Characterization of Dual-Disk Refined Paper and Polypropylene Composites

Christopher Webb[1,6], Cecile Grubb[2], Patrick Gontarz[3], Leo Huntington[4], Karl Englund[2], Hui Li[5], David Harper[6]

1: Department of Materials Science and Engineering, The University of Tennessee, Knoxville
2: Washington State University, WA
3: Wilbur Wright College, IL
4: Cornell University, NY
5: North Carolina State University, NC
6: Center for Renewable Carbon, TN

Background and Motivation

Pressure on Automotive Industry to Improve Sustainability

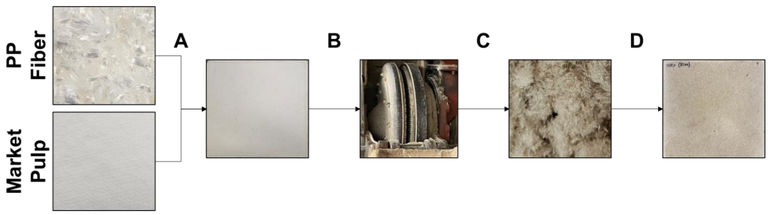
- Transportation contributes 23% of US GHG in 2023 [1]
- Pulp fibers offer low density, low cost, carbon-neutral, robust supply chains, and damping benefits
- PP-pulp composites are viable automotive materials [2]
- Need for robust recycling methods to meet EU ELV regulations [3]

Dual Disk Refiner for Composites Recycling

- Dual-disk refiners offer high throughput size reduction
- Potential to retain fiber aspect compared to other aggressive methods

Composite Manufacturing and Characterization

Manufacturing Method Overview:



Manufacturing Steps:

A. PP fiber and market pulp were wet-laid and compression molded
B. Composite is shredded and steamed
C. Composite is refined via dual-disks
D. Recyclate is wet-laid with virgin PP fiber and market pulp to make composites with varying amounts of refined composite content

Overall composition: 60% market pulp, 40% PP

Various recyclate contents: 0, 25, 50, 75, 100%

Characterization Methods:

Sample	ASTM	Dimensions (mm)
Flexural	D256	60 × 12 × 3
Water Uptake	D570	76.2 × 25.4 × 3
Izod Impact	D790	63.5 × 12.7 × 3 with 45° rounded notch at midpoint

Abstract

The automotive industry is under pressure to significantly reduce the greenhouse gas emissions of their products. To curb greenhouse gas emissions, natural fiber composites are of interest due to having a lower carbon footprint as well as being cost-effective. Previous research has shown that optimized paper composites offered an increase in the flexural modulus and a decrease in water sorption. Paper fibers are of interest due to being globally available and inexpensive while not competing against food resources. This work seeks to investigate the effect of dual disk refinement on the mechanical and thermal properties of polypropylene (PP)-paper fiber composites. Virgin paper composites were recycled using a dual disk refiner and then blended with virgin paper composites of ratios 0, 25, 50, 75, and 100 wt.%. Recycled paper composites were characterized by properties such as flexural strength, impact strength, water sorption, and crystallinity. It was found that increasing the recyclate content reduced the mechanical properties while reducing the water uptake.

Results and Discussion

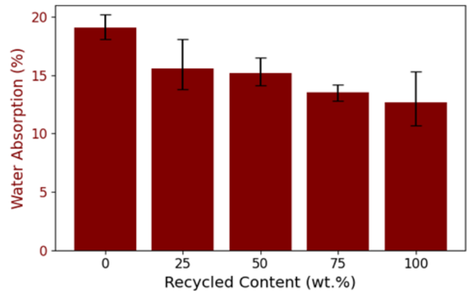
Composite Density & Consolidation

Recycled Content	Density (g/cm³)	Void Content (%)
0	1.05	24
25	1.01	28
50	0.99	30
75	1.03	26
100	0.97	32

Density & Void Content Results:

- Increasing the recyclate content reduces density, indicative of increasing void content.
- Overall composite consolidation is worse with increasing recyclate content.

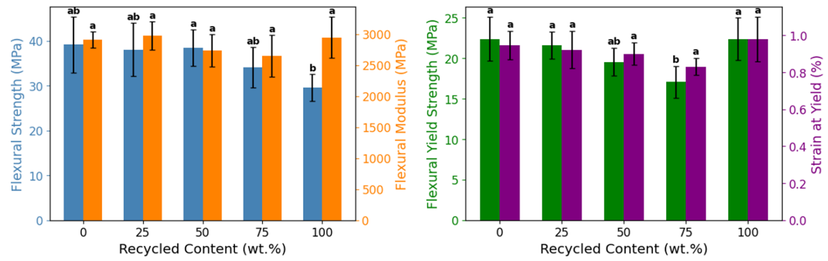
Water Sorption Behavior



Water Sorption Results:

- Increasing recycled content reduces moisture uptake
- Likely due to better coverage of cellulose by PP after refinement

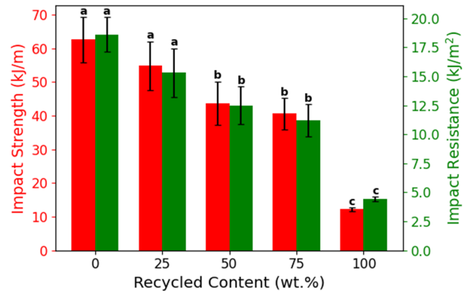
Composite Flexural Properties



Flexural Testing Results:

- Recyclate content negatively affects strength not elasticity
- Stiffness is independent of recycled content

Composite Impact Properties



Impact Testing Results:

- Increasing recycled content worsens impact performance
- 100% recycled sample has very poor impact strength and resistance

Conclusions & Acknowledgments

Conclusions

Dual-disk refining is a viable means of mechanical recycling. With high recycling loading, stiffness and chemical stability is preserved, where flexural and impact properties worsen.

Acknowledgments

Kendhl Seabright for laboratory assistance; Quintinne Madsen for data procurement; University of Tennessee Graduate Student Research Grant and VW Group of America for funding this research.

1. https://doi.org/10.1002/amp2.70017.
2. https://doi.org/10.1016/j.compositesa.2024.108339
3. https://ec.europa.eu/commission/presscorner/detail/en/ip_23_3819

SPE Poster Number: #####