Recyclable Epoxy Resin and Its Biochar Composite Using Anhydride Curing Agents

MNEXT MATERIALS & ENERGY TRANSITION

With use of agricultural cashew nutshell waste stream

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This project focuses on developing a sustainable thermoset based on cardanol, a biobased compound derived from cashew nutshell liquid (CNSL), a food industry by-product. Figure 1 shows the used epoxy resin. As part of the "Totally Nuts" research program, this work contributes to MNEXT's mission by turning waste into high-performance, circular materials. The resin systems are characterized through DSC, TGA, DMA, gel content, EEW titration, and mechanical testing. This research supports the shift toward biobased alternatives in coatings and composites, reducing reliance on fossil resources.

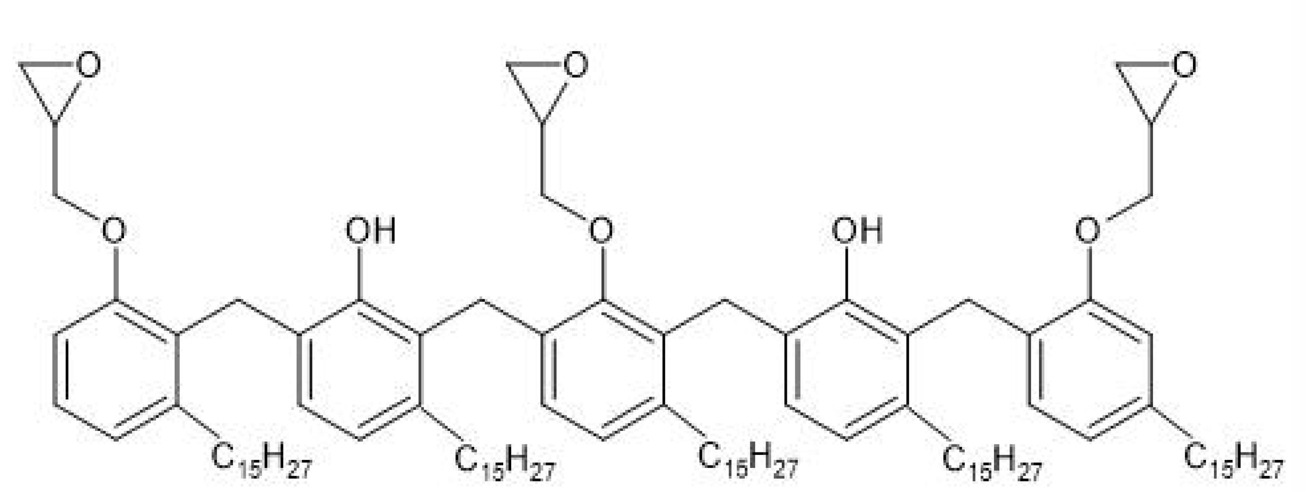

Figure 1: Epoxy resin

Methodology

Three cardanol-based epoxy resins were tested hardener to resin ratios of (1.00:1.00), (1.25:1.00), and (0.90:1.00), combined with 1–8 wt% biochar and various catalysts. After analyzing the ratios, it was determined that (0.90:1.00) worked the best. After mixing at 75 °C, samples were cured in molds using a four-step program (100–160 °C). Properties were analyzed using DSC, TGA, DMA, gel content, and tensile tests. Zinc octoate showed effective vitrimer behavior. Coatings were applied to steel for future adhesion and surface testing.

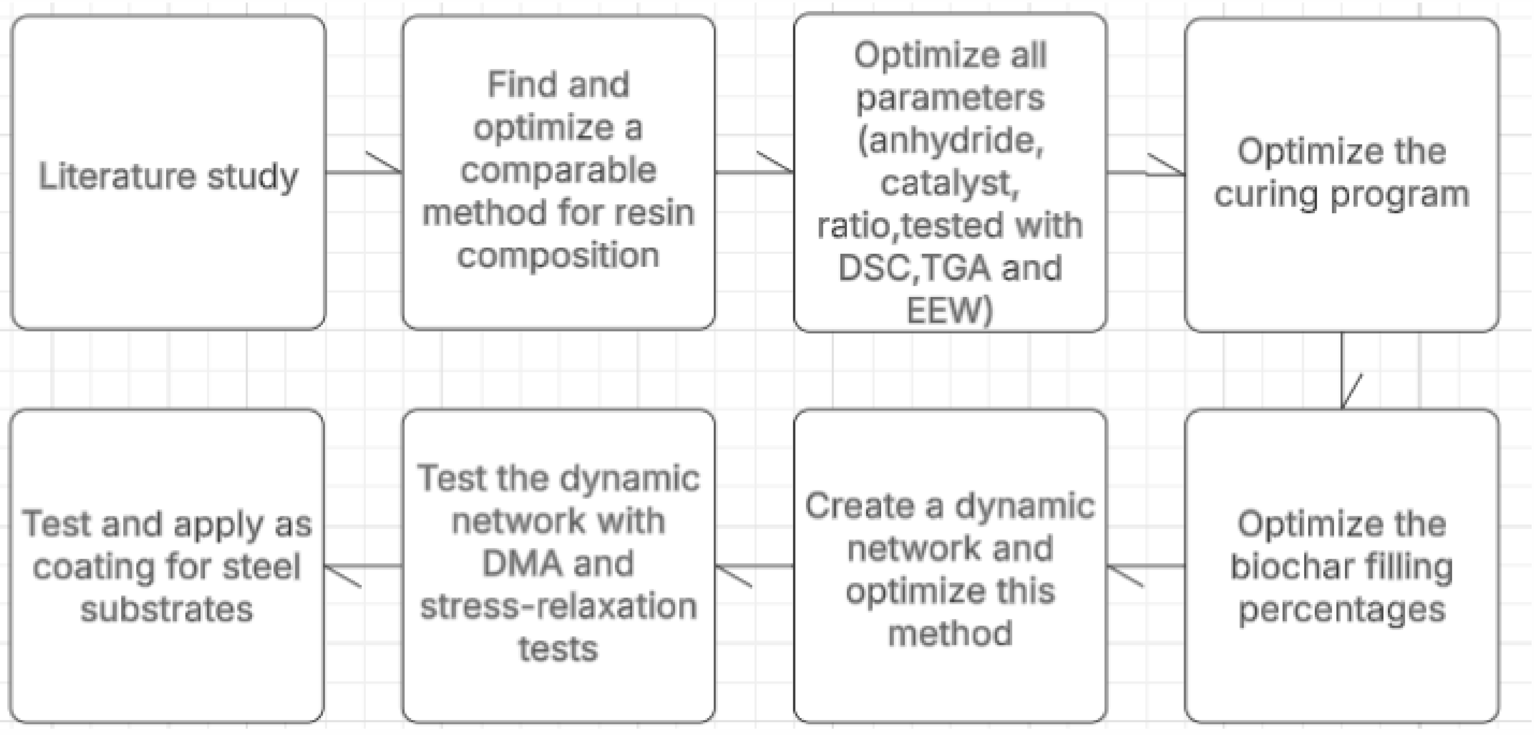

Figure 2: Scheme of methodology

Figure 3: Tensile testing bars (unfilled).

Figure 4: Tensile testing bars filled with 1 µm wood biochar.

Figure 5: Coating application before curing

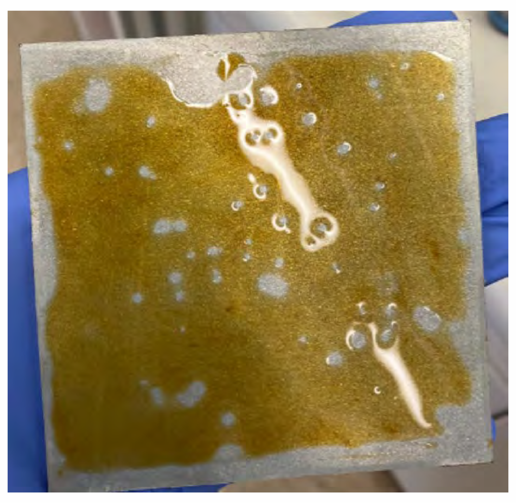

Figure 6: Coating application after curing

Results

This study optimized cardanol-based resin systems by varying ratios, filler content, and catalysts. A stepwise cure yielded Tg > 95 °C and gel contents > 90%, confirming full curing. The 5 wt% biochar formulation offered the best mechanical performance. Zinc-catalyzed systems showed dynamic behavior, and coating trials confirmed good adhesion despite some inhomogeneity.

Table 1: Overview of Sample Appearance, Gel content, and average Glass Transition Temperatures (Tg)

Sample	Tg (°C)	Gel content (%)	Picture
S1	110.6	94.6	 Figure 7: Epoxy resin without biochar
S2	116.10	104.5	 Figure 8: Epoxy resin with biochar

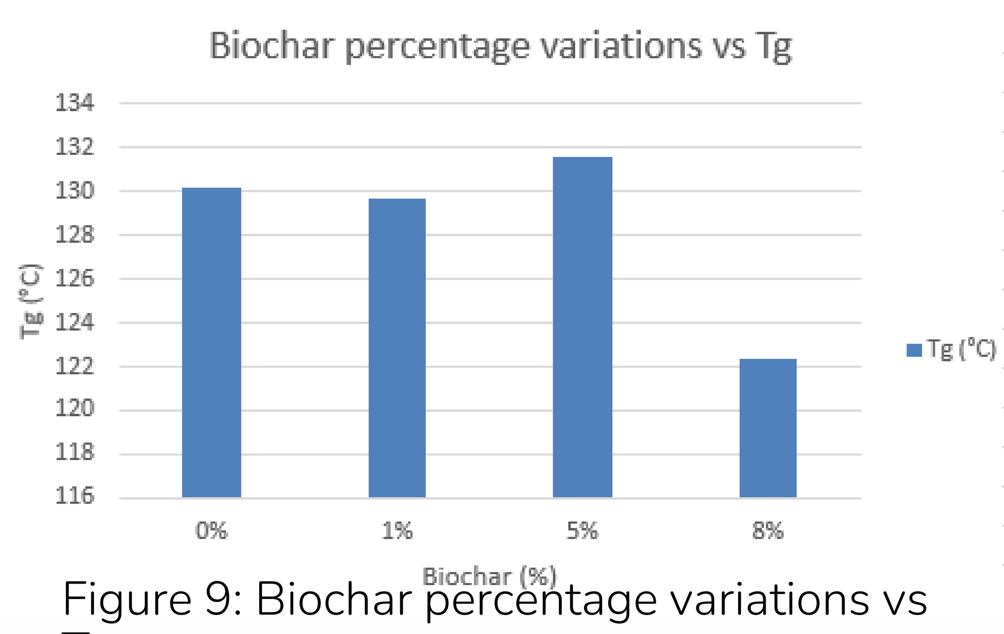

Figure 9: Biochar percentage variations vs Tg

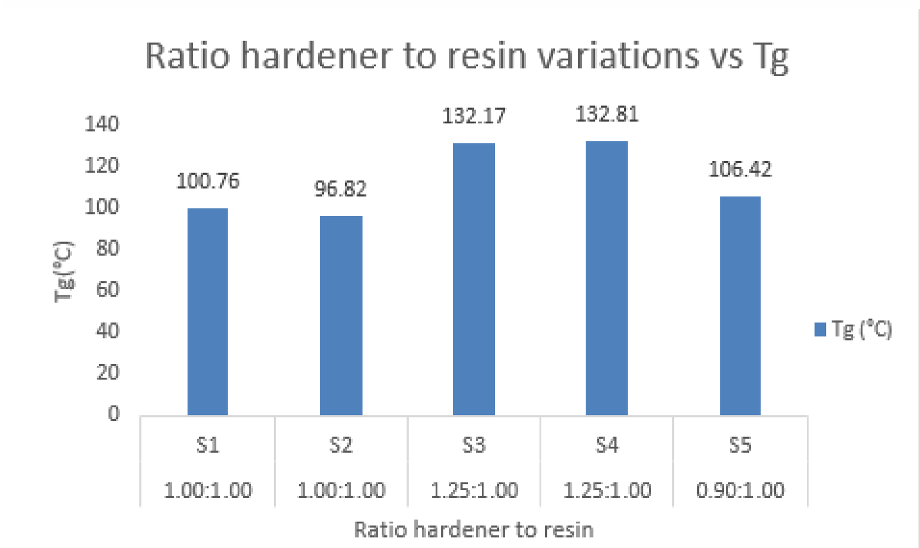

Figure 10: Ratio hardener to resin variations vs Tg

Resin composition	Gelcontent (%)
Resin+anhydride+catalyst	98.4
Resin LV +anhydride+catalyst	96.2
Resin LV EPO +anhydride+catalyst	94.6
ResinLV EPO +anhydride+catalyst+ BC	100.3
ResinLV EPO +anhydride+catalyst+ Co-katalyst	89.4

Table 2: Gelcontent results different samples

Conclusion

The developed thermoset formulations exhibited consistent curing behavior and thermal stability across all systems. All combinations achieved gel contents above 90% and glass transition temperatures exceeding 95 °C, confirming successful network formation. The presence of biochar did not negatively affect the curing process or thermal properties, indicating its compatibility within the material system and potential for use in sustainable, high-performance applications.

Acknowlegement

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References

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