CHARACTERIZATION OF FIBER/MATRIX INTERFACE FOR UPCYCLING COMPOSITES

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Introduction

- Current composite waste disposal methods include downcycling composite materials or sending composite waste to landfills.
- Although these two methods are considerably cheaper and easier to perform, it results in high environmental damages. However, upcycling composite waste is both economically and environmentally favorable.

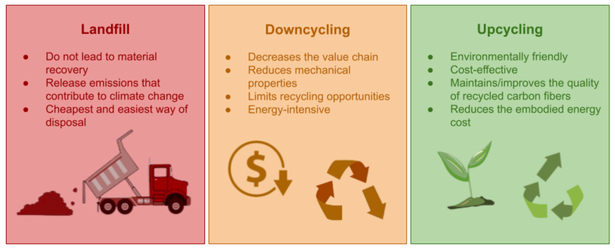


Figure 1: The Effects of Current Composite Waste Disposal Methods.

- Elium 188 O is a thermoplastic resin that can be recycled as chopped carbon fiber compounding resin or recovered through depolymerization.
- The goal is to be able to use recycled carbon fibers in their original function at an efficiency that does not greatly reduce its functionality.

Figure 2: Elium 188 O made Off-shore Windmills[1]

Materials

- Liquid Elium 188 O resin is supplied by Arkema.
- Elium 188 O resin is PMMA combined with a peroxide (Luperox AFR 40) also supplied by Arkema. The peroxide starts the free radical polymerization reaction
- T700SC-12K-F0E sized fibers are supplied from Toray. These carbon fibers are currently used in pressure vessels such as natural gas vehicles and storage tanks.

Figure 3: Bobbin of T700SC Carbon Fibers[4]

Chemical Name
Methyl methacrylate
Acrylic copolymers
2,6-Octadienal, 3,7-dimethyl-
Minor components eye corrosion

Figure 4: Elium 188 O Composition[2]

Problem and Process Overview

- Elium 188 O resin evaporates at a fast rate under normal conditions. Because of this evaporation, normal fiber inserts cannot be done. To prevent evaporation during the fiber insertion process, Elium 188 O preforms are made.

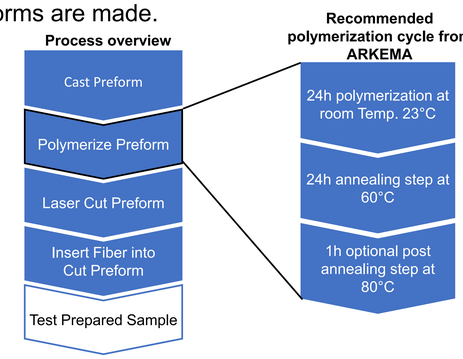


Figure 5: (Left) Preparing Pull Out Testing Samples with Elium 188O Resin. (Right) In depth polymerization cycle provided from ARKEMA.

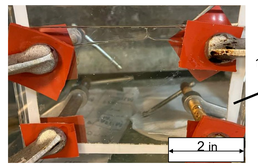


Figure. 6: Elium 188 O preform made with 2 glass plates

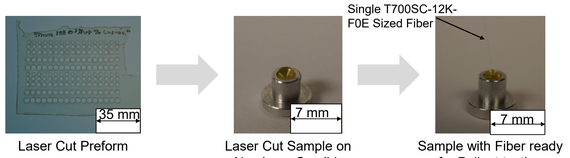


Figure 7: (Left) Elium 188 O Preform after Laser cutting. (Middle) Elium 188 O sample prepared for fiber insertion. (Right) Elium 188 O sample after fiber insertion.

- To reduce sample variability in Pullout testing Elium 188 O Samples are laser cut into 2.5 mm circles.

DSC

- DSC is run on each polymerized preform to determine the thermal glass transition temperature (Tg). The Tg is directly correlated with molecular weight.
- Each sample is tested to determine the effect degree of polymerization has on the sample. A heat cool heat (HCH) process is used to test each sample.

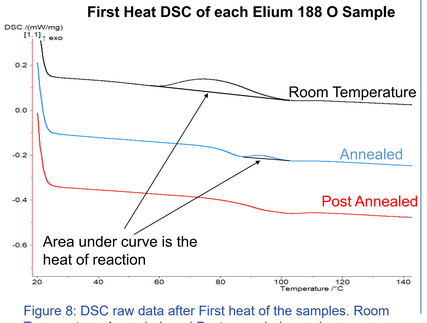


Figure 8: DSC raw data after First heat of the samples. Room Temperature, Annealed, and Post annealed samples are run under the same conditions.

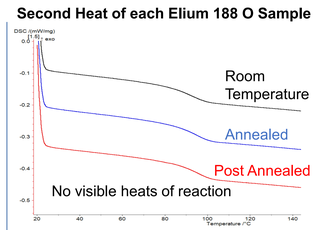


Figure 9: DSC raw data after second heat of the samples. Room Temperature, Annealed, and Post annealed samples are run under the same conditions.

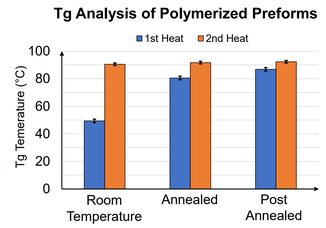


Figure 10: Tg temperature range of each type of polymerized preform.

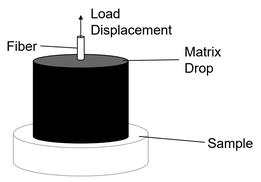
- Residual reactions occur in the first heat that create a higher Tg in the second heat.

Fiber Pullout Testing

- Axiom can be used in the TUFF (fiber alignment) process. Since it can be used, it will be considered as a baseline for the Elium 188 O pullout testing.
- Fiber embedded length (L_e) are calculated using:

$$L_c = \frac{\tau_f}{4 * IFSS} d$$

- The fiber is displaced from the matrix. The maximum force required to displace the fiber from the matrix is used to calculate the maximum IFSS.



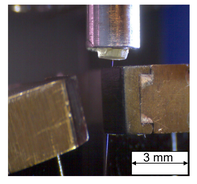


Figure 11: (Left) Schematic of a typical pullout test[3]. (Right) Elium 188 O Laser Cut Sample Loaded Sample in FAVIMAT+ for pullout test.

- IFSS is calculated using:

$$IFSS = \frac{Force}{Area} = \frac{F_{max}}{\pi L_e d}$$

- The force required to pullout the F0E sized fiber is lower than expected due to a smaller embed length (Le)

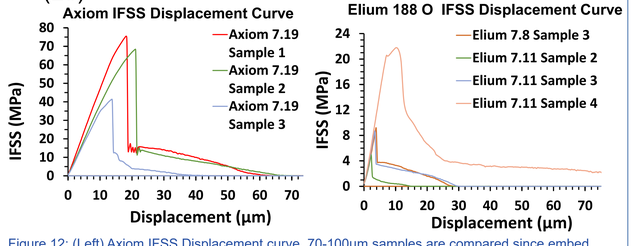


Figure 12: (Left) Axiom IFSS Displacement curve. 70-100µm samples are compared since embed length affects IFSS. (Right) Elium 188 O IFSS Displacement curve.

- Sample 4 in the Elium 188 O IFSS Displacement graph has an L_e close to 100um target while the other samples range from 15-30µm.

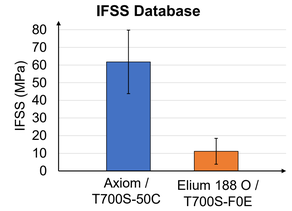


Figure 13: IFSS Database. The average IFSS of each sample composition.

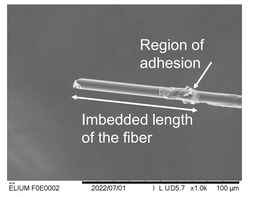


Figure 14: SEM image of a T700 fiber after pullout testing

- Higher imbed lengths occurred due to a creep of liquid Axiom resin up the fiber when inserted
- Since the Elium 188 O resin is an elastic solid when inserting, it is difficult to control the L_e.
- Fibers are placed on a Scanning Electron Microscope (SEM) disc to be find actual embed length.

Conclusion and Future Testing

- Elium 188 O resin can be casted and used for sample testing.
- The thermal history of the Elium 188 O resin affects the degree of polymerization of the resin.
- Single fiber insertion is affected by the viscosity of the Elium 188 O resin.
- Future testing will determine if heat transfer laser cutting significantly changes the Elium 188 O resin.
- Molds shaped like FIMABOND crucibles will be redesigned to allow imbedding of fibers when resin is still a liquid.

Figure 15: Current silicon mold for mold method of single fiber sample creation

- Future testing will be done on Tg vs Molecular weight.

References

[1]*Elium Tegoglas CAREFLEX DICUP Oleris accolade - arkema. (n.d.). Retrieved August 1, 2022, from https://www.arkema.com/files/live/sites/shared_arkema/files/downloads/products-documentations/Brochure_ELIUM_2022-BD.pdf*

[2]*Elium 188 O Safety Data Sheet. Retrieved August 1,2022 from Arkema.*

[3]*Raheem, Zainab. (2019). THE APPLICATION OF FRACTURE MECHANICS TO POLYMERS, ADHESIVES AND COMPOSITES.*

[4]*Toray Torayca 12k T700SC carbon fiber tow continuous carbon fiber filament yarn thread tape. 10m, 20M, 50m or 100m. DirectVoltage.vom. (2022, June 29). Retrieved August 1, 2022, from https://directvoltage.com/shop/carbon-fiber-material/toray-torayca-12k-t700-carbon-fiber-tow-continuous-carbon-fiber-filament-yarn-thread-tape*

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