TENSILE PROPERTIES OF EPOXY COMPOSITES REINFORCED WITH HEMP FIBERS*

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Abstract
Synthetic fibers have been gradually replaced by lignocellulosic fibers. Compared to the synthetic fiber, natural fiber showed economic and environmental advantages presenting interfacial characteristics with polymer matrices that favor the impact energy absorption by the composite structure. However, so far little has been reported about the hemp fiber embedded in polymer matrices, such as tensile properties. This study aims to evaluate the resistance in tensile tests of epoxies composites reinforced with different percentages of hemp fiber. Tensile tests were submitted with percentage of 0%, 10%, 20% and 30% incorporated hemp fiber in epoxy matrix. The tensile strength and deformation substantially increased the relative amount of hemp fibers incorporated into the polymeric matrix.
Keywords: Hemp fiber; Epoxy matrix composite; Tensile properties.

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1 INTRODUCTION

In recent years, there has been an increase application of natural fibers as reinforcement of polymer matrix composites in several industrial sectors, with special participation in automobile components [1-3]. The advantage of natural fibers, especially those extracted from plants, over the glass fiber are presently a great motivation for the increasing use of “green” composites in automobiles [4-6]. Glass fiber is more expensive, heavier and abrasive to processing equipment.
Moreover, this synthetic fiber presents a health risk when inhaled and its production is associated with CO_2 emissions. None of these shortcomings apply to lignocellulosic fibers that, in addition, are renewable, biodegradable and neutral with respect to greenhouse gases, the major responsible for global warming. Application of natural fiber composites is rapidly increasing in the automobile industry with annual growth rates above 20% [7].
Less known natural fibers like Piassava [8], Ramie [9], Curaua [10] and Buriti [11] sisal [12] and other are currently being investigated for their potential as composite reinforcement. Hemp is one the lignocellulosic fiber with least knowledge as far as mechanical properties are concerned. Characterizations of these composites are being carried out for different polymer matrices and mechanical tests [12-22].
However, no tensile characterization was done so far for polymer composites reinforced with hemp fibers. Therefore, the objective of this work was to conduct the tensile tests of epoxy matrix composites reinforced with hemp fibers.

2 EXPERIMENTAL PROCEDURE

The material used in this work was untreated hemp fiber extracted from the stem hemp plant supplied by *Desigan Natural Fibers Company* and epoxy resin. Statistical analysis were performed on one hundred fibers randomly removed from the as-received the lot. Figure 1 shows the histogram for the distribution of hemp fiber diameters by considering 6 diameter intervals. From this distribution, presented elsewhere an average diameter of 0.065mm was found for the as-received lot.

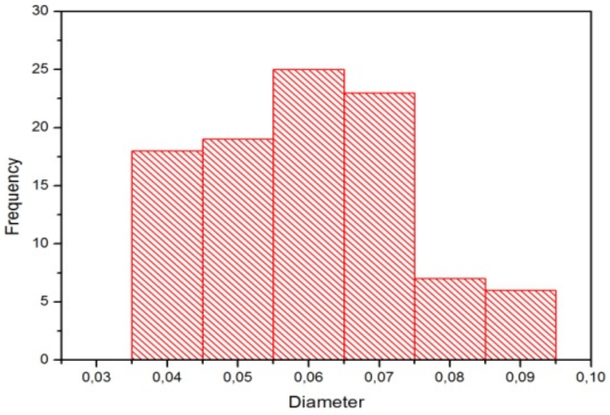

Figure 1.Distribution histogram for six diameter intervals.

For composite fabrication, the as-received hemp fibers were initially cleaned and then dried at 60ºC for 24 hours. Tensile specimens were individually prepared by laying down continuous and aligned fibers in a rectangular “dog-bone” shaped silicone mold with 5.8 x 4.5 mm of reduced gage dimensions. Fibers in amounts of up to 30% in volume were aligned along the 35 mm length of the specimens, corresponding to its tensile axis. Still fluid DGEBA/TETA epoxy resin was poured onto the fibers in the mold and allowed to cure for 24 hours. Some composite specimens were fabricated for each fiber composition. Each specimen was room temperature tested in a model 5582 Instron universal machine at a strain rate of 3 x 10^{-3} s^{-1}. 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.

3 RESULTS AND DISCUSSION

Figure 2 exemplifies the typical load vs. extension curves for different composites. These curves were recorded directly from the Instron machine and revealed that the hemp fiber reinforced composites apparently present limited plastic deformation. Consequently, these composites, in principle, may be considered as brittle materials.

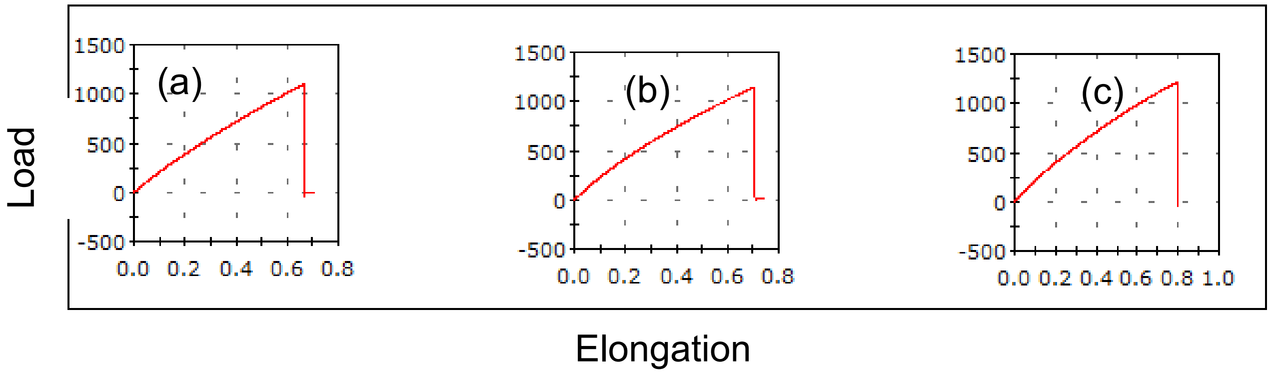

Figure 2. Load *vs.* elongation curves for epoxy composites reinforced with (a) 0%, (b) 10% and (c) 30% of volume fraction of hemp fibers.

From the results of the load *vs.* elongation curves, Fig. 2, the ultimate stress (tensile strength), elastic modulus, and total strain were calculated. Table 1 shows the average values for these tensile properties for the different amounts of hemp fiber investigated.

Table 1. Tensile properties for the hemp fiber reinforced epoxy composites.

Amount of Hemp Fiber (Vol. %)	Tensile Strength (Mpa)	Elastic Modulus (Gpa)
0	28.99 ± 6.58	0.83 ± 0.23
10	37.43 ± 3.29	1.88 ± 0.16
20	45.56 ± 6.73	1.70 ± 0.05
30	53.08 ± 3.28	1.75 ± 0.13

Figure 3 plots the results of tensile strength and elastic modulus in Table 1 as a function of the volume fraction of hemp fibers. In this figure it should be noted that both the composite tensile strength and stiffness significantly increase with the hemp fiber incorporated into the epoxy matrix.

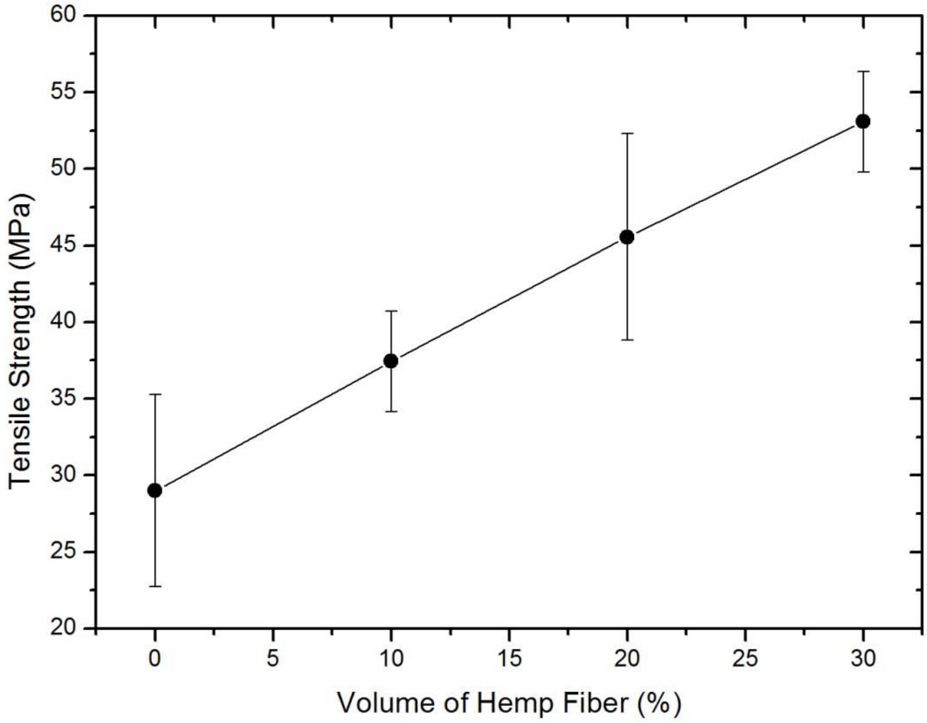

Figure 3 - Tensile strength variation with the amount of hemp fiber in the composite.

The elastic modulus variation in Fig 4 could also be adjusted to a linear relation and demonstrates a relevance increase in it values with the increase of fibers in the matrix. This can be attributed to the same mechanical proprieties analyzed for the tensile strength.

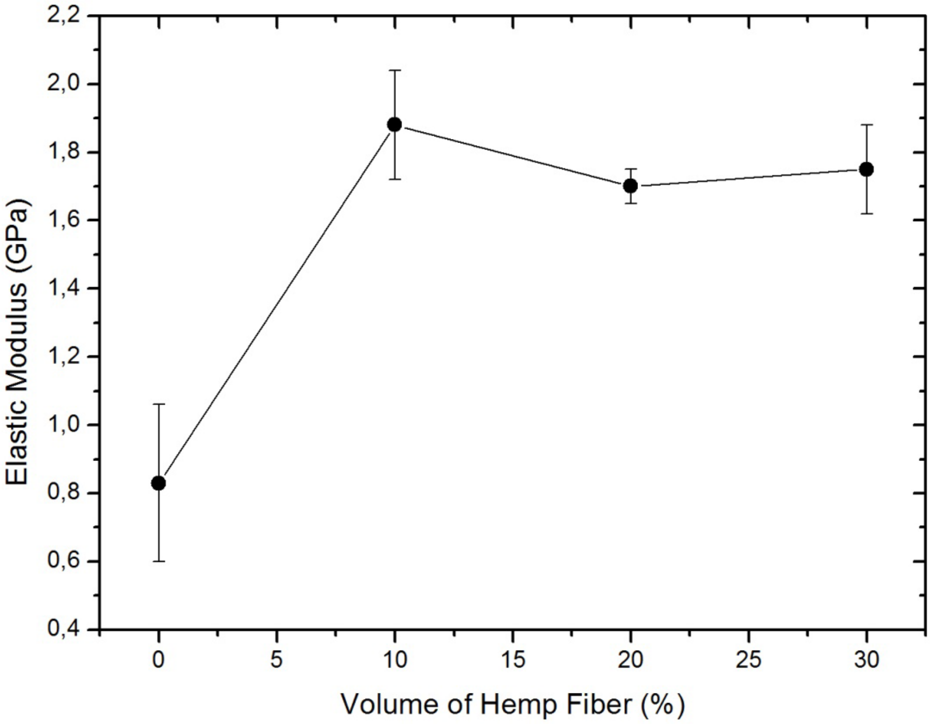

Figure 4. Variation of the elastic modulus with the volume fraction of hemp fiber reinforcing epoxy composites.

The fracture analysis of the tensile tested specimens was performed both by macroscopic observation, and SEM microscopic analysis. Figure 5 shows a typical SEM fractograph of a tensile rupture specimen for an epoxy composite reinforced with 30% of hemp fiber. In Fig. 5(a) it is possible to observe a few broken fibers well adhered to the epoxy matrix. By contrast, an empty space corresponding to a fiber that was detached from the matrix can also be seen. In Fig. 5(b), the crack associated with this empty space suggests that the fiber had initially acted as a barrier for the rupture process.

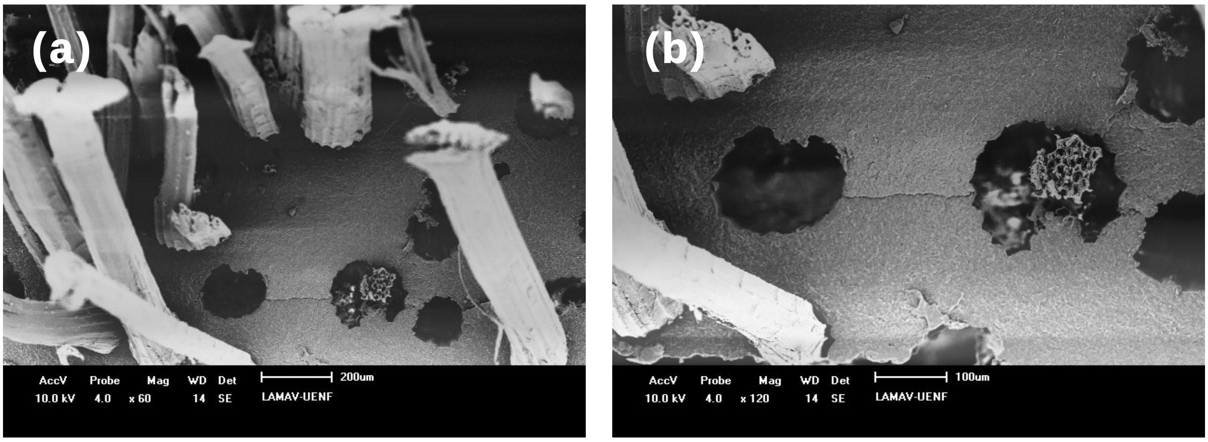

Figure 5. Composite with 30% in vol. of hemp fiber, with different magnifications: 200x (a) and (b) 500x.

4 CONCLUSIONS

The incorporation of continuous and aligned hemp fiber significantly increases the tensile strength and stiffness of DGEBA/TETA epoxy matrix composites.
An apparent linear increase occurs up to a volume fraction of hemp fiber of 30%. This corresponds to a better performance than similar composite that were flexural tested.
Macroscopic and microstructural evidences indicate that the strong hemp fiber acts as effective barrier for rupture propagation throughout the brittle epoxy matrix, in spite of the weak fiber matrix interface.

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