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UNDER PRESSURE TENSILE EPOXY COMPOSITES WITH HIGH AMOUNT OF BANANA FIBER*

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Abstract
Natural fibers are attracting the interest of engineering sectors owing to specific advantages such as lightweight and lower cost as well as for their inherent condition of being renewable, biodegradable, recyclable and environmental correct material with respect to CO_2 emission. The banana fiber is nowadays recognized by its mechanical properties. It is known that with the increase of fibers volume fraction the composite significant increases its tensile strength. This was obtained with amounts up to 30% in volume of banana fiber. However no higher volume of fibers was able to be molded in a composite plate until now. Thus the present work aims to study higher volumes of fiber in terms of the influence on the tensile strength of specimens prepared under 5 tons of pressure. The fibers were previously washed and dried in an oven at 60ºC, after that poured together with the epoxy resin and catalyst mixture in the metal molds bone-shaped, and pressured to ensure specimens quality. The tensile strength increased significantly with higher amounts of banana fiber incorporated in the epoxy matrix. This better performance can be directly related to the fracture obstacle imposed by the fibers as well as the type of cracks resulting from the fiber/matrix interaction.
Keywords: Banana fiber; Epoxy matrix; Tensile strength.

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1 INTRODUCTION

The fiber reinforced polymer composite emerged in the middle of last century as a versatile engineering material for applications requiring mechanical resistance in association with lightness. Its most commonly used example is “fiberglass”, i.e., a thermoset polymer matrix composite reinforced with glass fiber. Indeed, “fiberglass” has a specific strength of the order of 500 MPa.cm³/g, which is the double of the strongest steels like the maraging. This motivated, at earlier times, “fiberglass” to replace many conventional materials including wood and natural fiber composites. Today, “fiberglass” has a wide range of uses from aerospace systems and appliances to sport and leisure components. However, its fabrication as well as those of any synthetic fiber such as carbon and aramid composites, requires a relatively large amount of energy. Presently, a growing concern exists regarding the consequences to the environmental by gases like CO_2 associated with both the energy consumption and the processing of synthetic fibers and their composites. These gases are well known responsible for global warming [1].
A reverse movement toward natural materials is now under way. In particular, lignocellulosic fibers are currently being added to polymer composites, totally or partially, in substitution for synthetic fibers [2-7]. The environmental motivation for the use of lignocellulosic fibers is the neutral balance between CO_2 absorption during cultivation and its industrial processing emission [6]. Other advantages such as renewability, biodegradability, reduced process equipment wear, low cost and lower density also favor the lignocellulosic fibers over the glass fiber [7-8]. On the other hand, the low adhesion to the matrix as well as the non-uniform dimension and considerable scatter in property values are recognized [2-6] as serious drawbacks for the engineering use of lignocellulosic fibers. In particular, the maximum specific strength known so far for these composites is of the order of 100 MPa.cm³/g. This is one fifth of the corresponding for “fiberglass”.
In recent years, investigations have been carried out to improve the performance of lignocellulosic fiber composites. Kalia et al [9] indicated that due to a tremendous change in the quality of natural fibers, they are fast emerging as reinforcing materials in composites that hold an enormous potential and are critical for achieving sustainability. It was also found [10] that high strength lignocellulosic fibers such as ramie, curaua and sisal could be selected with thinner diameters to reinforce improved polymer composites.
Banana fiber (*Musaceae* family), illustrated in Fig.1, with average diameter of 0.2 mm could reach tensile strength higher than 700 MPa. Other investigations on the strength of banana fiber had already revealed significant results [11,12]. These reported results have shown that polymer composites reinforced with banana fibers present very interesting potential improvement. Therefore this work evaluated the tensile behavior of epoxy composites reinforced with continuous and aligned banana fibers.

2 EXPERIMENTAL PROCEDURE

The banana fibers investigated in this work were commercially supplied by a local producer. Figure 1 illustrates the typical banana plant and a bundle of fibers extracted from its stem.

Figure 1. Typical banana plant, the pseudo stem with average diameter of 15-30 cm, the sun-dried for a week and the group of fibers after the defibrillation.

Initially, one hundred fibers were randomly taken out from the bundle for diameter statistical evaluation, figure 2 shown the diameter distribution with mean diameter of 0.2 mm.

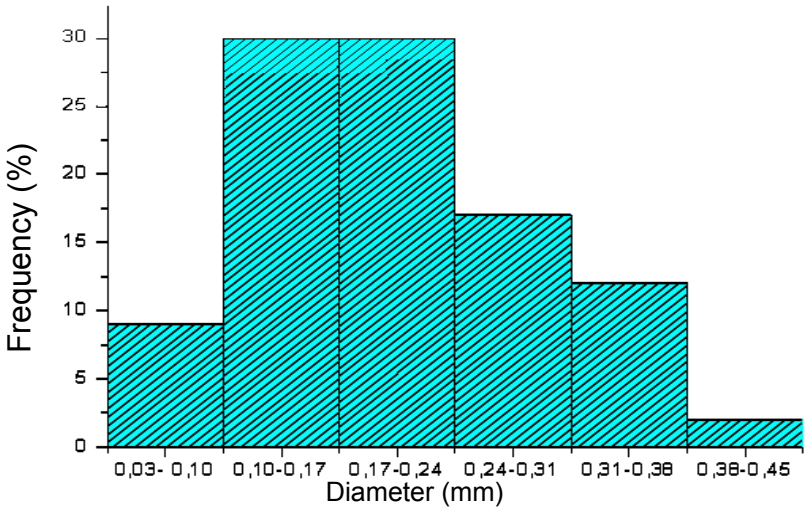

Figure 2. Statistical distribution of the banana fibers.

The fibers were aligned and continuous way in a bone-shaped mold made of steel, the volume fraction of fiber used in this work was increased from 0 up to 60%. Onto the fibers the still fluid epoxy resin was poured into the mold. During this process particular care was taken to avoid air bobbles on the samples. Then the system was subjected to gradual increase of pressure coming to 25 tons which was relieved only after 24 hours at room temperature to make sure that the samples was not misshapen. Then the samples were to post cured in a stove at 100ºC for 1 hour.
For the next step, the samples were sanded to improve the surface quality. The dimensions of the samples were measured and catalogued to make possible the further analysis. After that the samples was submitted to tensile tests in a Instron machine model 5582 with a strain rate of 4,2x10-4s^{-1} in controlled temperature environmental at 25ºC.
The fracture surface of selected specimens was gold sputtered and then analyzed by scanning electron microscopy (SEM) in a model SSX-550 Shimadzu microscope operating at an accelerating voltage of 7- 15 kV. These specimens were subjected to tensile tests in a model 5582 Instron machine, shown in the Figure 3.

Figure 3. Instron model 5582, LAMAV/UENF.

3 RESULTS AND DISCUSSION

The table 1 shown the results of tensile strength for the composites incorporate with the corresponding volume of fiber incorporated. Also, the figure 4 contains the plotted curve based on these results.

Table 1. Tensile strength obtained by the corresponding sample Volume fraction of fiber

Volume fraction of fiber (%)	Tensile strength (MPa)
0	27.85 ± 06.58
10	57.89 ±10.47
20	65.13 ± 12.79
30	69.87 ± 07.88
40	78.21 ± 13.13
50	91.35 ± 07.03
60	103.17 ±16.82

The figure 5 and table 1 shown that occur a very high enhance when the volume fraction of fiber is increased. It can be seen especially when compared the results of pure epoxy (0% of volume fraction of fiber) and the high volume of fiber incorporated (60%). Comparing both is observed an increase about 370%.
Figure 4 illustrates the macro aspect of tensile ruptured specimens corresponding to the different volume fraction of banana fibers. In this figure, the fracture of neat epoxy specimens tends to be transversal to the tensile axis but with the increase of banana amount the evidence of banana fiber participation could be detected. What indicates that the fracture mechanism for the pure epoxy matrix was mainly associated with the propagation of transversal cracks although for the composites the non-transversal crack indicate a low interface relation between the banana fiber and the epoxy matrix.

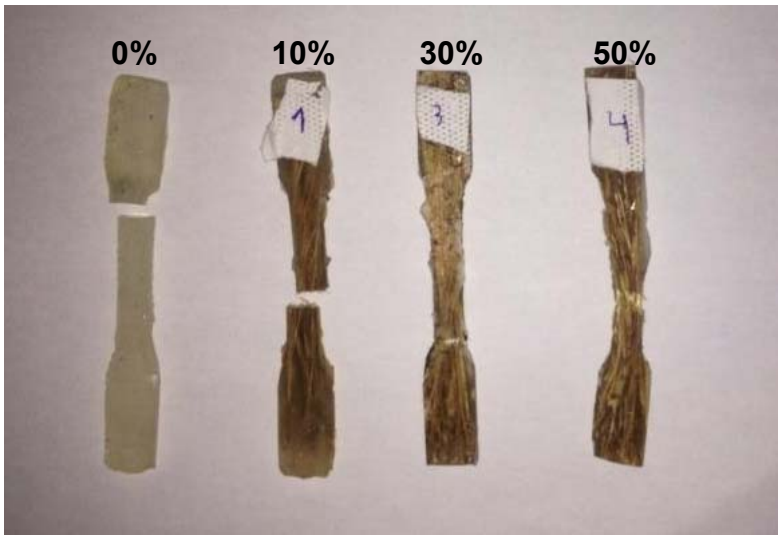

Figure 4. Typical tensile ruptured specimens volume fraction of banana reinforced epoxy composites.

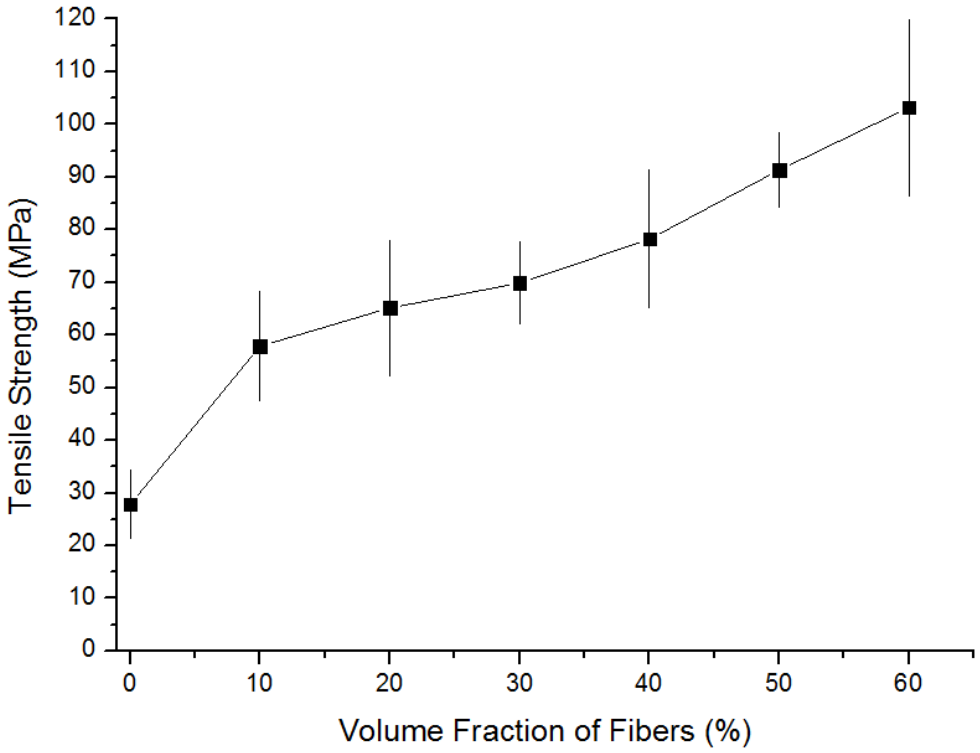

Figure 5. Curve volume fraction of fiber versus tensile strength.

However is wise to notice that the deviations of some of these results are significant. It can be explained by the difficult of prepare samples uniformly. Also it can be explained by the irregular surface of the natural fibers which causes irregularities on the interface between the fiber and polymer.

Another explanation of the weak interface is because of the natural fibers are hydrophilic and the polymer matrix is hydrophobic. Therefore, even after drying in the oven, these fibers always have residual surface moisture which difficult the adhesion between banana fiber and matrix.

This kind of deficiency can be solved improving the techniques of preparation of the samples by taking extra care with the process of putting fibers and resin on the mold.

Also the pressure it the system was submitted improve the interface between fiber and matrix which leads to superior materials.
The Figure 6 shown SEM micrographs at different magnifications of a 10% banana fiber epoxy composite fracture surface. In Fig. 6 (a), is visible some fibers loose of matrix, which suggests a low interfacial shear stress. Is possible to see too evidences in interface of nucleated cracks between banana fiber and epoxy matrix. With higher magnification, Fig. 6 (b), is visible a banana fiber well fix to epoxy matrix. Is notable the crack propagation is blocked by the fibers, opening a space between the fiber and the matrix. Even after of epoxy matrix fracture the fibers continue resisting to tensile effort, because this behavior the composite find higher resistance values in correlation with pure matrix.

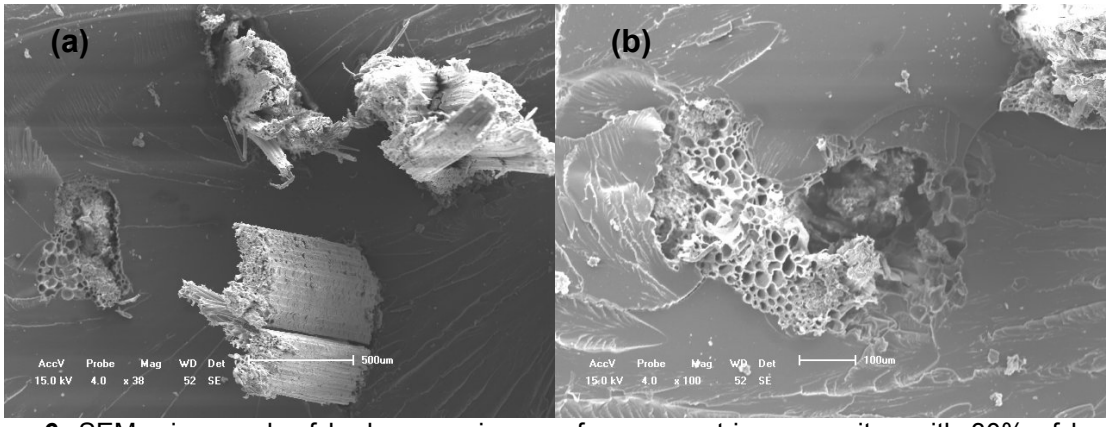

Figure 6. SEM micrograph of broken specimens of epoxy matrix composites with 30% of banana fibers at different magnifications: (a) 38x and (b) 200x.

4 CONCLUSIONS

- The increase amount of banana fibers have directly influence of the mechanical behavior of composites reinforced with natural fibers. An increase of the mechanical property occurs in higher volume of fibers incorporated.
- The samples studied in this work had they properties improved with the pressure which these were submitted.

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