MECHANICAL BEHAVIOR OF HYBRID COMPOSITES WITH SYNTHETIC AND NATURAL FIBERS

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Abstract

Actually, natural fibers has gained attention as an alternative to synthetic fiber by using natural fibers as reinforcement in plastic to reduce cost, increase productivity and improve mechanical properties of product. However, the applications are limited due to its poor mechanical properties and high moisture absorption, compared to composites with synthetic fibers. Then, to minimize these problems and to enlarge the possible applications, the objective of this work was to evaluate the mechanical behavior of hybrid composite combining natural (sisal) and synthetic fibres (glass) in a polyester matrix. A comparative study of the flexural mechanical properties among the hybrid composite and two others, one just with fibreglass and other with layer number different. Besides, water absorption tests were carried out for all composites. Results showed the mechanical properties of the hybrid and fibreglass composites were very close. It was observed also layer number influenced in mechanical properties.

1 Introduction

Nowadays, the effects of natural fibres as reinforcement on the mechanical properties of polymeric composites have been studied. These fibers present advantages related to their low density, availability from renewable sources, low cost, and non-abrasive processing characteristics when compared with glass fibers [1-3]. However, these natural fibers are relatively poor moisture resistance, fiber wetting, and its adhesion to the matrix, which affecting mechanical properties. Then, several chemical surface modifications in the natural fibers have been carried out to improve [4-6].

A more efficient way to enhance properties of these composites is to combine distinct fibers, i.e., to produce a hybrid composite, so that their individual characteristics may be transferred to the final composite, originating a material with intermediate properties and with potential increase in the range of applications. In this case, the properties of the hybrid composites are controlled by factors such as matrix type, fibers used, fiber length, the relative content of each fiber, along with fiber–matrix interface and how they are distributed in the composite [7].

Some works in the literature shows results interesting with hybrid composites. Resende et al [8] studied the effect of hybridization on the mechanical properties of treated pineapple and glass fabric-reinforced polypropylene composites. Aquino et al [9] evaluated the moisture absorption effect on the mechanical properties of a hybrid sandwich composite with a matrix of orthophthalic polyester resin reinforced by bi-directional woven fabrics of glass and jute fibers with a central layer of a polyester fabric. Schmith et al [10] studied RTM experiments to determine in-plane permeability of glass mats, non-woven polypropylene flow media (PP) and hybrids (glass+PP), with different stacking sequences, and to compare these with various sisal mats and hybrids (glass+sisal) composites by RTM.

In this work, it was evaluated the mechanical behavior of hybrid composite combining natural (sisal) and synthetic fibers (glass) in a polyester matrix. A comparative study of the flexural mechanical properties among the hybrid composite and two others, one just with fibreglass and other with different layer number.

Table 1 presents the interaction between fiber and matrix during the mixture process obtained by flexural tests, which depends fiber/matrix interface.

Samples	***Properties***		
	Strain at rupture (%)	***Flexural Strenght (MPa)***	***Flexural Modulus (MPa)***
LV3 (ggg)	4.2 ± 0.5	144 ± 5.8	2930 ± 124
LV5 (ggggg)	3.5 ± 0.2	158 ± 5.5	3579 ± 263
LH3 (gsg)	5.0 ± 0.2	140 ± 9.4	2359 ± 149
LH5 (gsgsg)	3.9 ± 0.5	148 ± 5.3	3235 ± 193

Table 1. Mechanical properties obtained of the materials (LV –glass fibers composites; LH - hybrid composites)

Analyzing the Table 1 it was observed a decrease in flexural strength and modulus to insert the sisal fiber reinforcement in polymer matrix. However, inserting a larger number of layers (gsgsg) it was possible to achieve a stiffness higher compared to the glassfibre laminate (3 layers) and compared to the 5-layer glassfibre laminate occurred a decrease of 10% in stiffness. Thus, it is suggested that this new material can be replaced. This fact occurred due to interaction fibers/matrix.

The surface of the fractures was examined by scanning electron microscopy technique (SEM), as can be evidenced in Figure 1.

Figure 1 evidence the fractured region after flexural tests, where it was verified the impregnation polyester matrix on fibers surface. Therefore, it was observed fibers fractured in the matrix and pull out fibers, characterizing mechanism of fragile fracture. It was also observed energy dissipation during the frictional process mechanics.

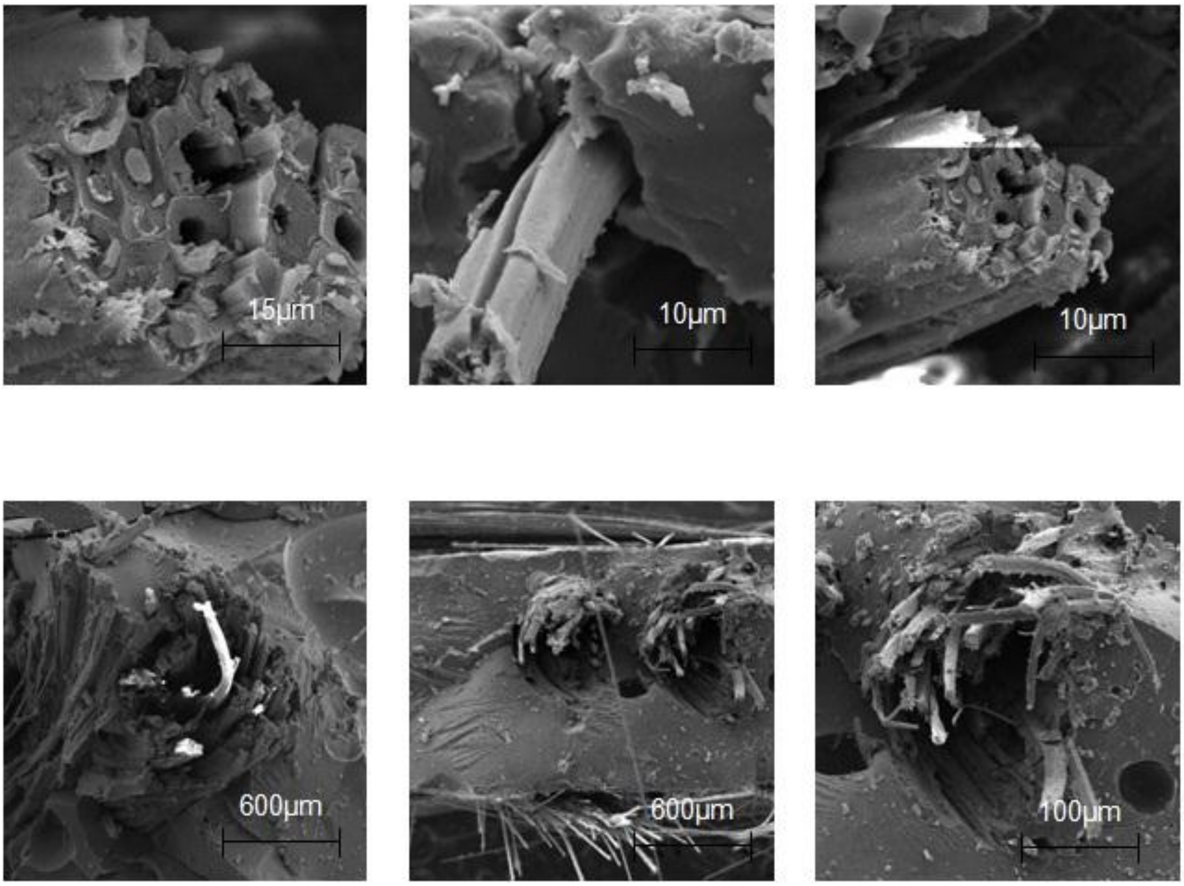

Figure 1. SEM of the fractures. Hybrid composites (gsgsg).

Also it was analyzed the water absorption all composites. The moisture absorption test, carried out in accordance with ASTM D570. Moisture absorption in composites with natural fibers leads to degradation of the fibers-matrix interfacial region, creating poor stress transfer efficiencies and resulting in a reduction of mechanical and dimensional properties [11]. Figure 2 evidences moisture absorption in materials.

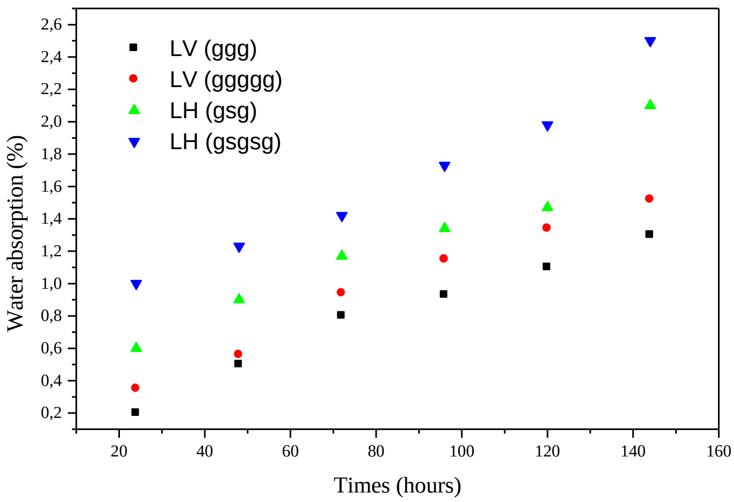

Figure 2. Water absorption of the materials (LV –glass fibers composites; LH – hybrid composites).

Analyzing the results presented in Figure 2, it was observed variation to inserting sisal fibers. Therefore, results wasn´t significant due to good fiber/matrix interaction. The hybridization was efficient to reduce the water absorption of composite. The hybrid composite proved a promising replacement for composites of fiberglass, even in applications with contact with water.

2 Materials and testing methods

The methodology developed in this work was optimized to evaluate the feasibility of technical-scientific proposal.

For the manufacture of hybrid were used:
. Glass fiber blanket
. Sisal fibers from the Northeast region of Brazil
. Ortophtalic unsaturated polyester resin 430-C from NOVAPOL
. Initiator methyl-ethyl-ketone peroxide (P-MEK) from NOVAPOL

2.1. Composites preparation

The composites were manufacture in a glass mold (250 mm x 250 mm) by compression molding. Firstly, the ortophtalic polyester resin was mixed with 2wt% of the peroxide and then cast on the fibrous reinforcements within the mold. The fibrous reinforcements were varied and the assembly was compression molded at room temperature under 3 ton of load for 10 min (Figure 3).

Figure 3. Composites manufactured using the compression molding technique.

Three different groups of composites were studied:
1. Glassfibers /polyester composites: Pure glass composites, called ggg and ggggg.
2. Glass/sisal hybrid composites: The hybrid composites were molded using various layer stacking sequences of washed sisal fiber (s) mats and glass fiber (g) mats, as described below, called gsgsg and gsg.

After curing around 24 hours, the composites were demolded (Figure 4) and cut to the appropriate width for the flexural tests.

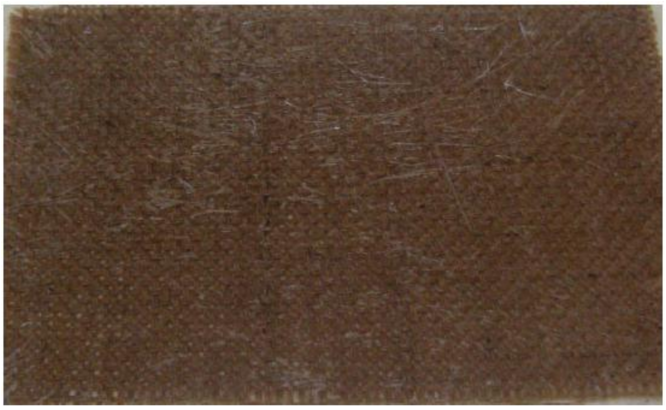

Figure 4. Composites manufactured by gsg.

2.2. Flexural test

Three-point flexural testing was carried out using an EMIC DL2000 universal testing machine and according to ASTM D790-03 [12]. Test speed varied according to each specimen thickness (mostly around 3 mm). About five specimens (dimensions: 127 x 12.7 mm) were tested for each type of composite. After tests the micrographics were obtained on a JEOL scanning electron microscope, JSM5310 with tungsten filament operating at 10 kV, using secondary electrons in order to obtain information about the fractures.

2.3. Water Absorption Tests

Effects of water absorption on composites were investigated in accordance to ASTM D570 [13]. The percentage of water absorption in the composites was canceled by the difference between the samples immersed in water and the dry samples, using the following equation (1).

$$\Delta M(\%) = \frac{M_f - M_i}{M_i} \quad (1)$$

where $\Delta m(\%)$ is moisture uptake, and Mf and Mi are the mass of the specimen after and before immersion, respectively.

References

[1] Yousif, B. F.; Saijod, T. W. L.; McWilliam, S. Polyester composite based on betelnut fibre for tribological applications. *Tribology International*, **v.43**, pp. 503-510, 2010.

[2] Brugnago, R. J.; Satyanarayana, K. G.; Wypych, F.; Ramos, L. P. The effect of steam explosion on the production of sugarcane bagasse/polyester composites. *Composites: Part A, v. 42*, 364-370, 2011.

[3] Wong, K. J.; Zahi, S.; Low, K. O.; Lim, C. C. Fracture characterisation of short bamboo fibre reinforced polyester composites. *Materials and Design*, **v.31**, pp. 4147-4154, 2010.

[4] Carvalho, K. C. C.; Mulinari, D. R.; Voorwald, H. J. C.; Cioffi, M. O. H. Chemical modification effect on the mechanical properties of HIPS/ coconut fiber composites. *BioResources*, **v.5(2)**, pp. 1143-1155, 2010.

[5] Mulinari, D. R.; Baptista, C. A. R. P.; Souza, J. V. C.; Voorwald, H. J. C. Mechanical properties of coconut fibers reinforced polyester composites. *Procedia Engineering*, **v.10**, pp.2074-2079, 2011.

[6] Florentino, W. M.; Brandão, A. T.; Miléo, P. C.; Goulart, S. A. S.; Mulinari, D. R. Biocompósitos de poliuretano reforçados com fibras de coco verde. *Cadernos UniFOA*, **v. 17**, pp. 23-28, 2011.

[7] Amico, S. M.; Angrizani, C. C.; Drummond, M. L. Influence of the stacking sequence on the mechanical properties of glass/sisal hybrid composites. *Journal of Reinforced Plastic and Composites*, **v.29,** pp.179–189, 2010.

[8] Resende, J. M.; Oliveira, F. L.; Mulinari, D. R. Avaliação de compósitos híbridos para aplicação na engenharia. *Cadernos UniFOA*, **v. 15**, pp. 11-18, 2011.

[9] Aquino, E. M. F.; Sarmento, L. P. S.; Oliveira, W.; Silva, R. V. Moisture Effect on Degradation of Jute/Glass Hybrid Composites. *Journal of Reinforced Plastic and Composites*, **v.26(2),** pp.219–233, 2007.

[10] Schmidt, T. M.; Goss, T. M.; Amico, S. C. Permeability of hybrid reinforcements and mechanical properties of their composites molded by resin transfer molding. *Journal of Reinforced Plastics and Composites*, **v. 28**, pp.2839-2850, 2009.

[11] Mulinari, D. R.; Voorwald, H. J. C.; Cioffi, M. O. H.; Da Silva, M. L. C. P.; Rocha, G. J. M. Surface modification of sugarcane bagasse cellulose and its effect on mechanical and absorption properties of sugarcane bagasse cellulose/HDPE composites. *Bioresource*, **v. 5**, pp.661-671, 2010.

[12] AMERICAN SOCIETY FOR TESTING AND MATERIALS. **ASTM D 790**: Standard Test Method for Flexural Properties of Unreinforced and Reinforced Plastics and Electrical Insulating Materials. United States of America, 2003.

[13] AMERICAN SOCIETY FOR TESTING AND MATERIALS. **ASTM D 570**: Standard Test Method for Water Absorption of Plastics. United States of America, 2005.