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TENSILE STRENGTH OF POLYESTER COMPOSITES REINFORCED WITH THINNER RAMIE FIBERS

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Abstract

This study evaluated the tensile properties of polyester composites reinforced with ramie fibers with thinner diameters. Specimens with different ramie fibers percentages (0,10,20 and 30%) in continuous and aligned ramie stalk fibers volume , were tensile tested at room temperature to evaluate the ultimate strength, elastic modulus and total strain. The results indicated that the tensile properties tend to improve with increasing volume fraction of ramie fibers. The role played by the fiber/matrix interaction was analyzed by scanning electron microscopy.

Introduction

Nowadays, composites are the most popular materials with engineered combinations of properties that cannot be achieved by a conventional monolithic material [1,2]. This is particularly the case of components with special requirements for aerospace, underwater and transportation applications [3].

Modern aircrafts demand lighter, stronger, tougher and stiffer structural parts that can only be made with carbon fiber reinforced composites. The space shuttle is a high-tech example of a vehicle using different types of expensive composites including carbon fiber reinforcing pyrolized graphite matrix composites. Less expensive glass fiber composites are also used as interior components of aircrafts in addition to an extensive application in many other products, from packaging to automobile components [3].

All synthetic composites like the aforementioned ones reinforced with carbon and glass fibers are, however, associated with environmental drawbacks. Their production is energy-intensive and they cannot be easily recycled. Moreover, glass fiber is related to health problems [4].

Several natural fibers are increasingly being considered as viable alternatives to replace glass fiber in polymer composites reinforcement. Lignocellulosic fibers extracted from plants have shown a real potential for this substitution [5-10]. Their comparative advantages are lower density and cost as well as renewability, biodegradability, recyclability and neutrality with respect to CO_2 emission, which is one of the gases responsible for global warming. Less known natural fibers like piassava, sponge gourd, caroa, curaua [11] and ramie [12] are currently being investigated for their potential as composite reinforcement, even review works on the application of natural fibers in composites [12-21] fail to report on Ramie fibers (Figure 1 shows the plant and fibers of ramie). Since the heterogeneous characteristics of lignocellulosic fibers indicates that the strength varies inversely with the fiber diameter [22], the present work carried out a mechanical behavior analysis on the tensile strength of polyester composites reinforced with thinner ramie fibers.

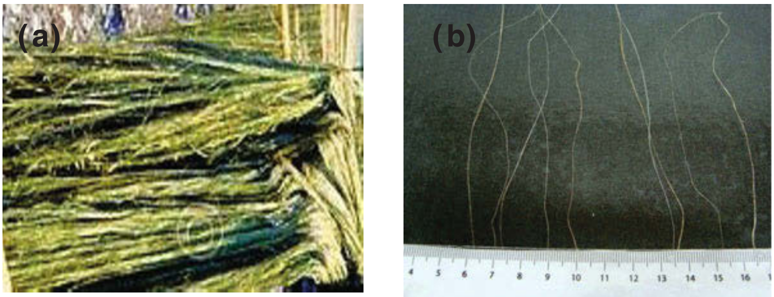

Figure1 (a) Ramie Fibers and (b) individually separated fibers

Experimental Procedure

Ramie fibers extracted from *Boehmeria Nivea*, as illustrated in Figure 1, were obtained from a Brazilian firm SisalSul. The petiole was cleaned with water and dried for one hour at 60°C. Then, with a razor blade, the fibers were extracted from the petiole. No treatment was applied to the fibers. Thinner fibers with diameter between 0.1 and 0.4 mm were manually separated and considered for polyester composites reinforcement. A commercially supplied unsaturated orthophtalic polyester resin hardened with 0.5% of methyl-ethyl-ketone was used as the composite matrix.

Figure 2. Specimens of 0, 10, 20 and 30% of ramie fibers in volume fraction.

Figure 2 illustrates the macro aspect of tensile ruptured specimens corresponding to the different volume fraction of ramie fibers. In this figure, the fracture of neat polyester specimens tends to be transversal to the tensile axis but with the increase of ramie amount the evidence of ramie fiber participation could be detected.

Composite specimens were individually prepared with continuous and aligned ramie fibers placed inside dog-bone shape silicone molds. The thinner fibers in amounts of up to 30% in volume were aligned along the specimens corresponding tensile axis. Still fluid polyester resin was poured onto the thinner ramie fibers, and cured for 24 hours. These specimens were subjected to tensile tests in a model 5582 Instron machine at room temperature and 0.5 mm/min. For each volume fraction of ramie fiber, from 0 to 30% in volume, six samples were tested and the results statistically analyzed. The specimens were gold sputtered and observed by scanning electron microscopy (SEM) in a model SSX 550 Shimadzu microscope.

Results and Discussion

From the data acquisition system of the Instron machine, were obtained results that revealed that ramie fibers does not act as effective reinforcement, and decrease the plastic deformation of the composites. The data of these tests also were recorded and used to find the values of tensile strength at break.

The Table I shown the results of tensile strength for the composites incorporate with the corresponding volume of fiber incorporated.

Table I. Tensile properties of polyester composites reinforced with ramie fibers

Volume Fraction of Ramie Fiber [%]	Tensile Strength [MPa]	Elasticity Modulus [GPa]
0	29.27 ± 3.42	0.42 ± 0.26
10	17.02 ± 5.72	0.32 ± 0.09
20	16.50T ± 5.23	0.19 ± 0.12
30	25.52 ± 5.21	0.45 ± 0.13

Table I shown that occur a decrease in the tensile strength when the volume fraction of fiber is increased. It can be seen especially when compared the results of pure polyester (0% of volume fraction of fiber) and the higher volume of fiber incorporated (30%). Comparing both is observed an decrease about 15%.

The mean values of the tensile stress and elasticity modulus, listed in Table I for the polyester composites, are plotted in Figure 3 as a function of volume fraction of ramie thin fibers. In this figure it can be noteworthy that the introduction of ramie fibers does not represent an increase neither strength, Figure 3(a), nor the elastic modulus, Figure 3(b), to the polyester matrix composites. The cause of this can be an error in the cure of the specimens or the during the tensile strength test.

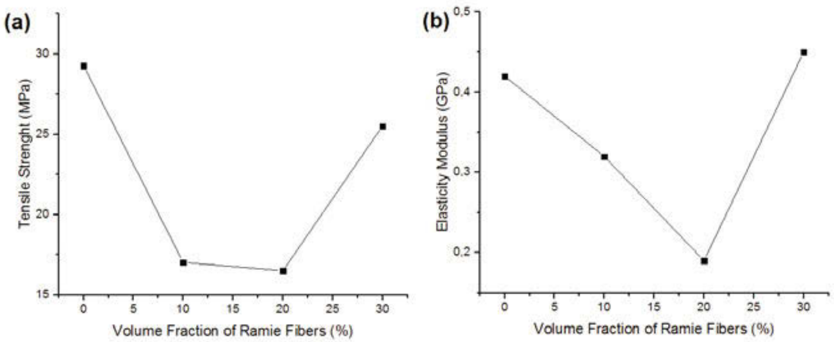

Figure 3. Variation of tensile strength (a) and elastic modulus (b) with the volume fraction of
thinner ramie fibers

The macro aspect of tensile ruptured specimens showed in figure 2 can indicate that the fracture mechanism for the pure polyester matrix was mainly associated with the propagation of transversal cracks although for the composites the non transversal cracks indicate a low interface relation between the ramie fiber and the polyester matrix.

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 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.

Figure 4 shows a typical SEM fractograph of a tensile rupture specimen for a polyester composite reinforced with 30% of ramie fiber. In this figure, one can see a few broken fibers well adhered to the polyester matrix. By contrast, an empty space corresponding to a fiber that was detached from the matrix can also be seen. A crack associated with this empty space suggests that the fiber had initially acted as a barrier for the rupture process, in agreement with the macroscopic rupture in Figure 2.

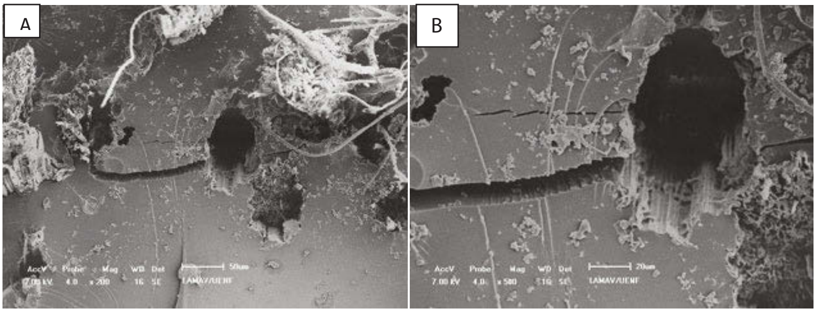

Figure 4. Composite with 30% in vol. of ramie fiber, with different magnifications: (a) 200x and (b) 500x.

Conclusions

The ramie fibers may not be strong enough to provide reinforcement of polyester matrix composites, but the bad result in the reinforcement test can be also attributed to a problem with the resin cure time or other trouble in the manufacture procedure. In fact, polyester composites reinforced with aligned ramie fibers, significantly improve the mechanical performance in literature, what can indicate some problem in the manufacture or test procedure. This decrease can be attributed to ramie fibers not acting as a barrier for the crack propagation throughout the brittle polyester matrix. The resistance decreased in the samples tensile energy can be attributed to the fiber hydrophilic characteristic and the resin hydrophobic property, which would compromise a tougher interface. In the literature lignocellulosic fibers inclusion into polymer matrix normally increase the tensile strength, but for the ramie/polyester composite it does not occur, ramie fibers are not acting as a barrier for the crack propagation throughout the brittle matrix.

Acknowledgements

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