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IZOD TOUGHNESS CHARACTERIZATION OF EPOXY COMPOSITES REINFORCED WITH CONTINUOUS AND ALIGNED JUTE FIBERS[1]

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Abstract

A wide variety of natural lignocellulosic fibers are increasingly being considered as viable alternatives to replace glass fiber in polymer composites. Jute fibers reinforced polymer composites are among the most investigated and applied natural composites. In this past decade the mechanical properties of these composites has been assessed for various types of test conditions. Owing to its low cost and weight, it may be used in many applications, including engineering composites. In fact, epoxy composites reinforced with natural lignocellulosic fibers have attracted interest in several areas, especially engineering due to its low cost, besides being lighter. The present work investigates the toughness of epoxy composites reinforced with up to 30 wt% of continuous and aligned jute fibers. Standard Izod notched specimens were impact tested and the results showed an increase in toughness with the amount of jute fibers. Observation of the composite fracture by SEM revealed that the jute fibers act as an effective obstacle to crack propagation.

Key words: Jute fibers; Epoxy composites; Izod test; Fracture analysis.

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1 INTRODUCTION

Some measures are currently being taken in order to benefit the environment, such as reducing energy consumption, the promotion of clean systems, the control of CO_2 emissions and the use of natural materials.(1) In particular, the substitution of synthetic materials similar nature also contributes to other environmental protection measures.(2)

The interest of this research is to develop composites with epoxy resin matrix reinforced with continuous and aligned jute fibers, for applications in various industries, including construction and automotive industry. Conflicts related to the use of non-renewable forms of energy are increasing the interest to enter the market to replace natural materials, synthetic materials synthetics have a higher power consumption in its manufacture.(3-6)

Therefore, applications of natural lignocellulosic fibers obtained from cellulose-based plants are receiving increased attention as an alternative to replace more environmentally correct non-recyclable materials, energy intensive and glass fiber composites in Netravali and Chabba.(7)

The production system of composites reinforced with these lignocellulosic fibers, in comparison with similar composites reinforced with glass fibers, causes low equipment wear, as well as a relative saving in energy. In addition, it has been shown(8-10) that the incorporation of lignocellulosic fibers may significantly improve some mechanical properties of polymeric composites.

These applications require that they be known mechanical properties of the composite, especially his tenacity, of importance both in processing and in the use of components manufactured with this type of material. Therefore, the objective of this work was to investigate the toughness of epoxy composites reinforced with continuous and aligned jute fibers by the impact energy determined in standard Izod notched specimens. The fracture of the specimens was analyzed by scanning electron microscopy (SEM) to investigate the possible mechanisms causing the rupture of the material.

Jute is an abundant fiber extracted from leaves of a cultivated bush-like plant (*Chorchorus capsularis*) illustrated in Figure 1.

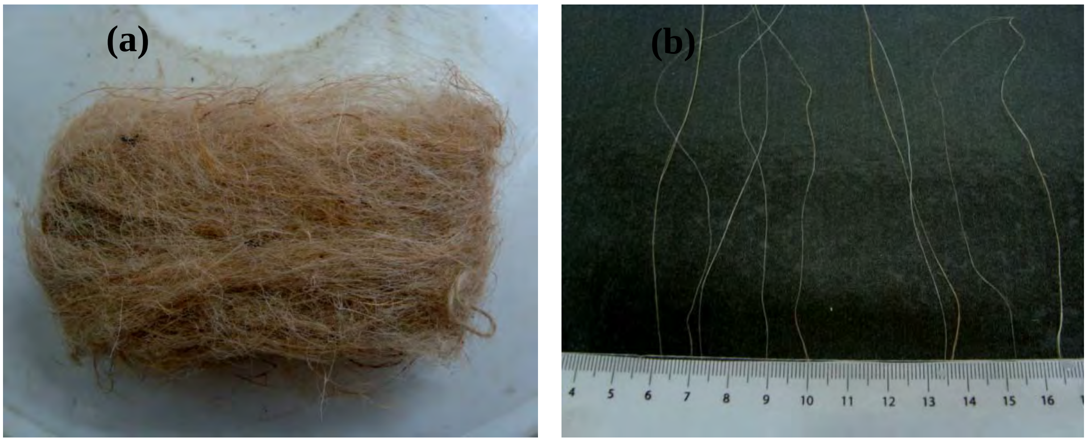

Figure 1. A bundle of as-received (a) and individually separated jute fibers (b).

2 MATERIALS AND METHODS

The jute fibers used in this work were supplied as a 5kg lot by the Brazilian firm Sisalsul.

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Once received, the fibers were separated, cleaned and dried at room temperature. This was followed by the blending of fibers in amounts of 0, 10, 20 and 30% by volume epoxy resin type commercial diglycidyl ether of the bisphenol A (DGEBA) cured with triethylene tetramine (TETA) in a stoichiometric ratio of 13 parts of hardener to 100 parts of resin.
Plates with 10 mm thickness, in the rectangular steel mold with dimensions of 152 x 125 mm were prepared. The fibers were aligned along the dimension of 125 mm. Samples of each composite were then cut, according to the direction of alignment of the fibers into bars measuring 12.7 x 62,5 x 10 mm which served as a basis for making specimens for Izod impact test in accordance with ASTM D256 .

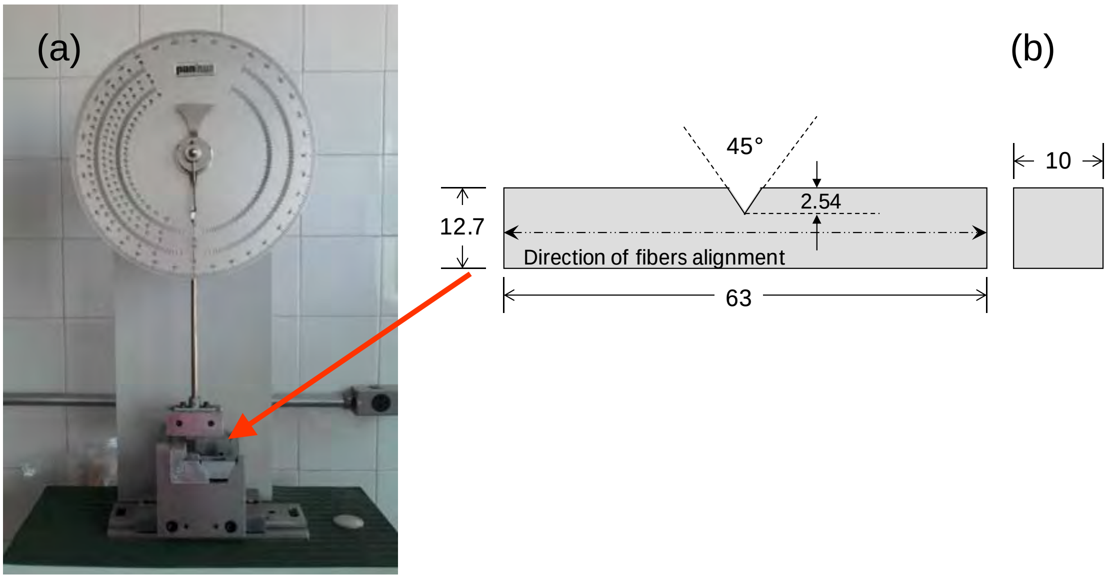

Figure 2. Izod equipment and standard specimen schematic.

The notch was prepared with a depth of 2.54 mm and angle of 45° required by the standard (Figure 2b), we used a manual carver style brand CEAST Notchvas. The specimens were tested in an instrumented pendulum Pantec (Figure 2a), in Izod configuration.
The impact fracture surface of the specimens was analyzed by scanning electron microscopy, SEM, in a model SSX-500 Shimadzu microscope. Gold sputtered SEM samples were observed with secondary electrons imaging at an accelerating voltage of 15 kV.

3 RESULTS AND DISCUSSION

The results obtained in the Izod impact tests of epoxy composites reinforced with continuous and aligned jute fibers with different volume fractions are shown in Table.

Table 1. Izod impact energy for epoxy composites reinforced with jute fibers

Volume fraction of jute fibers (%)	Izod Impact Energy (J/m)
0%	39 ± 12,74
10%	144,4 ± 28.19
20%	235.06 ± 28,75
30%	353,38 ± 46,29

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Based on the results shown in Table 1, the variation of the Izod impact energy with the amount of jute fiber in the epoxy composite is shown in Figure 3.

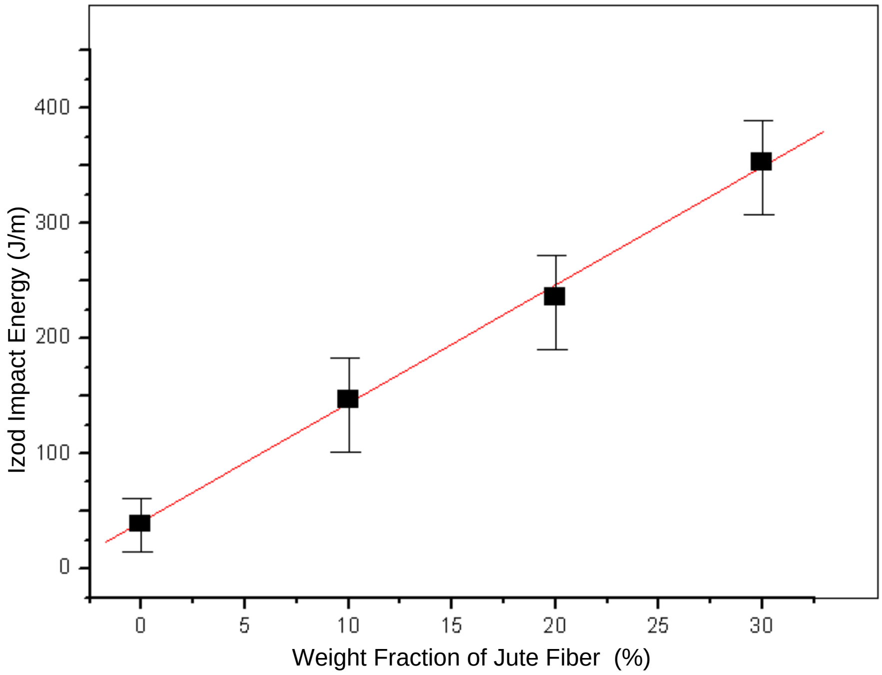

Figure 3. Izod impact energy as a function of the amount of jute fiber.

In this figure it should be noticed that the jute fibers incorporation into the epoxy matrix increase in Izod impact energy with the volume fraction of jute fibers. It is also important to note that the points relating to composites have error bars, relative to the standard deviation, relatively large. The relatively high dispersion of values, given by the standard deviation associated with the higher fiber percentage points in Figure 3, is a well known heterogeneous characteristic of the lignocellulosic fibers.[11-13]
Even considering the error bars, it is possible to interpret the increase of impact energy, i.e., toughness of the composites in Figure 3, as varying linearly with volume fraction of jute fibers. A straight line passing through the median demonstrates this growth. The mathematical interpretation for this growth corresponds preliminarily Equation 1.

$$E_e = 10.48 + 19\ F \quad (1)$$

Where E_e is the energy absorbed by the epoxy matrix composite in the Izod impact J/m and F the volume fraction of ramie fibers in percentage.
Table 2 compares values of Izod impact toughness of polymeric composites with different natural fibers. In this table, it is worth mentioning that among available data on thermoset polymeric composites reinforced with continuous and aligned lignocellulosic fibers, the present work on jute reinforced epoxy composite is the one that shows the highest toughness.
In any case, polyester matrix or epoxy of this work, boosting with jute fibers substantially increases the resistance of the composite. In fact as shown in Table 2, using aligned and long jute fibers for composites are obtained relatively to the impact toughness greater than composites reinforced with other lignocellulosic fibers.

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Table 2. Impact toughness values of composites reinforced with lignocellulosic fibers

Composites with 30% of fiber	Impact Test	Impact Thougness (J/m)	Reference
ramie/epoxy	Izod	353,38	This work
ramie/polyester	Charpy	1004,8	(11)
coir/polyester	Charpy	241,2	(12)
coir/epoxy	Charpy	174,7	(12)
curaua/polyester	Charpy	169,7	(13)
curaua/epoxy	Charpy	103,2	(13)

The relatively low interface strength between a hydrophilic natural fiber and a hydrophobic polymeric matrix contributes to an ineffective load transfer from the matrix to a longer fiber. This result in relatively greater fracture surface and higher impact energy needed for the rupture. Another factor is the flexural compliance of a long fiber during the impact test, which will be further discussed. The macroscopic aspects of the typical specimen ruptured by Izod impact tests are shown in Figure 4. In this figure it should be noted that the incorporation of aligned jute fiber results in a marked change with respect to pure epoxy (0% fiber) in which a totally transversal rupture occurs.

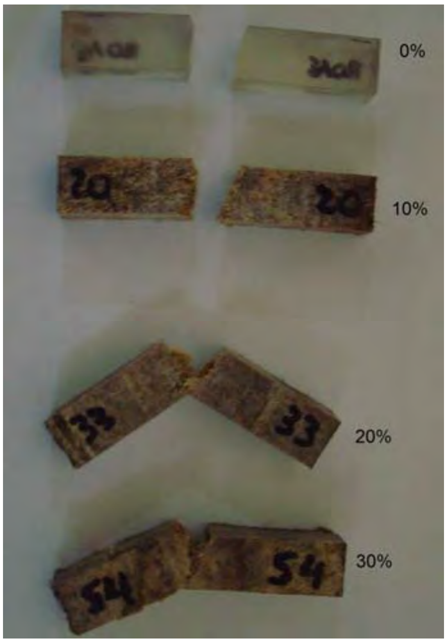

Figure 4. Typical ruptured specimens by Izod impact tests.

The SEM analysis of the Izod impact fracture permitted to have a better comprehension of the mechanism responsible for the higher toughness of epoxy composites reinforced with jute fibers. Figure 5 presents details of the impact fracture surface of an epoxy composites specimen with 30% of jute fibers. This fractograph shows an effective adhesion between the fibers and the epoxy matrix, where cracks preferentially propagate. Some of the fibers were pulled out from the matrix and others were broken during the impact. By contrast, the part of the specimen in which the rupture preferentially occurred longitudinally through the fiber/matrix interface reveal that most of the fracture area is associated with the fiber surface.

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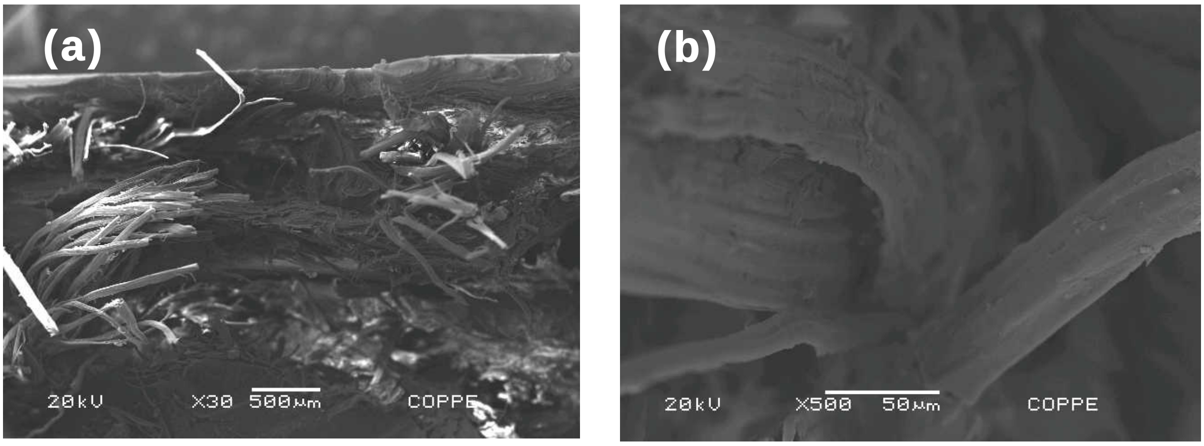

Figure 5. Impact fracture surface of an epoxy composite reinforced with 30% jute: (a) 30 X and (b) 500 X.

This behavior corroborates the rupture mechanism of cracks that propagate preferentially in between jute fibers surface and the epoxy matrix due to the low interfacial strength. The greater fracture area, Figure 5, associate with the aligned jute fibers acting as reinforcement for the composite, justify the higher absorbed impact energy, Figure 3, with increasing amount of jute fibers.

4 CONCLUSIONS

- Composites of aligned jute fibers reinforcing an epoxy matrix display a significant increase in the toughness, measures by the Izod impact test, as a function of the amount of the fiber;
- most of this increase in toughness is apparently due to the low jute fiber/epoxy matrix interfacial shear stress. This results in a higher absorbed energy as a consequence of a longitudinal propagation of the cracks throughout the interface, which generates larger rupture areas, as compared to a transversal fracture;
- amounts of jute fibers above 10% are associated with incomplete rupture of the specimen owing to the bend flexibility, i.e., flexural compliance, of jute fibers.

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