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Mechanical properties of HDPE/textile fibers composites

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Abstract

The use of natural fibers as reinforcement for thermoplastics has generated much interest due to the low cost, low density, high specific properties characteristics. In this work the mechanical properties of high density polyethylene/ textile fibers residues composites were studied. Effect of pretreatment with sulfuric acid on textile fibers to prepare composites was made to provide an improvement in mechanical properties of these materials. This treatment on fibers was evaluated by X-ray diffraction technique. Composites were produced in a thermokinetic mixer in the following composition: 5 and 10 wt% fibers. After mixing the samples were injection molding according to ASTM D-638 specification. Specimens were tested in tensile mode and composite fractures surface were analyzed in a scanning electron microscopy. Also was studied moisture absorption. Results showed that HDPE/ textile fibers residue presents good mechanical performance compared with high-density polyethylene.

Keywords: Textile fibers; Mechanical properties; Interfacial bonding; Moisture absorption

1. Introduction

Natural fibers reinforced polymer composites represent one of today's fastest growing industries. These fibers present a potential alternative in reinforced composites because of growing environmental awareness and legislated requirements compared to synthetic fibers such as carbon and glass [1-3]. Due environmental consciousness, worries about the ever faster depletion of limited petroleum reserves as well as the government regulations around the world have encouraged the scientists to develop eco-friendly, sustainable and biodegradable composite materials and plastics. This petroleum- based synthetic fiber, resins and composites have caused serious ecological and environmental problems due to their non biodegradable nature [4]. Several authors reported the use of natural fibers such as bagasse [5], sisal [6], banana [7], jute [8], and hemp [9] as reinforcement in polymer matrix.

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These fibers present much advantages as reinforcement in polymers such as are biodegradability, abundance, health risks to be minimal, stiffness, impact resistance, low density, low flexibility during processing and less wear and tear resulting from the machine, desirable fibers aspect ratio and relatively high tensile and flexural modulus [10].

However certain drawbacks, such as the incompatibility between fibers and polymer matrices, the tendency to form aggregates during processing and the poor resistance to moisture, reduce the use of these natural fibers as reinforcements in polymers. Because of this, several treatments and modifications are being used to improve fibers/matrix compatibility, such as bleaching, acetylation, estherification and use coupling agent [11, 12].

Of this way, the objective of this work was available the effect of the modified textile fibers from industrial residue on mechanical properties high density polyethylene/textile fibers composites. The modification the fibers were evaluated by X-ray diffractometry (XRD) technique.

2. Experimental

2.1. Fibers

The fibers textile residue used in this study were manufactured by provided by Primar in Juiz de Fora-MG. Chemical modification of the textile fibers from industrial residue were submitted to dilute acid pretreatment, under these conditions: 1.0% (w/v) H_2SO_4 solution in a 1:10 solid: liquid ratio, 120 ˚C for 10 min. After reaction the resulting solid material was separated by centrifugation, washed with water until neutral pH, and dried at 50 ± 5 ˚C to attain 50% moisture content. This modification was made to remove the soluble extractives and to facilitate adhesion between fibers and matrix

2.2. X-ray diffraction of fibers

XRD measurements were performed on a Shimadzu diffractrometer model XRD6000. The diffracted intensity of CuKα radiation (0.154 nm, 30 kV and 40 mA) was measured in a 2θ range between 10^o and 40^o. The textile fibers samples (modified and unmodified) were subjected to crystallinity analysis.

2.3. Composites preparation

Textile fibers modified were mixed with the HDPE in a thermokinetic mixer, model MH-50H, with speed rate maintained at 5250 rpm, in which fibers were responsible for 5 and 10 wt% in the composition. After the mixture, composites were dried and ground in mill, model RONE. Composites and pure HDPE were placed in an injector camera at 165 ^oC and 2 ºC min^{-1} heating rate in a required dimensions pre-warm mold to obtain tensile specimen.

2.4. Mechanical properties

Composites were analyzed in an EMIC testing machine (model DL2000), equipped with pneumatic claws. In the tensile tests, five specimens of composites were analyzed, with dimensions in agreement with the ASTM D 638 standard: 19 mm width, 165 mm length and 3.2 mm thickness and 10 mm min^{-1} crosshead speed. Samples submitted to tensile tests were cut and of the composites fractured surface were analyzed by scanning electron microscopy.

2.5. Moisture absorption property

Effect of moisture absorption on composites and pure HDPE were investigated in accordance to ASTM standards D570. The percentage of moisture absorption in these materials was calculated by weight difference between the samples immersed in water and the dry samples using the following expression (1):

$$\Delta M\,(\%) = (M_f - Mi\,/\,M_i\,) * 100 \qquad (1)$$

where ΔM(%) is moisture uptake, M*f* and M*i* are the mass of the specimen after and before immersion.

3. Results

3.1. Characterization of fibers

XRD studies of the modified and unmodified textile fibers from industrial residue were done to investigate the crystalline behavior of the fibers. The major peaks observed for fibers are at 2θ diffraction angles of 15.1^o, 16.9^o and 22.8^o representing (110) and (200) planes indicating the presence of type I cellulose as can be seen Figure 1. Table 1 presents the crystallinity index calculates according method utilized by Mulinari et al [2].

Table 1. Crystallinity index of the fibers

Samples	Crystallinity (%)
Unmodified textile fibers	69
Modified textile fibers	78

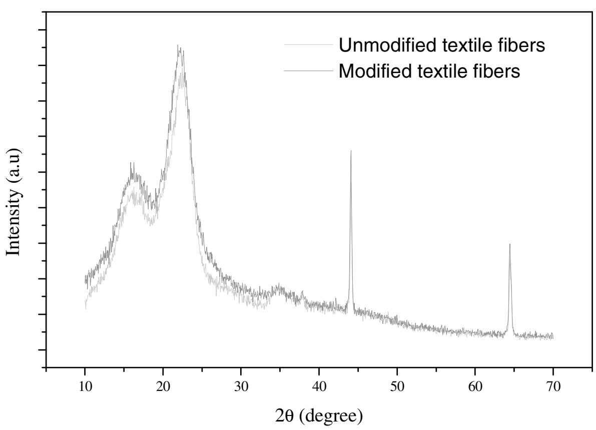


Figure 1. X-ray diffractogram of the textile fibers from industrial residue.

3.2. Mechanical properties

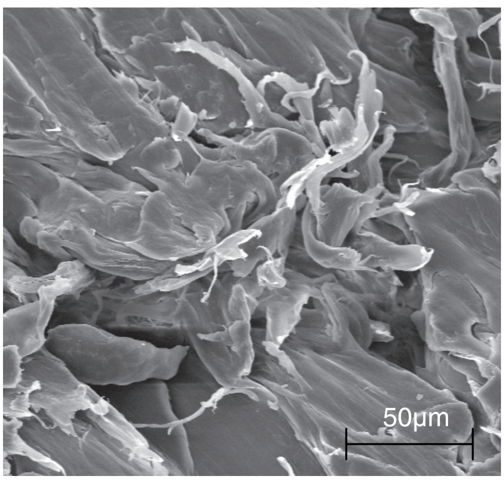
Mechanical properties of composites are summarized in Table 2. Composites presented higher tensile strength and modulus when compared to the pure high density polyethylene (HDPE).

Table 2. Mechanical properties of the materials

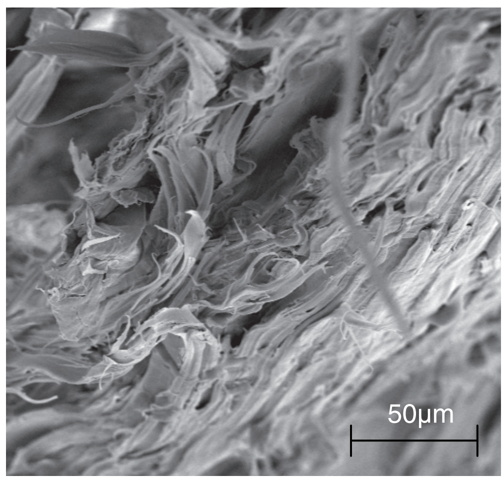
Samples	Tensile strength (MPa)	Tensile Modulus (MPa)
HDPE	15.7 ± 1.1	732.5 ± 90.6
HDPE/FT5%	22.8 ± 0.7	1239.6 ± 72.2
HDPE/FT10%	24.1 ± 0.6	1557.3 ± 88.8

(Reinforcement in wt%)

The amount of added reinforcement also contributes to variation of the tensile modulus. Fibers insertion can contribute to the modulus increase, because the Young's modulus of the fibers is higher than the thermoplastic modulus. However, to obtain a significant increase, a good interfacial bond between fiber and matrix is necessary. The tensile strength exhibited a good interaction between fiber and matrix, with increases of 45.2% and 53.5%, compared to the pure polymer. However, HDPE/FT 10% composite presents higher average values for tensile strength and modulus compared to the pure HDPE and HDPE/FT 5% composite. Experimental results in Table 2 may be explained by interaction between fiber and matrix during the mixture process. Of this way, can be affirmed that the modified textile fibers made was adequate. This can be confirmed by the fracture surface analysis as can be observed Figure 2. It corresponds to the surface of fractured HDPE/ FT5% composite (Figure 2A) and HDPE/ FT 10% composite (Figure 2B). Analyzing fractures is observed a significantly improve in the compatibility between the matrix and fibers, and the matrix was well bonded to the fibers.



(a)



(b)

Figure 2. SEM of fractures composites: (a) HDPE/ FT 5%; (b) HDPE/ FT 10%.

3.3. Moisture absorption property

Figure 3 shows percentage of moisture absorbed in materials. It was observed that the composites presented higher moisture absorption compared to HDPE pure. This fact occurred due the natural fibers change its dimensions when absorb humidity. Therefore the composite (HDPE/FT 10%) presented higher moisture absorption compared to the others. Moisture absorption increases with increasing fibers loading. Mulinari et al. [2] investigated the relationship between the moisture absorption of sugarcane bagasse fibers reinforced HDPE composites and the fibers loadings 5%, (10%, 20%, 30% and 40% by weight). They found that the moisture absorption increased almost linearly with the fibers loading.

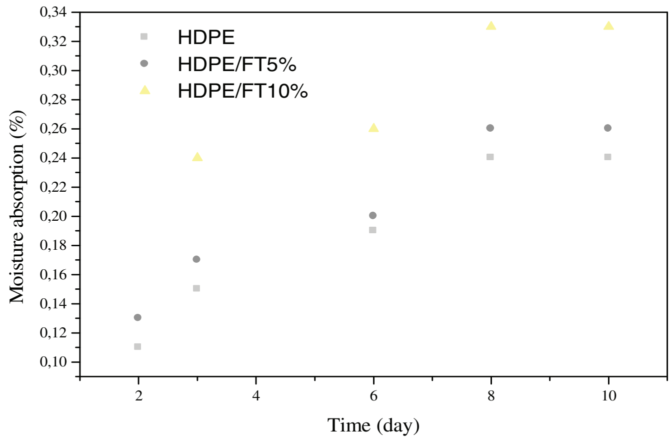


Figure 3. SEM of the textile fibers from industrial residue: (a) unmodified; (b) modified.

4. Conclusions

After conducting the experimental work and discussing the results relieved that addition of modified textile fibers from industrial residue to matrix (HDPE) improved the tensile strength and modulus, well as moisture water. The fracture region showed that there was an excellent dispersion of fibers in the matrix and a good interfacial bonding between fiber-matrix, which caused this improve in the mechanical properties of composites.

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