EFFECTS OF NOVEL SOLVOLYSIS RECYCLING PROCESS ON MECHANICAL PROPERTIES OF CARBON FIBERS

Stephen Wagner, (BME)[3], Matthew Blair, (BME)[2], Munetaka Kubota, (Ph.D.M.S.E.)[1], Joseph M. Deitzel, Ph.D.[1]
University of Delaware | Center for Composite Materials[1] | Department of Mechanical Engineering[2] | Syracuse University, Department of Mechanical and Aerospace Engineering[3]

Introduction

- Carbon fiber reinforced polymer composites (CFRP) have rapidly become a widely used material for weight sensitive applications
- Lack of established recycling process and infrastructure results in scrap CFRP and end of life parts going to landfills
- CFRP has similar embodied energy to steel and aluminum, which are widely recycled materials

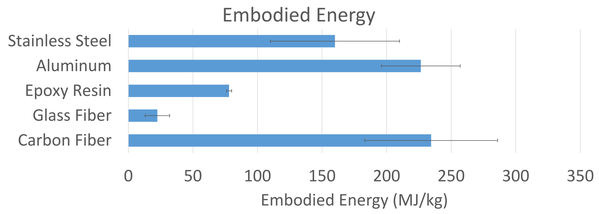

Figure 1: Energy requirement to manufacture 1kg of various materials[1]

- Pyrolysis (Fig 3) and Solvolysis (Fig 2) are two potential recycling processes

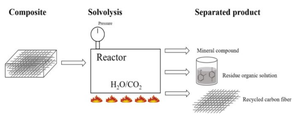

Figure 2: Diagram of solvolysis process[2]

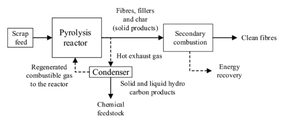

Figure 3: Diagram of pyrolysis process[3]

Recycling Process

- Toray T700 50C carbon fibers were infused using Axiom 2201 UD to make a CFRP, data sheet values seen in the table below.

Sizing Type	Diameter (µm)	Strength (MPa)	Modulus (GPa)	Strain to Failure
Epoxy	7	4900	230	2.1%

- Our collaborators at the National Renewable Energy Laboratory used their novel solvolysis based process to remove the epoxy matrix and recover recycled fibers, which was evaluated

Methods

Isolate fibers into Dia-Stron trays

Image on Confocal laser microscope

Measure fiber diameter from confocal images using ImageJ

Test fibers on Dia-Stron

Correct Dia-Stron data for compliance

Create stress-strain curves from force-displacement curves

Figure 4: Dia-Stron tray with tabs

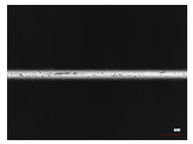

Figure 5: Raw confocal image

Figure 6: Confocal image with ImageJ thresholding

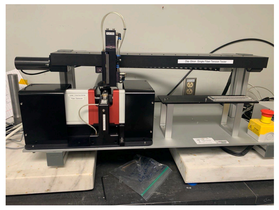

Figure 7: Dia-Stron testing area

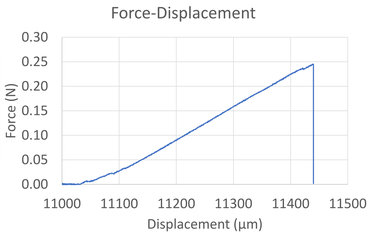

Figure 8: Force-Displacement curve from Dia-Stron data

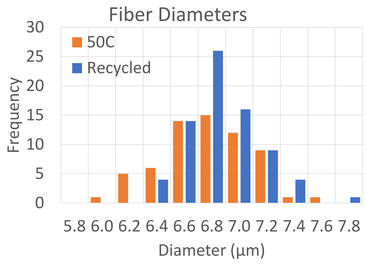

Figure 9: Diameter distribution for recycled and 50C fibers

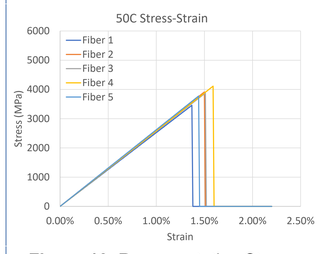

Figure 10: Representative Stress-Strain curves for five 50C fibers

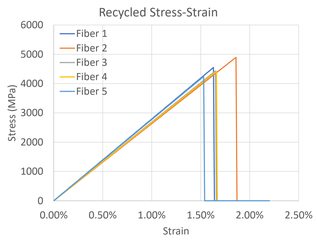

Figure 11: Representative Stress-Strain curves for five recycled fibers

Results

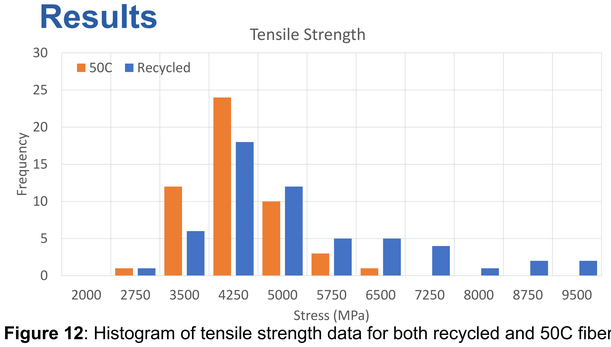

Figure 12: Histogram of tensile strength data for both recycled and 50C fibers

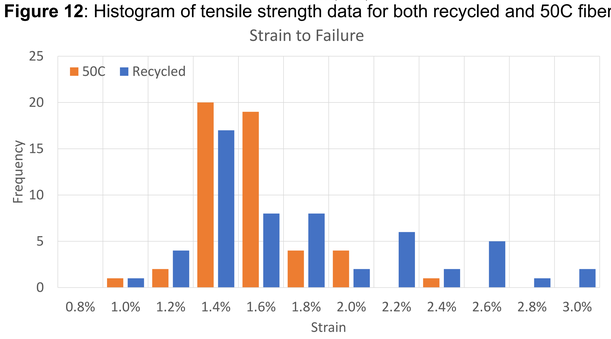

Figure 13: Histogram of strain to failure data for both recycled and 50C fibers

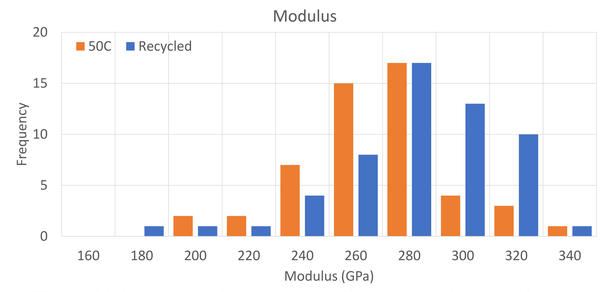

Figure 14: Histogram of modulus data for both recycled and 50C fibers

- The 50C fibers underperformed what was expected, possibly due to damage caused when separating the fibers
- The recycled fibers performed as expected, similarly to the manufacturer's data sheet with a large distribution

	50C			Recycled		
	Average	Standard Deviation	Coefficient of Variation	Average	Standard Deviation	Coefficient of Variation
Strength [MPa]	3926	685	17.44%	4911	1569	31.95%
Modulus [GPa]	258.8	26.41	10.21%	273.22	29.46	10.78%
Strain to Failure	1.47%	0.24%	16.49%	1.71%	0.5%	28.99%

Conclusion

- The 50C fibers were potentially damaged during isolation due to the sizing process making fibers difficult to separate, causing the fibers to underperform comparatively
- The tested recycling process does not seem to degrade the carbon fibers compared to the data sheet

Path Forward

- Perform more analysis on the collected data, including Weibull distribution, to get more conclusive results

References

1. Young S. Song, Jae R. Youn, Timothy G. Gutowski, Life cycle energy analysis of fiber-reinforced composites, Composites Part A: Applied Science and Manufacturing, Volume 40, Issue 8, 2009, Pages 1257-1265, ISSN 1359-835X, https://doi.org/10.1016/j.compositesa.2009.05.020.
2. Kim, Y.N., Jung, Y.C. (2022). Recycling Studies of Epoxy Fiber-Reinforced Composites. In: Mavinkere Rangappa, S., Parameswaranpillai, J., Siengchin, S., Thomas, S. (eds) Handbook of Epoxy/Fiber Composites . Springer, Singapore. https://doi.org/10.1007/978-981-15-8141-0_46-1
3. Karuppannan Gopalraj, S., Kärki, T. A review on the recycling of waste carbon fibre/glass fibre-reinforced composites: fibre recovery, properties and life-cycle analysis. SN Appl. Sci. 2, 433 (2020). https://doi.org/10.1007/s42452-020-2195-4

Acknowledgements

This material is based upon work supported by the U.S. Department of Energy's Office of Energy Efficiency and Renewable Energy (EERE) under the Advanced Manufacturing Office Award Number DE-EE00009303

Recycled fibers were provided by Dr. Stephen Dempsey at the National Renewable Energy Laboratory

Special thanks to Dr. Ankita Bisht for Confocal and Dia-Stron training.