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Laminated Epoxy Biocomposites Based on Clay and Jute Fibers

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Abstract

Jute/epoxy hybrid laminated biocomposites were manufactured by using Illite clay particles at various content (5 wt.% − 20 wt.%). The effects of hybridization on the morphology, structure, and mechanical properties were investigated. The properties of the biocomposites reinforced with jute fibers were mainly influenced by the interfacial adhesion between the jute fibers and the epoxy matrix. An alkali treatment was applied to improve the interfacial fiber-matrix adhesion and thus obtaining better mechanical properties. Besides the chemical treatment, epoxy hybridization using clay particles also had a strong effect on the overall properties of laminated biocomposites. The mechanical properties of the jute/epoxy biocomposites reinforced with Illite clay increased with clay content, up to an optimum value at 15 wt.%. The average technique and the laminates theory were performed to validate the coherence of the elastic moduli between the calculated and experimental values. A difference between the experimental and predicted data was observed, which was attributed to the simplifying assumptions made in both models. The laminates theory gave better overall predictions.

Keywords: laminated biocomposites, hybridization, mechanical properties, interfacial adhesion, surface treatment

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1 Introduction

Composite materials based on polymer matrices are widely used in different industrial sectors such as aerospace, automotive, and civil applications[1]. Because of growing environmental awareness, the use and disposition of composite structures typically produced with synthetic fibers such as glass fibers, have been criticized. The main problem is how to get rid of these materials at the end of their useful life. Today, one of the main research areas is the development of composites reinforced with natural/lignocellulosic fibers. These fibers can provide interesting properties, especially related with environmental protection such as recyclability, renewability, low cost, biodegradability, low density, and high specific properties[2–5].

Typically, long and short natural fibers such as flax, jute, pine cone, bagasse, doum, alfa, and sisal are used to reinforce thermoplastic and thermoset matrices. Studies on natural fibers reinforced composites have increased over the last years and opened up further industrial possibilities[6–8]. However, the hydrophilic character of natural fibers due to their high polysaccharides content limits their use as reinforcement in hydrophobic matrices[9]. This incompatibility between hydrophilic fibers and hydrophobic matrices leads to weak interfacial adhesion. This is why the control of the interface plays an important role in stress transfer from the matrix to the fibers[10]. Owing to the hydrophilic character of natural fibers, the applied stresses are not effectively transferred to the fibers and their reinforcing effect remains underexploited[11]. Nevertheless, interfacial adhesion can be improved through a chemical surface treatment. Generally, these treatments (*e.g.* alkali) are used to remove lignins, pectins, and impurities on the fibers surface. As a result, the relative cellulose content increases to get better mechanical properties of the resulting fibers[12,13].

The mechanical properties of composites, especially the properties of thermoset matrices such as polyester, epoxy, and phenol, can be improved by the

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addition of inorganic fillers such as talc and calcium carbonate[14]. These fillers also reduce the costs and improve the mechanical and thermal properties of the resulting materials[11].

In this study, alkali treated jute fibers reinforced epoxy composites were prepared following Liquid Composite Molding (LCM) techniques. The epoxy matrix was also reinforced with different clay content (0 wt.% – 20 wt.%). Fourier Transform Infrared Spectroscopy (FTIR) analysis was used to confirm the efficiency of the fiber surface treatment. The resulting composites were mechanically characterized using tensile and torsion tests. Finally, the prediction of the mechanical properties (Young's modulus, shear modulus, and Poisson coefficient) was done using simple models.

2 Materials and composite preparation

2.1 Materials

Jute fibers mats were obtained from SONAJUTE (Casablanca, Morocco) and the epoxy resins from the ATLAS Company. Illite clay extracted from the Rhamna region in Morocco was used to improve the mechanical properties.

2.2 General process for jute and clay treatment

An alkali treatment was applied to the jute fibers to remove lignins which have a hydrophilic character, and improve the compatibility with the matrix. The chemical treatment was performed in a 6.4% NaOH aqueous solution at 50˚C for 24 h. Thereafter, the fibers were washed several times with distillated water until all the sodium hydroxide was eliminated. Finally, the treated fibers were dried at 60˚C for 24 h. On the other hand, the clay particles were treated to remove any organic compounds, impurities and non-clay materials. Accordingly, a clay suspension was obtained by mixing clay of 100 g with distilled water of 500 mL. The suspension was filtered through a 100 μm sieve and dried at 110˚C. Then, the material was crushed and powdered using a universal cutting mill (FRITSCH Pulverisette 19) with 1mm sieve openings.

2.3 Composite preparation

The jute mats were first cut to the desired dimensions of 120 cm in length and 120 cm in width. Then, the epoxy resin was filled with a selected amount of clay using mechanical stirring. The contents of clay used here are presented in Table 1.

The samples were prepared in a stainless steel mold with jute impregnation by the epoxy resin filled with the different clay content.

The mold was closed with a hydraulic press until the desired thickness was obtained. Then, the compressed system was maintained for 24 h and then a demolding step was performed as shown in Fig. 1. The samples were cut at 0˚ and 45˚ direction. Finally, crosslinking (curing) was carried out on the prepared samples in an oven (MTI KSL 1400X) at 150˚C for 15 min.

3 Characterization techniques

3.1 Scanning Electron Microscopy (SEM)

SEM was used to determine the morphology of the clay and to investigate the clay dispersion/distribution in the polymer matrix. To obtain clean and accurate fractures, all the composites were cryofractured in liquid nitrogen. Then, the exposed surfaces were covered by Au/Pd and viewed with a JEOL JSM 840 SEM at 15 kV with different magnifications.

3.2 Fourier Transform Infrared Spectroscopy (FT-IR)

FT-IR of the treated and untreated jute fibers was carried out using an ABB Bomen FTLA 2000-102 spectrometer (ATR, SPECAC GOLDEN GATE). The spectra were obtained by an accumulation of 16 scans and a resolution of 4 cm^{-1}. FT-IR enabled to characterize the chemical structure by identifying the functional groups present in each sample.

3.3 Tensile testing

Tensile tests were performed on a universal testing machine INSTRON 8821S (Instron, USA) at a crosshead

Table 1 Contents of clay used for the production of composites

Layers stacking	Clay (wt.%)	Cutting direction
[0/45/0/45/0]	0	0˚
		45˚
	5	0˚
		45˚
	10	0˚
		45˚
	15	0˚
		45˚
	20	0˚
		45˚