

Dimensional Stability and Creep Performance of Glass Fiber Reinforced Thermoplastic Polyurethane as a Recyclable Alternative to Fiberglass Epoxy Composites for Wind Turbine Blade Applications

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Q1: Research Question

Q3: Data Analysis & Results

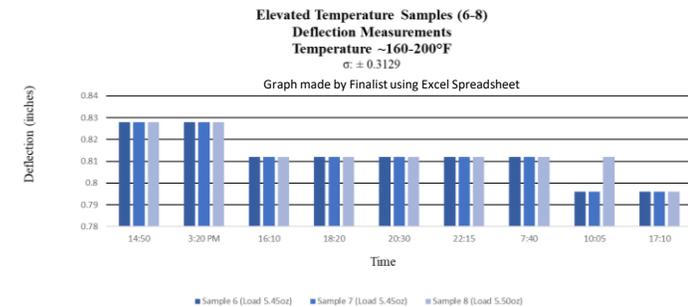
Can glass fiber-reinforced thermoplastic polyurethane (GFRTPU) match or exceed the creep resistance and thermal stability of fiberglass epoxy resin for wind turbine blade applications?

Hypothesis

In a previous project, I was able to demonstrate that GFRTPU's strain is better than fiber-glass epoxy resin, and tensile strength is comparable. The glass fibers in the GFRTPU improve the creep resistance of the material. If GFRTPU's creep, and thermal resistance are comparable to or better than fiberglass epoxy resin, then GFRTPU should be considered a viable alternative material for wind turbine blades. Advantages of using thermoplastic composites (TPU), such as GFRTPU, are that they are more impact resistant and less prone to delamination. Further, TPU composites have a high strength to weight ratio, excellent fatigue resistance, good impact resistance, good weather and UV resistance, and most importantly, recyclability.

I tested five GFRTPU samples that were tested under three thermal conditions (68°F, 120-140°F, 160-200°F) with a ~5.5 oz load to measure creep behavior, and three samples were tested on an electronic tensile testing machine at ~65% ultimate tensile strength (UTS). Data from GFRTPU testing was then compared to E-Glass epoxy composites (a type of fiber glass epoxy resin)

Results from the Findley Power Law analysis revealed creep rate coefficients (a_0) of essentially zero at room temperature and 120-140°F and only 0.003 ± 0.0053 at 160-200°F, indicating negligible time-dependent deformation. The low R^2 values reflect GFRTPU's superior dimensional stability—unlike E-glass/epoxy that continuously deforms, GFRTPU maintained constant strain under load. Electric tensile testing demonstrated consistent stress relaxation behavior ($42.3\% \pm 2.8\%$ over 16 hours), confirming reproducible material performance despite testing at 55-61% UTS rather than the target 70% UTS due to cross-sectional area variations.



Findley's Power Law Analysis (ϵ_0, a_0, n, R^2) + Elevated Creep Strain Standard Deviations (68,120-140,160-200°F)					
Temperature Condition	Creep Strain	Instantaneous Elastic Strain (ϵ_0)	Creep Rate Coefficient (a_0)	Time-Dependency Exponent (n)	Percentage of Variance (R^2)
Room Temperature	0.537 ± 0.0005	0.537 ± 0.0004	0.000 ± 0.000	0.088 ± 0.041	0.000 ± 0.000
Elevated Temperature	0.540 ± 0.0008	0.540 ± 0.0008	0.000 ± 0.000	0.07 ± 0.0366	0.000 ± 0.000
Elevated Temperature	0.541 ± 0.0006	0.541 ± 0.0006	0.003 ± 0.0043	0.0496 ± 0.032	0.370 ± 0.306

Table made by Finalist using Excel Spreadsheet

Q2: Methodology

Q4: Conclusion

- 1 - Cut samples to specifications outlined in ASTM D638-14
- 2 - Measure the dimensions of the samples
- 3 - Sample Preparation and Marking
- 4 - Load Preparation
- 5 - Room Temperature Creep Testing
- 6 - Moderate Temperature Creep Testing
- 7 - High Temperature Creep Testing
- 8 - Calculate load for Electric Tensile Testing Machine (~70% of UTS)
- 9 - Operate the Electric Tensile Testing machine
- 10 - Change the fractional deflection to decimals
- 11 - Calculate Creep Strain
- 12- Calculate Standard Deviation
- 13 - Findley Power Law Analysis

Photo taken of the finalist by the finalist's parent, Mike Walker

Photo taken by Finalist

Photo taken by Finalist

ASTM International. (2014). Standard test method for tensile properties of plastics (ASTM D638-14). <https://doi.org/10.1520/D0638-14>

- **Superior Creep Resistance:** GFRTPU maintains exceptional dimensional stability with near-zero creep rates (CV as low as 0.11%) and only 7.4% strain increase across 62°F.
- **Thermal Stability:** The material demonstrated remarkable consistency across operational temperature ranges (68°F to 200°F), with minimal performance degradation compared to traditional fiberglass epoxy composites that exhibit double-digit percentage increases in creep strain.
- **Predictable Long-Term Performance:** Findley Power Law analysis shows creep rate coefficients approaching zero with consistent linear behavior across all test samples, eliminating need for complex time-temperature superposition modeling required for fiberglass epoxy and confirming dimensional stability for multi-decade service life.