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CHARPY IMPACT TESTS IN EPOXY MATRIX COMPOSITES REINFORCED WITH MALVA FIBERS

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Abstract

Environmentally friendly materials are currently being investigated to replace synthetic materials, usually more expensive, more polluting and less sustainable. Indeed polymer matrix composites reinforced with natural fibers is supposed to be applied in components such as helmets and shielding for which toughness is a major requirement. Therefore the present work evaluates the Charpy impact resistance of epoxy matrix composites, reinforced with 10, 20 and 30% in volume of continuous and aligned malva fibers (*Urena Lobata,L*). The impact tests were performed on standard specimens obtained by pressing mold and then cured for 24 hours. The results showed a significant increase in impact energy with the malva fibers incorporated fraction. The fracture surface was analyzed by scanning electron microscopy, SEM. The performance of the samples incorporated with 30% of malva fibers, suffered only partial rupture due to the difficulty imposed by breaking the malva fibers. The brittle matrix/fiber relation makes the cracks switch way to the interface between the malva fiber and epoxy matrix, which helps to absorb more impact energy.

Introduction

The United Nations Food and Agriculture declared the year 2009 as the international year of natural fibers. This aims to raise awareness and reinforcing the use of natural fibers. Government policies are also amplifying sustainable actions as the exploitation of these raw materials[1-13].

The productive potential of lignocellulosic fibers in Brazil, as well as their market, extraction methods, morphology, properties and common applications have been investigated [1-13].

Lignocellulosic fibers such as coir, flax, jute, ramie and curaua are currently being used in automobile composite parts that require both strength and toughness [14]. The malva fiber, although strong and flexible has not yet been applied in composites for automobile components. Actually, the fibers obtained from the leaves of the malva plants (*Urena lobata, L*), Fig. 1a, are among the strongest lignocellulosic with tensile strength above 600 MPa [15]. In spite of existing works on the properties of malva fiber composites [16], the impact resistance of continuous and aligned malva fiber reinforced polymeric composites has yet to be evaluated. Therefore, the objective of the present work was to access the toughness through the energy absorbed by notched Charpy impact specimens of epoxy composites reinforced with different amounts of continuous malva fibers.

Experimental Procedure

A lot of malva fibers was donated for the study by the Companhia Textil de Castanhal from Pará, North region of Brazil. Fibers from the as received lot were cleaned and dried at room temperature. Figure 1 shown the malva fibers and the separate malva fibers.

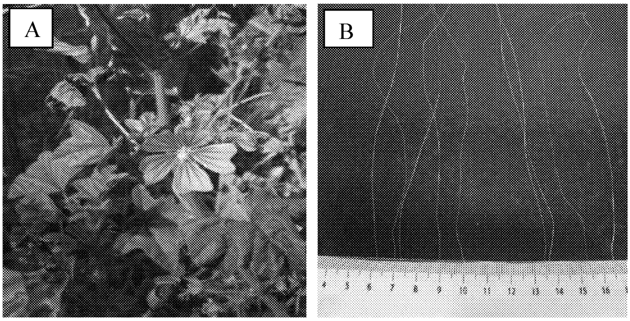

Figure 1(a) Malva plant, and (b)Malva fibers individually separated.

After separation, cleaning and drying at room temperature, the malva fibers were mixed in amounts of 0, 10, 20 and 30% by volume with unsaturated epoxy resin to prepare the composites. Plates of the composites with 10 mm thickness were fabricated in a rectangular steel mold with dimensions of 152 x 125 mm. The fibers were maintained aligned along the dimension of 125 mm, corresponding to the final length of the test specimens. The fabrication procedure was the following. The still liquid epoxy resin DGEBA, with TETA as hardener, was poured onto the malva fibers inside the mold. The composite thus formed was allowed to cure for 24 hours at room temperature. The plate of each different composite was then cut according to the direction of fiber alignment in bars measuring 10 x 125 x 12.7 mm. These bars were used for preparation of samples for Charpy impact test, according to ASTM D256.

The samples were impact tested in a PANTEC pendulum with Charpy configuration. The impact energy was obtained using an 15 J power hammer for composites with 0, 10, 20 and 30% of fibers. For each volume fraction of fibers, ten specimens were used for statistical validation.

Results and Discussion

Table 1 shows the results of the values of Charpy impact energy with their respective standard deviations for pure epoxy and composites with different volume fractions of malva fibers.

Table 1 - Energy impact Charpy for epoxy matrix reinforced with malva fibers.

Malva Fibers (%)	Impact Energy (J/m)
0	22.9 ± 9.7
10	101.1 ± 28.7
20	176.6 ± 41.1
30	310.2 ± 98.1

Based on the results of Table 1, the Charpy impact energy variation with the fraction of malva fiber is shown in Figure 2.

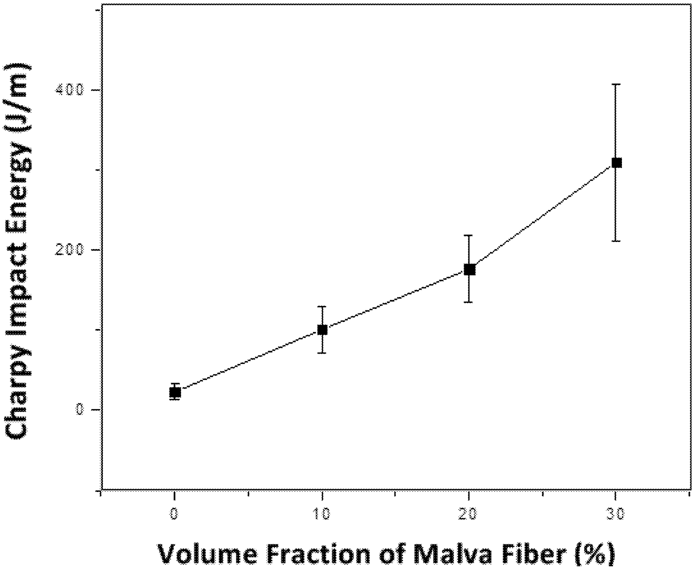

Figure 2 - Charpy impact energy as a function of the amount of malva fibers.

One should notice the marked increase in Charpy impact energy with the fiber volume fraction of malva. It is also important to note that the error bars present the standard deviation, a common feature for lignocellulosic fibers. This is due to the heterogeneous nature of natural fibers, resulting in substantial dispersion properties of the composites reinforced by them [17].

In fact as shown in table 2, using long and aligned malva fibers for composites obtains relatively higher impact toughness composites with other fibers too.

Table 2 - Comparison on Impact toughness values for different fibers [10].

Composites 30% fibers	***Impact Type***	***Impact Tougness* (J/m)**
malva/epoxy	Charpy	310.2
malva/polyester	Charpy	716.2
ramie/epoxy	Charpy	211.7
ramie/polyester	Charpy	1004.8
coco/polyester	Charpy	241.2
coco/epoxy	Charpy	174.7
curaua/polyester	Charpy	169.7
curaua/epoxy	Charpy	103.2

It is important to discuss the macroscopic rupture characteristic of the specimens after the test. Figure 3 illustrates the characteristic of rupture of the epoxy specimens for each amount of fiber incorporated. In this figure is shown that the some specimens with 30% of malva fiber, ie the highest toughness obtained, do not separated into two parts after impact as showed in other work in literature [18]. This indicates that cracks nucleated in the notch began to propagate across the brittle epoxy matrix, but when they reach the fiber interface, the crack changes direction.

Specimens with under 20% malva fiber incorporation undergo complete rupture. Specimens with 30% malva fibers incorporation, however, did not undergo complete rupture. This leads to the decrease in toughness observed in Figure 3. If all fibers were broken then the energy absorbed would have been even greater [19].

The reason for having a crack nucleated at the notch, changing its trajectory to reach the fibers malva, and going to propagate through the interface with the matrix is due to the low interfacial resistance. This is a consequence of the incompatibility caused by the fact that lignocellulosic fibers are hydrophilic while the polymer matrix is hydrophobic [20].

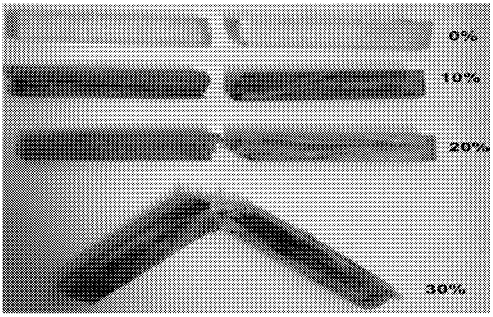

Figure 3 – Specimens typical epoxy matrix composites with different volume fractions of malva fiber, broken by Charpy Impact [21].

The SEM analysis of the Charpy impact fracture permitted to have a better comprehension of the mechanism responsible for the higher toughness of epoxy composites reinforced with long and aligned malva fibers. Figure 4 shows the aspect of the fracture surface of a pure polyester (0% fiber) specimen[21-24]. With lower magnification, the lighter layer in the left side of the fractograph, Fig 4(a), corresponds to the specimen notch, revealing the machining parallel marks. The smoother and gray layer on the right side corresponds to the transversal fracture surface. The fracture in Fig. 4 suggests that a single crack was responsible for the rupture with the roughness in Fig 4(b), being associated with voids and imperfections during the processing.

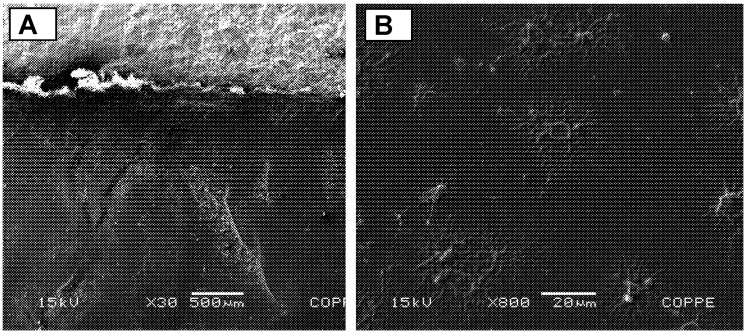

Figure 4 – Fracture surface of the specimen pure epoxy (0% malva fiber): (A) general view with low increase (B) higher increase.

Figure 5 presents details of the impact fracture surface of a epoxy composite specimen with 30% of malva fiber. This fractograph shows an effective adhesion between the fibers and matrix, where cracks preferentially propagate. Some of the fibers were pulled out from the matrix and others were broken during the impact[25,26]. 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. This behavior corroborates the rupture mechanism of cracks that propagate preferentially in between the malva fiber surface and the epoxy matrix due to the low interfacial strength [27]. The greater fracture area, Fig. 5, associated with the aligned malva fibers acting as reinforcement for the composite, justify the higher absorbed impact energy, Fig. 2 with increasing amount of malva fibers.

This behavior confirms the mechanism of rupture by cracks that due to the low interfacial shear stress, is preferably spread between the surface of the malva fibers and epoxy matrix as can be seen in Figure 5b[28].

This results in a longitudinal fracture area is relatively large compared to the transverse fracture of the specimens with up to 20% of malva fiber. Consequently have a higher impact energy to break an area comparatively higher as indicated by Yue ET AL (1995). Similar results were found in polyester matrix composites reinforced with malva fiber [23]. This indicates that the malva fiber provide high tenacity to polymeric matrices reinforced by it.

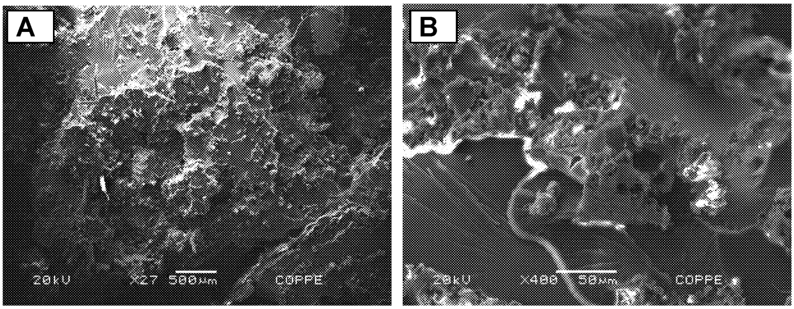

Figure 5 – Fracture surface of the specimen epoxy composite (30% malva fiber): (A) general view with low increase (B) higher increase.

Conclusions

- Malva fiber fractions increased in a linear way the notch toughness due to the energy required to bend the fibers after the impact with the Charpy hammer.
- Epoxy matrix composites reinforced with continuous and aligned malva fibers show a linear increase in toughness as measured by Charpy impact test as a function of volume fraction of fibers.
- This increase in toughness is apparently due to the low shear stress at the interface between the malva fibers and epoxy matrix. This results in a high energy absorbed as a result of propagation of longitudinal cracks through the interface, which generates a fracture area is relatively large compared to the simple transverse fracture.
- The incorporation of volume fractions exceeding 20% are associated with incomplete fracture of the specimens due to the flexibility of the malva fibers that despite the during the impact tests curving but are not ruptured.

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