BIOCOMPOSITES FROM HEMP FIBERS AND ACRYLATED EPOXIDIZED SOYBEAN OIL-BASED RESINS

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ABSTRACT

Biocomposites from hemp fibers (HFs) and acrylated epoxidized soybean oil (AESO) were prepared by using a bifunctional isocyanate, i.e., isocyanatoethyl methacrylate (IEM), as crosslinker and coupling agent. The static and dynamic mechanical properties of the obtained HF-AESO composites were evaluated to study the efficiency of IEM addition in the composites. The results showed that IEM incorporation greatly contributed to increasing the tensile and flexural properties, storage modulus, and glass transition temperature of the resulting composites. This improvement could be attributed to the dual role of IEM in the composite systems, i.e., the increased crosslinking density provides high rigidity and stiffness for the AESO resins, and the enhanced fiber-matrix interface bonding contributes to stress transfer through the interface of composites more effectively.

1 INTRODUCTION

Acrylated epoxidized soybean oil (AESO), synthesized from the reaction of epoxidized soybean oil with acrylic acid, has been commercially available and widely employed in developing thermosetting resins for fiber-reinforced composites [1-2]. However, AESO is highly viscous at room temperature and has a low crosslinking capacity due to its long aliphatic chains and low degree of unsaturation. Therefore, a reactive diluent (RD) is highly desired for AESO-based matrices because the RD could facilitate the formulation of a resin with low viscosity to wet reinforcing fibers well and the formation of a three-dimensional network with high crosslinking density after the resin is cured. Furthermore, for natural fibers reinforced AESO composites, the intrinsic challenge is the poor interfacial adhesion between the hydrophilic fibers and the hydrophobic matrices.

In this work, hemp fibers (HFs) reinforced AESO composites were prepared by using a bifunctional isocyanate, i.e., isocyanatoethyl methacrylate (IEM), as crosslinking and coupling agents to improve simultaneously crosslinking density of AESO matrix and interfacial adhesion between HFs and the AESO matrix. The effects of IEM addition on the properties of the composites were investigated by mechanical property tests and dynamical mechanical analysis (DMA).

2 MATERIALS AND METHODS

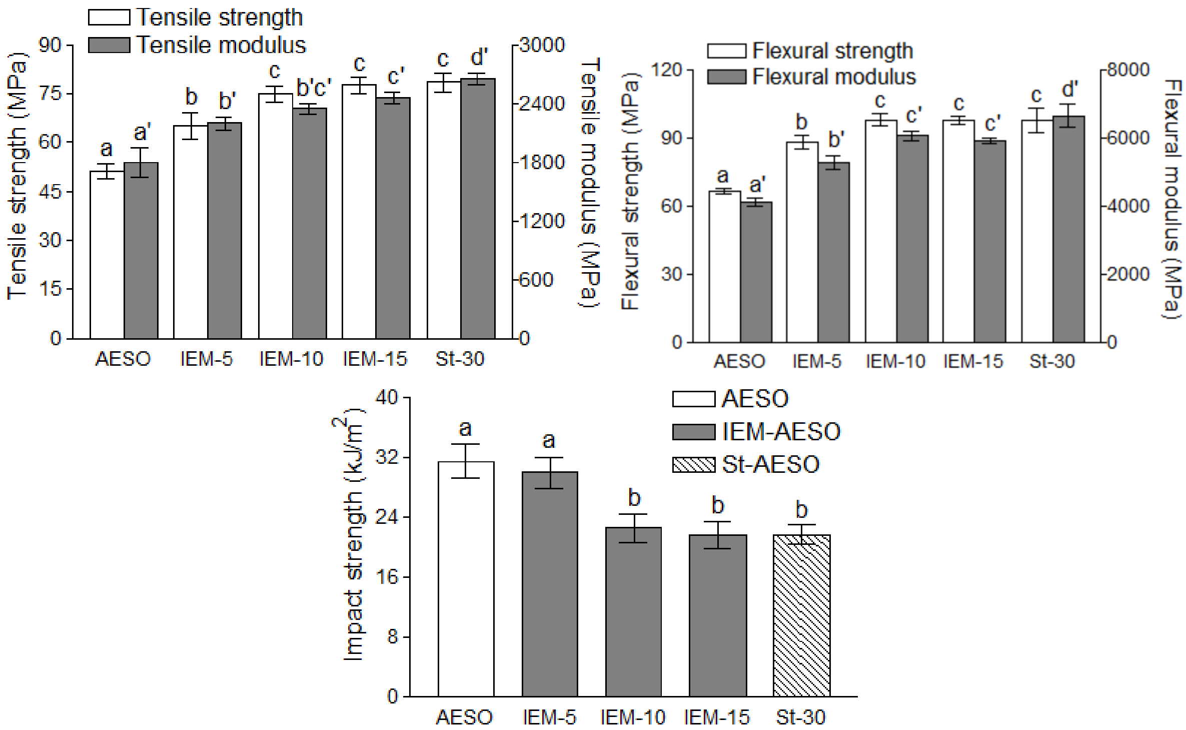
HFs (average length: 3.9 cm; average width: 64.6 μm) were provided by Sanxing Hemp Industry (Tongling, China). AESO was purchased from Sigma-Aldrich. IEM (98%, inhibitor: ≤ 0.1% BHT) was obtained from Runze Pharmaceuticals (Suzhou, China). tert-butyl peroxybenzoate (98%, TBPB) was purchased from Aladdin (Shanghai, China).

AESO was mixed with IEM at weight ratios of 95:5, 90:10 and 85:15 (AESO:IEM) in a beaker at 70 ℃ using a magnetic stirrer at 500 rpm for 10 min, respectively. After cooling to room temperature (r.t.), TBPB (2 wt% based on the resin) was added to the mixture, which was further stirred for 5 min to form the final resins. The AESO resins containing different IEM usages were denoted as IEM-5, IEM-10, and IEM-15, respectively.

The HF-AESO composites with 50 wt% fiber content were fabricated from HFs and AESO resins via a compression molding technique. The hot-press process was performed at r.t. for 5 min, at 70 ℃ for 5 min, and at 160 ℃ for 30 min under a pressure of 6 MPa. Finally, the prepared composite boards were used for static and dynamic mechanical properties tests.

3 RESULTS AND DISCUSSION

The mechanical properties of the composites were tested and given in Figure 1. The composites modified with IEM had much higher tensile and flexural properties than the composites from pure AESO resins. Compared to the composites from pure AESO, the tensile strength, tensile modulus, flexural strength, and flexural modulus of composites IEM-15 increased by 51.41%, 36.98%, 47.44%, and 43.86%, respectively. However, the modification significantly decreased the impact strength of the composites due to the increased crosslinking density. The impact strength of the composites decreased from 31.38 to 21.54 kJ/m^2 after the incorporation of 15 wt% IEM. Further, the composites with 10 wt% IEM as modifier indicated comparable tensile and flexural properties with the composites with 30 wt% styrene as crosslinking agent.



Note: The error bar on the top of each column represents the standard deviation of the mean. The means do not differ significantly from one another when they have the same letter(s) on the top of the columns.

Figure 1: Mechanical properties of HF-AESO composites.

The storage modulus and damping parameter (tan δ) as functions of the temperature for HF-AESO composites were presented in Figure 2. The storage modulus for all composites dramatically decreased with increasing temperature from 25 to 120 ℃ and then reached a rubbery plateau at higher temperatures. The initial storage modulus of pure AESO was 4250 MPa, whereas that of composites IEM-15 increased to 5500 MPa, which was slightly higher than the styrene-crosslinked composites (5350 MPa). Only a peak maximum (α-relaxation) was observed on the tan δ curves for the composites (Fig. 2b), which is taken as the glass transition temperature (T_g), showing the homogeneous nature of the composites. The T_g of the IEM-modified composite increased to 63.46 ℃ compared to the styrene-crosslinked composites (53.56 ℃). This indicated a considerably improved crosslinking density and interfacial adhesion of the composites after IEM modification.

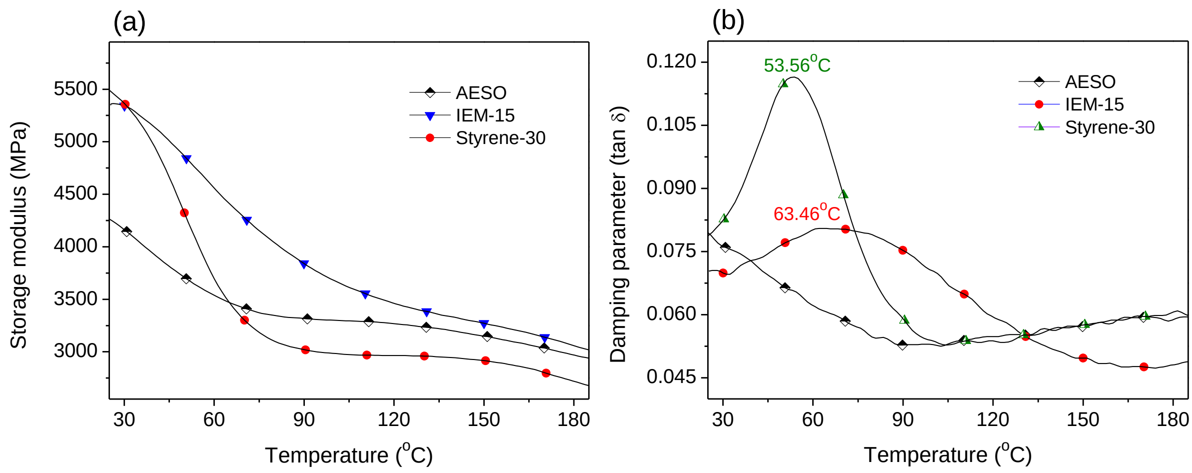


Figure 2: DMA curves of HF-AESO composites.

4 CONCLUSIONS

IEM was successfully introduced into HF-AESO composites and functions as crosslinking and coupling agents to improve the crosslinking level and interfacial adhesion of the composites and hence the static and dynamic mechanical properties.

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