (A) yielded an average shear strength of 41.8 MPa (B) yielded an average of 11.9 MPa. (C) is the equation used to determine the shear strength.

Tensile Testing

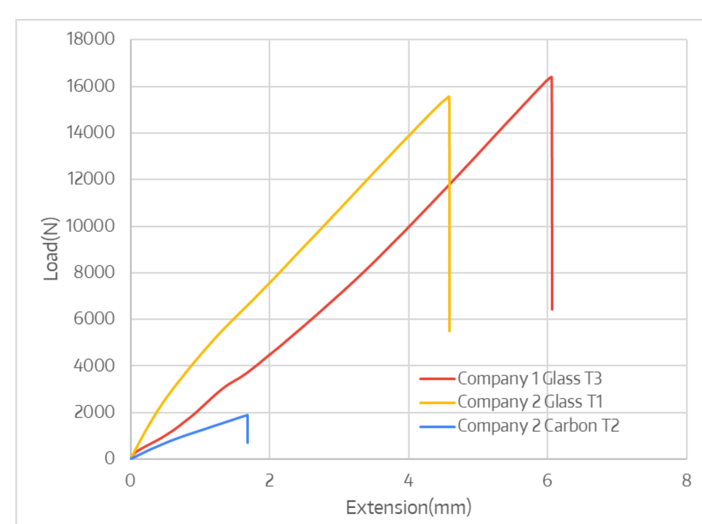


Figure 2. Tensile graphs of the three best tensile samples of each material. Average load of each material were as follows: (A) 15.8 kN, (B) 16.0 kN, (C) 1.81 kN. ASTM D3039 was used with rectangular samples to determine the maximum tensile load before fracture.

Thermal

mDSC

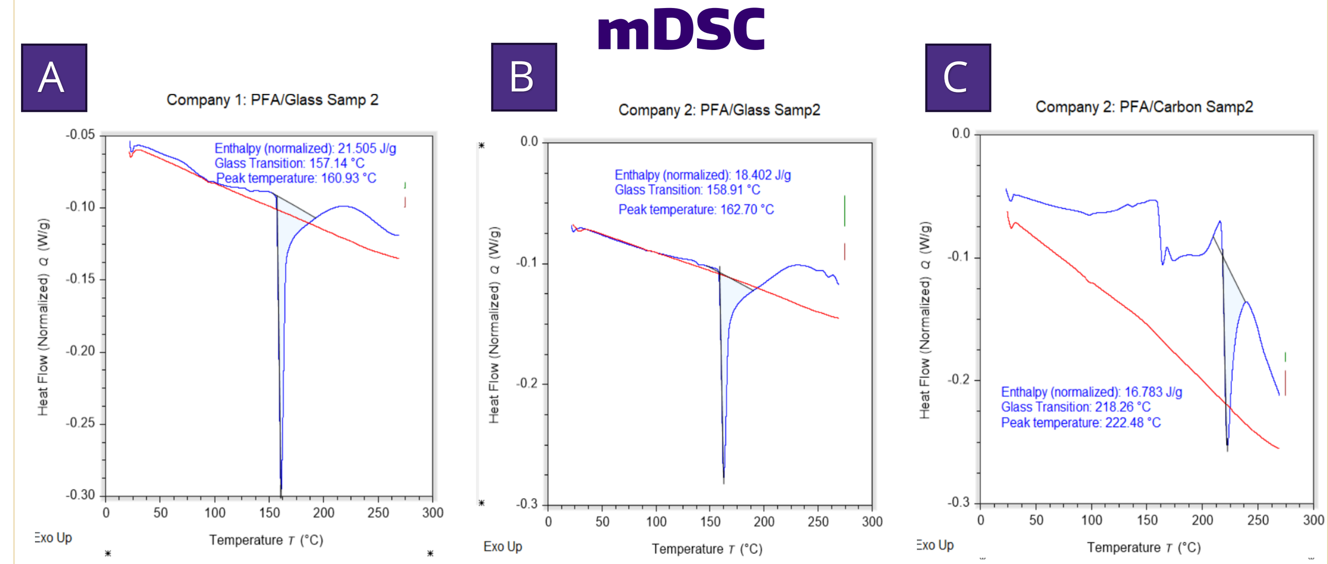
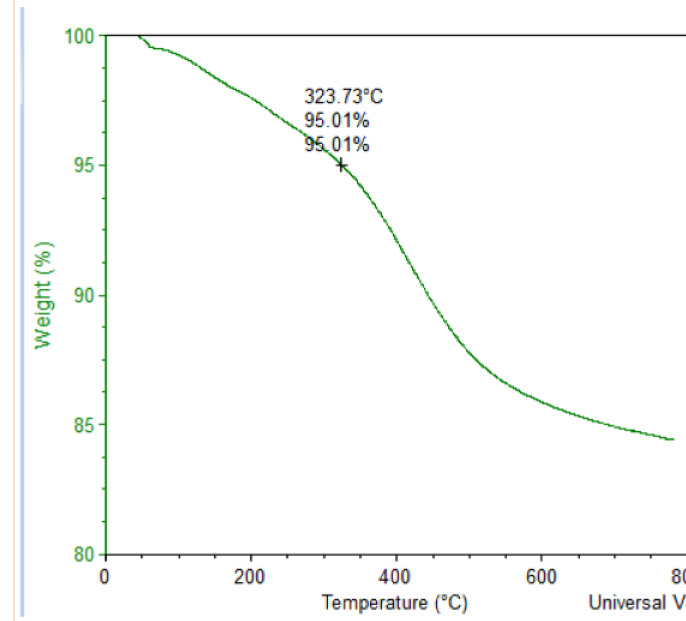


Figure 3. mDSC graphs of each material used to determine the glass transition temperatures (Tg) of cured samples. Determined as follows over average of 5 trials: (A) 166 C, (B) 180C, (C) 205 C.

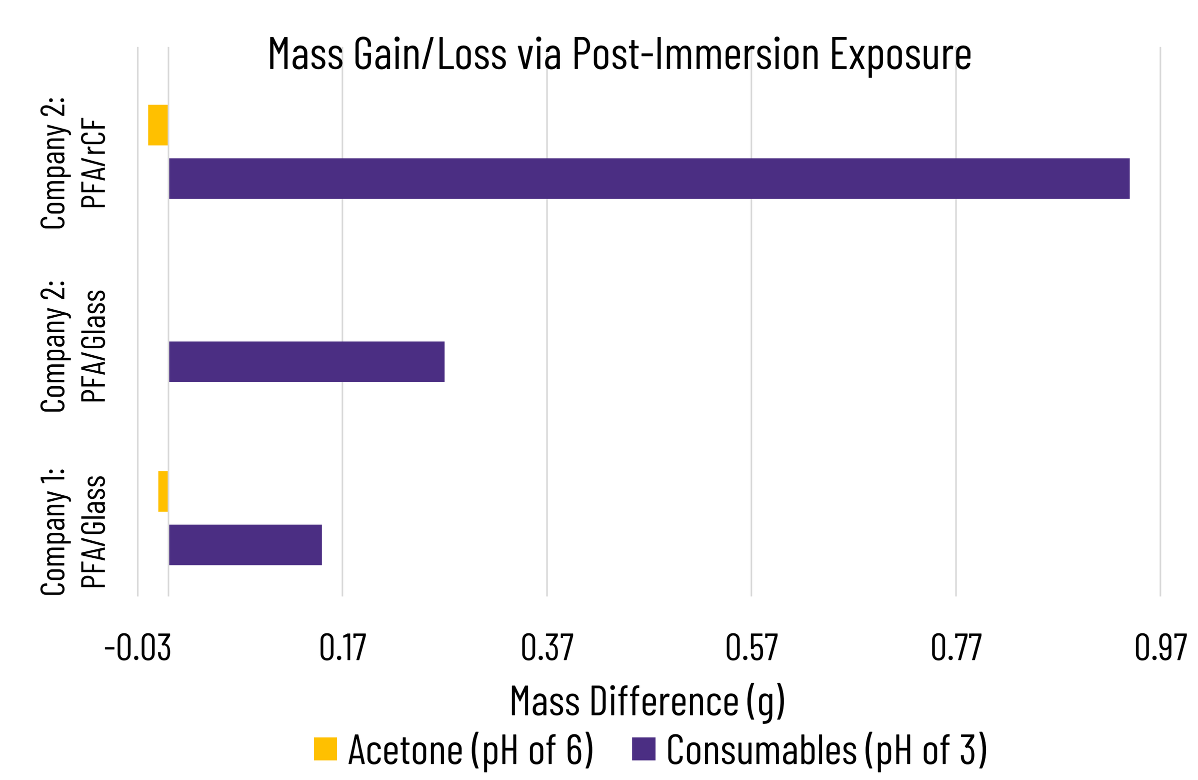
TGA



	5% Weight Loss Cured Average	5% Weight Loss Prepreg Average
Company 1: PFA/Glass	338 C	247 C
Company 2: PFA/Glass	342 C	231 C
Company 2: PFA/Carbon	231 C	N/A

Figure 4. Trial TGA run of Company 2: PFA/Glass Cured Sample.

Chemical Degradation



DISCUSSION

Short Beam Shear: Company 1 's PFA/Glass material yielded the highest shear strength at 41.8 MPa. This shear strength is comparable to composite materials used in aerospace such as 7781 E-Glass with a short beam strength of 41.4 MPa.

Tensile: The PFA/Glass composites showed a stronger engineering stress than the PFA/rCF composite. However, E-glass with epoxy resin is reported to show a tensile strength of 79 MPa showing that the PFA composite material is much weaker in tension.

DMA: Glass transition temperatures derived from loss and storage moduli were within around 10C and 30C from mDSC values for Company 2's PFA/Glass and PFA/rCF, respectively. Viscosity was 2.26E-05 N s/m higher for PFA/rCF, which could impact defects during cure. However, it is unknown how significant this difference is.

mDSC: Company 2 yielded the highest glass transition temperature with PFA/rCF.

TGA: Both PFA & fiberglass reinforcement materials maintained 95% of their mass by 330C.

FTIR: A full characterization of spectra for all materials is in progress, with functional groups classified into desired or undesired based on industry expectations.

Chem. Deg.: All 3 materials absorbed the consumables, with Company 1: PFA/Glass absorbing the least. Acetone results not reliably comparable.

OVERALL: PFA & fiberglass reinforcement has more durability thermally and mechanically compared to PFA/rCF reinforcement. Further replication and testing needs to be conducted to further accurately support these initial results.

FUTURE WORK

- Have chemical degradation test be monitored every 24 hours to ensure consistency in exposure between samples
- Investigation of resin-separation methods would improve compositional analysis and sustainability evaluations
- Characterization performed during this project is considered guidance for future materials characterization.
- Flammability testing to ensure materials are non-toxic if burning

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