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Mechanical Properties of Coconut Fibers Reinforced Polyester Composites

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Abstract

Actually, studies about the utilization of natural fibers as reinforcement in polymeric composites are increasing due to the improvements that fibers can provide to the product. In this work, chemical modification of the coconut fibers by alkaline treatment was studied in order to use them as reinforcement in polyester resin. Coconut fibers were modified during 1 hour with sodium hydroxide solution 1% wt/v. The modified fibers were evaluated by scanning electron microscopy, X-ray diffractometry, thermal analysis and Fourier Transform infrared spectroscopy. The composites were prepared by compression molding technique using 10% wt of fibers. The mechanical properties were evaluated by tensile and fatigue tests. The surfaces of the fractured specimens were examined in order to assess the fracture mechanisms. Results presented a decrease in fatigue life of composites when applied greater tension, due to bonding interfacial, which was not adequate.

Keywords: Coconut fibers; Composites; Fatigue; Interfacial bonding

1. Introduction

Nowadays, there is an increasing environmental consciousness and awareness of the need for sustainable development, which has raised interest in using natural fibers as reinforcements in polymer composites to replace synthetic fibers. The advantages of natural fibers include low cost, low density, unlimited and sustainable availability, and low abrasive wear of processing machinery [1].

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Several investigations have been carried out to assess the potential of natural fibres as reinforcement in the polymers [2–5]. The results have shown that natural fibers present potential to be used as reinforcement for plastics, but generally they do not attain the full mechanical performance levels of glass fibers reinforced plastics.

However, composite materials need a better understanding of their failure mechanisms. The stresses encountered during their service life are frequently cyclical in nature causing fatigue degradation and are responsible for the majority of failures of composite materials. Fatigue behaviour of composites reinforced with synthetic fibers has been extensively studied by several workers [6-8]. On the other hand, the study of fatigue behaviour of natural fibers composites has received little attention from the scientific community.

Recently, however the natural fibers reinforced composites have attracted substantial attention as a potential structural material for low cost applications. Hence the study of their fatigue behaviour is very important in order to predict their behaviour under various types of repetitive loading.

In this paper was examined the fatigue behaviour of polyester resin matrix composites reinforced with alkali treated coconut fibers.

2. Experimental

2.1. Fibers

Coconut fibers were extracted from exocarp and dried at 80 °C for 24 h. After being ground in a mill and sieved. To remove the soluble extractives and to facilitate adhesion between fibers and matrix, the untreated coconut fibers were modified by pre-treatment with alkaline solution 1% (w/v). Furthermore the fibers were filtered in a vacuum filter and fibers were washed with distilled water. Then, fibers were dried in an oven at 100 °C for 24 h.

2.2. Characterization of coconut fibers

Scanning electron microscopy (SEM) was used to investigate the surface morphology of treated and untreated coconut fibers. Samples were mounted on conductive adhesive tape and coated with gold using an ion sputter and observed with a JEOL JSM 5310 microscope operated at 15 kV. X-ray diffractometry (XRD) measurements were performed on a Shimadzu diffractometer model XRD6000. The diffracted intensity of CuKα radiation (0.154 nm, 30 kV and 40 mA) was measured in a 2θ range between 10° and 40°. The coconut fibers samples (treated and untreated) were subjected to crystallinity analysis. The chemical structure of coconut fibers was evaluated by Fourier Transform infrared spectroscopy (FTIR). The FTIR spectra were obtained on an FTIR spectrophotometer (Perkin Elmer). The samples were prepared by mixing the materials and KBr in a proportion 1:200 (w/w). For all spectra, 16 scans were accumulated with a 4 cm⁻¹ resolution. Thermal analysis (TGA) technique was used to analyze the thermal stability of coconut fibers treated and untreated. The thermal behaviour of each dried samples (~10 mg) was determined, using a TGA 50 series thermogravimetric analyzer (SHIMADZU), across a temperature range of 30–550 °C, at a heating rate of 10 °C.min⁻¹ in a nitrogen atmosphere.

2.3. Composites preparation

The composites were manufacture in a glass mould (250 mm x 250 mm). For the preparation of composites were used: polyester resin and treated coconut fibers. The composites were prepared by compression molding technique. The components of the polyester resin were mixed manually. Furthermore, the fibers were added. The concentration of fibers added was 10 wt% of the final mass of
2.6. Mechanical properties

To determine the fatigue behaviour of the composites was necessary to determine the parameters of static mechanics strength of the material, for use as reference in the fatigue tests. Mechanical tests were carried through in a servo-hydraulic MTS model 810.23M. The form and dimensions of the samples tension and tension-tension fatigue were defined were carried out according to ASTM standards D3039. It was tested a sample for each applied tension, under ambient temperature, to 6 Hz frequency and load ratio R=0.1. The values of maximum tension for each test were defined around 16 MPa (strength composite) aiming at to point out curve S-N in the band between $10^3$ and $10^7$ load cycles. The fractured surfaces were examined by scanning electron microscopy.

3. Results

3.1. Characterization of fibers

SEM provides an excellent technique for examining the surface morphology fibers. Figure 1 present SEM micrographs of treated and untreated coconut fibers. Examination of the untreated fibers shows a large amount of debris adhering to the surface of the fibers bundles, because they are coated with non-cellulosic material (Figure 1a). Li et al [9] also observed behaviour same to the analyze hemp fibers. After the treatment on coconut fibers it was observed the removal of wax, pectin, lignin and hemicelluloses on fibers surface (Figure 1b). It was verified also the elimination of superficial layer (parenquimas cells), increasing the contact area of exposition of fibrils (reentrance) and globular marks (salience). As a consequence, it was observed an increase in the roughness of fibers, which can increase of the adhesion between fibers and matrix.

Figure 1. SEM of coconut fibers: (a) untreated; (b) treated.
Figure 2. X-ray diffractogram of the coconut fibers.

Figure 2 evidence the X-ray diffractogram of coconut fibers, which presents two peaks well defined. These peaks are situated at \(2\theta = 15.4^\circ\) and \(2\theta = 22.5^\circ\), which can be attributed to cellulose I and IV. These two peaks are attributed to the (2 0 0) and (1 1 0) crystallographic planes. Crystallinity index (CI) was estimated using method similar to Mulinari et al [3]. The crystallinity index treated and untreated coconut fibers presented 61% and 68% of crystallinity, respectively. These values can be attributed to the fibers modification.

Figure 3 shows TGA curves of treated and untreated coconut fibers. From the TGA curves it was possible to observe the starting of treated and untreated coconut fibers weight loss at 100 °C. This corresponds to the vaporization and removal of bound water in the samples. The next weight loss of the coconut fibers is attributed to thermal degradation of fibers. Analyzing Figure 3, it was observed that treated coconut fibers present higher thermal stability compared to untreated fibers. This occurs in the temperature range of 220 – 300°C. After 380°C, the residual is due to decomposition of samples.
Figure 4 shows infrared spectra of coconut fibers. The most visible differences between the spectra of untreated and treated coconut fibers are the modifications of the signal at 2885 cm\(^{-1}\) and 1732 cm\(^{-1}\), characteristics of the stretching of symmetrical CH groups and stretching of unconjugated CO groups present in polysaccharides and xylans. Considering the first region, the ratio between intensity of the C-H stretching band (~2900 cm\(^{-1}\)) is lower in the spectrum of the treated coconut fibers compared to untreated coconut fibers.

3.2. Mechanical properties

Figure 5 shows curve SxN obtained from fatigue tests. Analyzing Figure 5, it was observed the relation between maximum tension applied and cycles number for rupture. The composites materials of performance high present a relation between tension strength and fatigue strength. However, this relation decrease when is used natural fibers. The material studied presented a relation between fatigue strength for \(10^5\) cycles and tension strength 6 MPa. An increase of this relation is necessary. This fact can have occurred due to bonding interfacial. Figure 6 shows the fracture region composites, which evidence failure mechanism.
Figure 6. SEM of fracture surface of composites.

Analyzing the Figure 6, it was observed poor dispersion of fibers in the matrix, fractured fibers and presence of pull out. Of his way is necessary improve treatment on fibers surface to obtain improve results of mechanical properties.

4. Conclusions

Fatigue behaviour in composites presented a decrease in fatigue life when was applied greater tension. It was observed some failure mechanism as fractured fibers and presence of pull out and poor bonding interfacial between fiber and matrix. This fact occurred due to the treatment suggested on fibers surface. Of this form will be necessary improve the treatment on fibers surface to obtain improve results.

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References