EVALUATING THE EFFECTS OF RECYCLING CONDITIONS ON CARBON FIBER STRENGTH AND THEIR ADHESION WITH PMMA

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Introduction

- Carbon fiber composites are commonly used in industry due to their high strength and durability

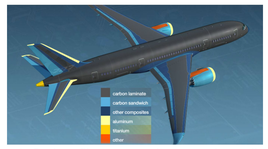

Figure 1. Carbon fiber composite example application[1]

- Recycling these composites lessen waste from scrap and end-of-life components
- There are no effective methods of recycling these components without influencing the integrity and surface chemistry of the fibers
- This study uses single fiber tensile test to evaluate tensile property degradation and fiber pullout for changes in fiber/matrix compatibility

Objective

- Measure the effects of the pyrolysis on the carbon fiber strength and their adhesion with PMMA to help optimize the pyrolysis process

Materials

Fibers

- Toray T700S Carbon Fiber with F0E sizing

Resin

- Arkema's Elium resin is useful due to its ability to polymerize at room temperature
- A PMMA-based castable Elium® 188 O with 3 wt% Luperox AFR 40 peroxide initiator was used for it's recycle by design chemistry

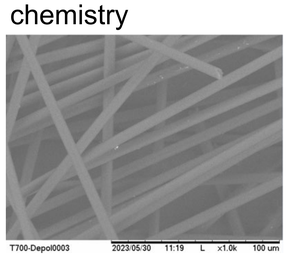

Figure 2. SEM image of recycled fibers

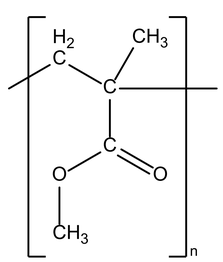

Figure 3. PMMA molecule

Procedure

Recycling/Pyrolysis Process

- The fibers, previously cast with Elium®, are pyrolyzed with a 20-minute elevated temperature oxidation step

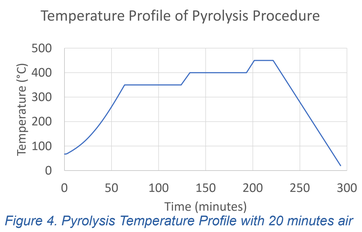

Figure 4. Pyrolysis Temperature Profile with 20 minutes air

Figure 5. Carbolite GLO furnace

Single Fiber Tensile Test (SFTT)

- Samples are placed into the grips and strained until failure to measure strength

Gauge Length	Displacement Rate
12 mm	0.01 mm/s

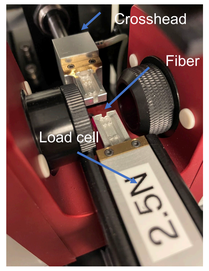

Figure 6. Dia-stron single fiber tensile test in progress

Fiber Pull-Out Testing

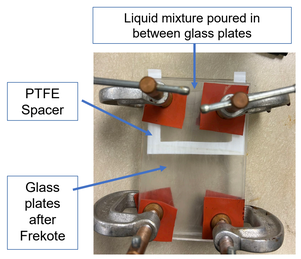

Figure 7. Cast (0.5 mm thickness)

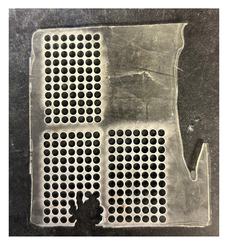
Figure 8. Cut plate (2.5 mm diameter)

- Single fibers are inserted into a resin and pulled out to measure the ability of the resin to transfer to the fiber through interfacial shear strength (IFSS)
- Samples were prepared using the Textechno Fimabond

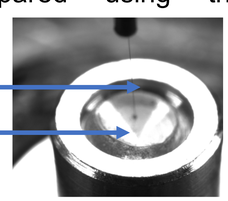

Figure 9. Fimabond prepared sample

- Samples were then annealed in an oven at 80°C for 2 hours
- Samples were tested using the Textechno Favimat+

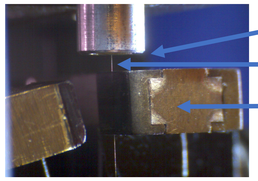

Figure 10. Pull-out test sample from Favimat+

Figure 11 Diagram of pull-out test

Results

Single Fiber Tensile Test

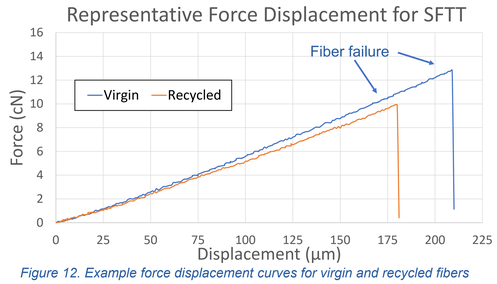

Figure 12. Example force displacement curves for virgin and recycled fibers

$$\sigma_f = \frac{F}{\pi * r^2}$$

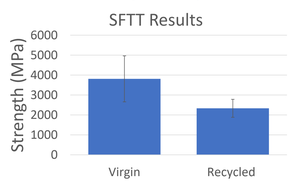

Figure 13. Average strength for both fibers

- The average strength for the recycled fibers is 38.8% less than the virgin fibers

Fiber Pull-out Test

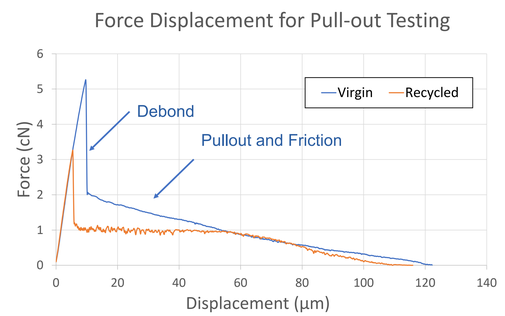

Figure 14. Example force displacement curves from fiber pullout tests for both fibers

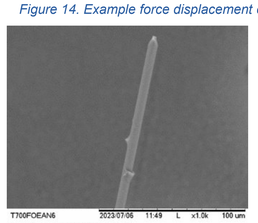

Figure 15. SEM image of virgin fiber after pullout

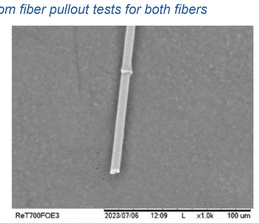

Figure 16. SEM image of recycled fiber after pullout

- SEM images were taken to determine embedded lengths and diameters of the fibers after pull-out testing
  - Because of low adhesion, many samples did not show resin residue used to determine embedded length
  - Total displacement was used instead to find the IFSS

$$\tau_{IFSS} = \frac{F}{\pi * 2r * L_e}$$

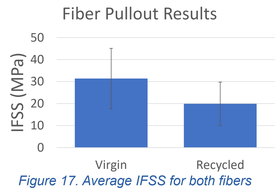

Figure 17. Average IFSS for both fibers

Conclusion

- The recycling procedures have a significant influence on the strength of the carbon fibers
  - This indicates that a better pyrolysis process needs to be developed to minimize degradation
- Data is inconclusive whether there is a negative effect on the fiber/matrix interface according to a T-test

Path Forward

- Prepare more samples for testing to strengthen data collection because of lack of adhesion from pull-out
- A new method to prepare IFSS samples should be implemented
  - Where the fiber is embedded into the resin prior to the polymerization step to better mimic the infusion process used in industry

Works Cited

1. *Protecting aircraft composites from lightning strike damage*. COMSOL. (2015). https://www.comsol.com/blogs/protecting-aircraft-composites-from-lightning-strike-damage/

Acknowledgements

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