Innovative Development of Sustainable Carbon Fiber Composites

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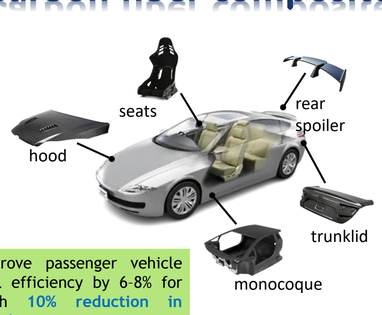
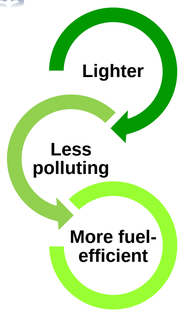
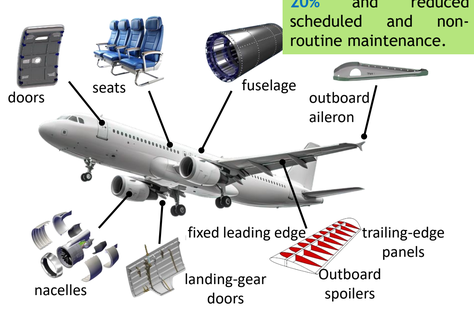
INTRODUCTION

Carbon fiber composites



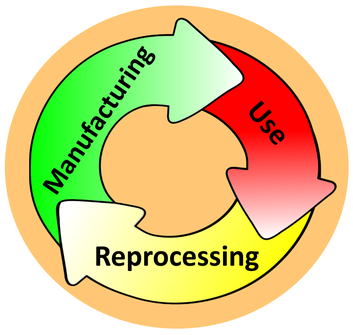
Improve passenger vehicle fuel efficiency by 6-8% for each **10% reduction in weight.**

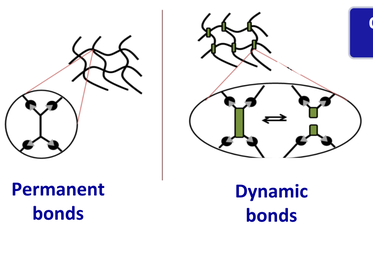




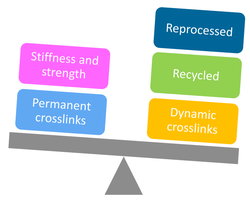
Reduction in weight of 20% and reduced scheduled and non-routine maintenance.

Sustainable epoxy resin





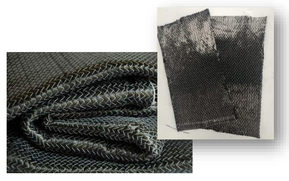
Conventional epoxy resin | **Dynamic epoxy resin**



MATERIALS AND METHODS

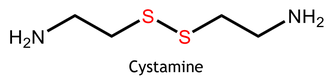
1) Materials

Epolam 2015
Epoxy resin system

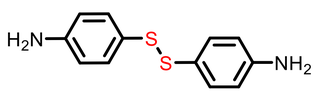


ZOLTEK™ PX35 Unidirectional Carbon Fiber

Disulfide-based hardeners



Cystamine

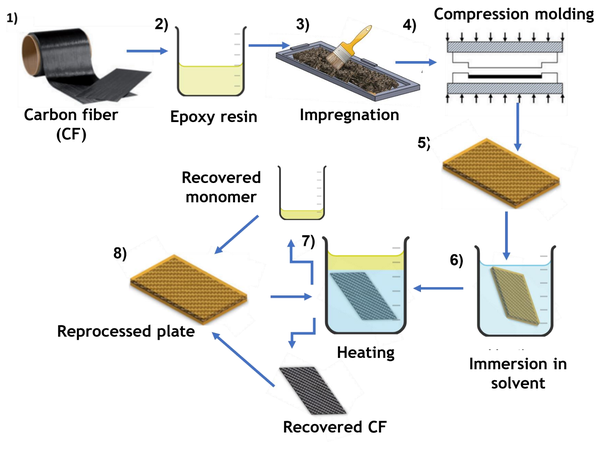


4-Aminophenyl disulfide (4-AFD)

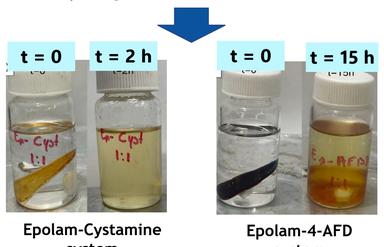
2) Methods

Modify the conventional epoxy resin with disulfide-based hardeners → **Manufacture a CFRP component** → **Depolymerization** → **Reprocessing to manufacture a new component**

Characterization: DSC, FTIR, TGA, optical microscopy



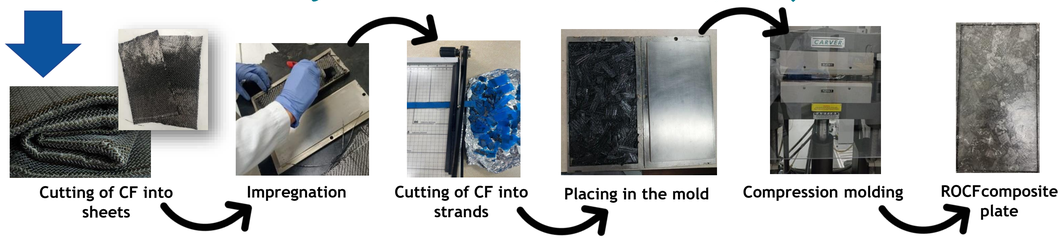
Depolymerization trials



Epolam-Cystamine system

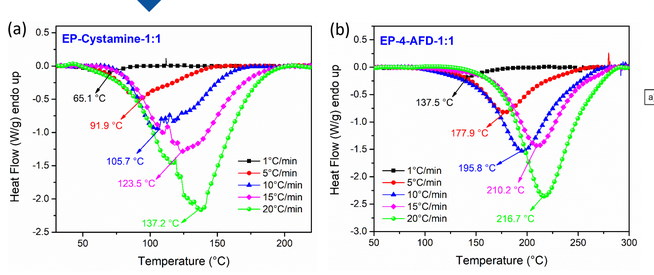
Epolam-4-AFD system

Fabrication of randomly oriented carbon fiber (ROCF) composites



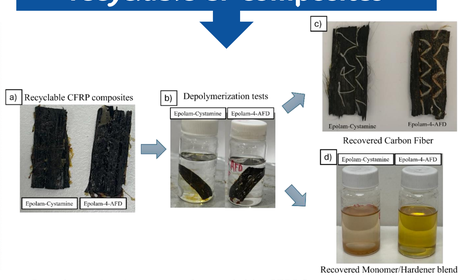
RESULTS AND DISCUSSION

DSC Analysis



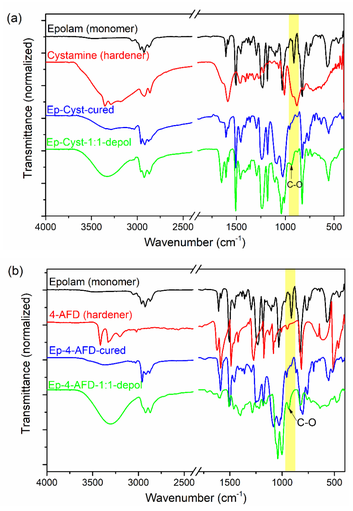
Non-isothermal DSC curves obtained at different heating rates for a) Epolam-cystamine and b) Epolam-4-AFD systems.

Depolymerization tests for recyclable CF composites



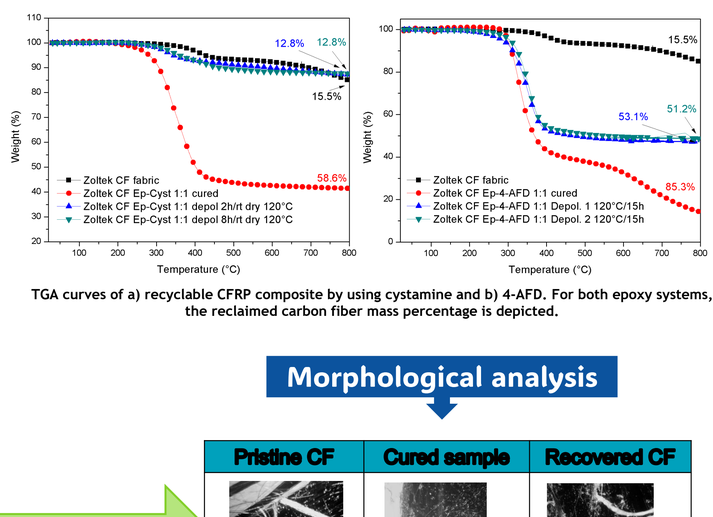
Depolymerization tests of recyclable CFRPCs and recovery of raw materials.

FTIR analysis



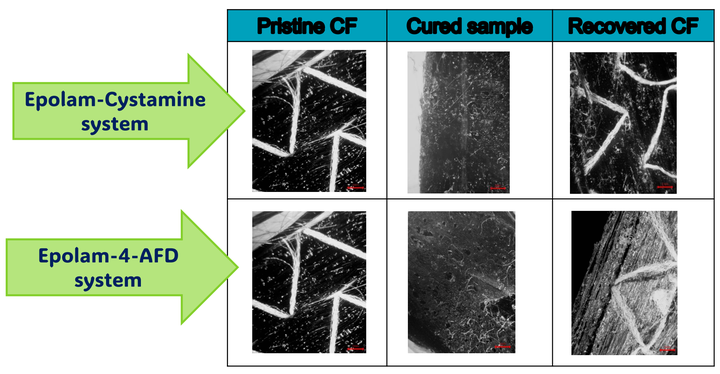
FTIR spectra of monomer, hardener, cured samples, and recovered resin from (a) Epolam-cystamine and (b) Epolam-4-AFD systems after depolymerization tests.

TGA analysis of recovered CF



TGA curves of a) recyclable CFRP composite by using cystamine and b) 4-AFD. For both epoxy systems, the reclaimed carbon fiber mass percentage is depicted.

Morphological analysis



Optical microscopy images of pristine CFs and composite samples before and after depolymerization test for Epolam-Cystamine and Epolam-4-AFD systems.

CONCLUSIONS

- ✓ A conventional epoxy monomer and chemically recyclable hardeners with degradable covalent bonds were combined to develop novel, recyclable resin for sustainable CFRPC manufacturing.
- ✓ The depolymerization trials for the two sustainable systems were very promising showing that the hardener was completely degraded after several hours in a solvent, meaning that the resin could be recycled.
- ✓ Analytic techniques such as FTIR, TGA, and optical microscopy confirmed the reversibility of the dynamic bonds of the modified epoxy resin.
- ✓ Future work is needed to investigate how the reclaimed monomer performs when reprocessed and how the composite system performs with these resins.

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BIBLIOGRAPHY

1] J. Zhang, G. Lin, U. Vaidya, and H. Wang, “Past, present and future prospective of global carbon fibre composite developments and applications,” Composites Part B: Engineering, vol. 250, p. 110463, 2023.
[2] J. H. Memon, Y. Wei, C. Zhu, “Recyclable and reformable epoxy resins based on dynamic covalent bonds – Present, past, and future,” Polymer Testing, vol. 105, p. 107420, 2022.
[3] A. Cooperman, A. Eberle, and E. Lantz, “Wind turbine blade material in the United States: Quantities, costs, and end-of-life options,” Resources, Conservation and Recycling, vol. 168, p. 105439, 2021.