MECHANICAL PROPERTIES OF CURAUA/GLASS COMPOSITES EVALUATED BY DESTRUCTIVE AND NON-DESTRUCTIVE TESTING

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Abstract - This article aims to evaluate the hybridization effect on the in-plane shear strength and some engineering elastic constants. The composites were produced by hot compression molding at pressure of 6 ton, 90 °C by 75 min. The overall fiber volume fraction (20, 30 and 40 vol.%) and curaua/glass content: pure curaua, pure glass and some hybrid curaua/glass fiber reinforced polyester composites. The elastic properties were obtained by a non-destructive test (NDT) based on an excitation vibration technique. The Iosipescu shear strength showed higher values for the composites with 30 vol.% and the elastic modulus increase upon more rigid fiber incorporation (glass fiber) and overall fiber volume fraction. Also, the shear modulus increased up to 30 vol.% and decrease for the composites with 40 vol.%.

Keywords: *Environmental composites, curaua fiber, non-destructive test; Iosipescu shear, elastic properties.*

Introduction

Composites are based on the union of two or more distinct materials, combining characteristics of both constituents. Concerning the continuous phase, polyester, vinyl ester and epoxy are some thermoset polymers. Already the dispersed phase, the reinforcement can be from two sources: synthetic or natural. Natural fibers have some advantages, as obtain from renewable sources, abundance, low cost, high electrical resistance [1] and high specific properties. Among the drawbacks, poor fiber/matrix adhesion, high moisture absorption, low mechanical properties and heterogeneity are reported.

The low mechanical properties and high moisture absorption restricts the applications of natural fibers. Curaua fiber (*Ananas erectifolius*) is found in abundance in the Brazilian Amazon region and is a plant from the Bromeliad family. These fibers have high tensile strength and Young's modulus when compared to other vegetable fibers like jute, sisal and banana [2]. Due to these reasons the curaua fiber is preferred to compose internal parts of cars, as sun visor bracket, upholstery, panels, hood and door inside, among others [3].

Hybridization with synthetic fibers can be a solution to this, combining good traits of both fibers, reducing the final cost and weight. Factors as fiber length, fibers orientation, stacking sequence [4], fibers content, fiber volume fraction ($\%V_f$) and dispersal mode of fibers influence on the final properties. Almeida Júnior et al. [1] studied hybrid intralaminate curaua/glass composites with different $\%V_f$ and curaua/glass ratio with fibers randomly oriented. They achieved mechanical and dynamic mechanical properties of the hybrid composite using a $\%V_f$ of 30 vol.% and replacing 30% of glass by curaua fiber similar to pure fiberglass composites. Monteiro et al. [5] studied the mechanical properties of curaua/polyester composites with different $\%V_f$ (5 – 30 vol.%) and the flexural strength reached a plateau from $\%V_f$ of 20 vol.%, around of 100 MPa. Thus, the aim of this study was evaluate the effect of curaua and glass fiber hybridization in polyester resin on its shear and elastic properties varying the curaua/glass ratio and overall fiber volume fraction.

Experimental

The raw materials used in present work were: curaua fiber rope; glass fiber roving; unsaturated orthophtalic polyester resin; acetyl acetone peroxide (AAP) as initiator and degassing agent A515, from BYK.

The curaua fiber rope was disentangled and selected. Both fibers (curaua and glass) were cut to 50 ± 2 mm in length. The fibers were randomly distributed in a pre-mold and compacted using hydraulic press (Marconi – MA 098/A3030) for 30 min at 3 ton and room temperature. The mats were dried in an oven at 105 °C for 30 min, except the pure glass mats.

The resin system was prepared by adding 2 wt.% of curing agent and 2 wt.% of degassing agent, in relation to the polyester. Both were followed by 2 min of manually stirring for homogenization. The resin was then submitted to ultrasonic bath at room temperature for 5 min. The composites were produced by compression molding under 6 ton, at 90 °C for 75 min, followed by post-curing at 80 °C for 120 min in an oven with air circulation. The overall fiber volume fraction ($\%V_f$) varied within 20, 30 and 40% and the curaua/glass fibers ratio also was varied. The nomenclature adopted was according to $\%V_f$, curaua fiber and glass one content, for instance: for the composite named 30/30/70, it has $\%V_f$ of 30%, 30% of curaua fiber and 70% of glass fiber. The nomenclature and composition of all composites studied are shown in Table 1.

Table 1 – Nomenclature and composition of all composites.

Sample	*Overall V_f (%)*	*Curaua fiber content (vol.%)*	*Glass fiber content (vol.%)*
20/100/0	20	100	0
20/30/70	20	30	70
20/0/100	20	0	100
30/100/0	30	100	0
30/70/30	30	70	30
30/50/50	30	50	50
30/30/70	30	30	70
30/0/100	30	0	100
40/100/0	40	100	0
40/30/70	40	30	70
40/0/100	40	0	100

The Iosipescu shear test was performed in a Shimadzu (AG-X model) testing machine, with load cell of 50 kN and test speed of 0.5 mm.min^{-1}. Three rectangular specimens (76 × 20 × 3 mm) with two symmetrical centrally located V-notches were tested, according to ASTM D5379-05 standard. The elastic properties of non-used Iosipescu specimens were also evaluated using a non-destructive test (NDT) based on impulse excitation of vibration, carried out in a Sonelastic® (ATCP Engenharia Física, Brazilian Company) equipment. In this technique, the specimen under test is subjected to a mechanical light tap and reacts emitting an acoustic response. The ASTM D1876-09 was used to precede these NDT tests and measurements. The elastic (E-modulus) and shear modulus (G-modulus) can then be obtained using Equations (1) and (2), respectively, according to ASTM E1876-09 standard.

$$E = 0.9465\left(\frac{m f_f^{\,2}}{w}\right)\left(\frac{L}{t}\right)^3 T \quad \text{and} \quad T = 1 + 6.858\left(\frac{t}{L}\right)^2 \qquad (1)$$

where m is the mass, f_f the fundamental resonance frequency in flexure, L the length, w the width, t the thickness and T the correction factor.

$$G = \left(\frac{4Lmf_t}{wt}\right)\left(\frac{B}{1+A}\right) \qquad (2)$$

where:

$$B = \left(\frac{w/t + t/w}{4(t/w) - 2.52(t/w)^2 + 0.21(t/w)^e}\right) \qquad (3)$$

and,

$$A = \left(\frac{0.5062 - 0.8776(w/t) + (0.3504(w/t)^2 - 0.0078(w/t)^3}{12.03(w/t) + 9.892(w/t)^2}\right) \qquad (4)$$

Results and Discussion

Fig. 1 shows the Iosipescu shear strength results. As can be seen, the composite 30/30/70 presented values near from the pure glass composite (30/0/100). An unexpected phenomenon was the pure curaua composites show higher properties than the hybrid composites in all $\%V_f$ studied. This may have possible to the folding during the test and a non-symmetrical notch in the center of the sample, harming the moment generated by the load applied in the testing.

These results did not show a clear trend, and most of the composites presented shear strength within the 20-24 MPa range. In accordance to Selmy et al. [6], the in-plane shear strength of Iosipescu specimens as the stress value corresponding to the ultimate load. Variation of specimen thickness and experimental difficulties may have negatively influenced these test results, such as those related to machining the symmetrical notches of specific dimensions especially when vegetable fibers are used.

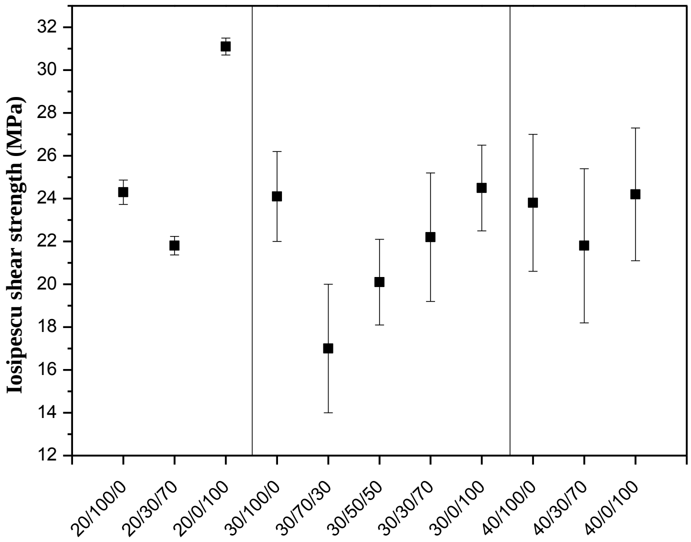

Figure 1 – In-plane shear strength of all composites studied.

The Elastic modulus (Fig. 2) presented an expected trend, increasing the elastic modulus upon glass fiber incorporation and with the *%V$_f$*. An highlight is the sample 30/30/70, with higher elastic modulus of all pure curaua and hybrid curaua/glass in all *%V$_f$* studied, excepted from the 30/0/100 composite, that had greater elastic modulus among all composites studied. But the sample 30/30/70 has only 21% less than the pure glass composite. Regarding rigidity of the composite, the properties of the fibers are more relevant than those of the resin, since modulus of the resin is much lower than those of the other constituents. The expected trend also repeated here, i.e. modulus increased for higher overall fiber content and for higher glass fiber content.

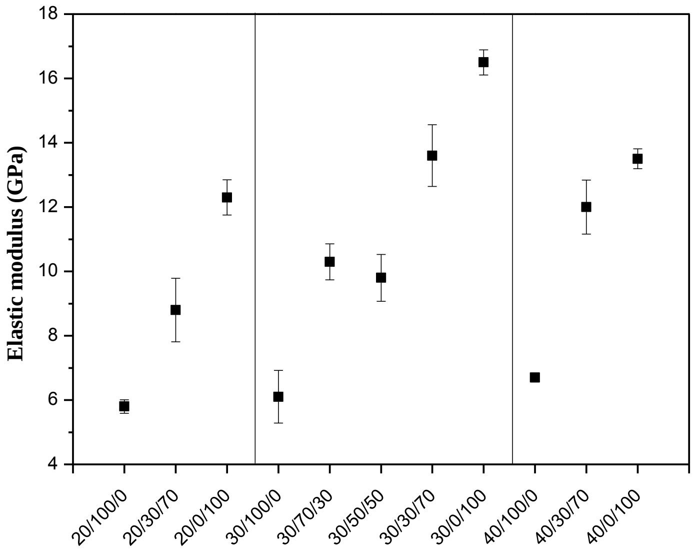

Figure 2 - Elastic modulus of the composites studied measured by NDT.

The shear modulus (Fig. 3) presented intermediately values for the hybrid composites and did show more expressive shear modulus for *%V$_f$* of 20 vol.% and the hybrid composites of 30 vol.% show greater shear modulus for 30/70/30 composite, since the stiffness of the fibers is not decisive in this parameter. The interfacial strength and specimen thickness are the most predominant variables in the shear modulus. This may have occurred due to thickness variations in the specimen, which disturbs coupling between the transducers (exciter and receiver), yielding distinct acoustic responses for the same sample. The Poisson's ratio of the produced isotropic composites could be estimated by $\nu = (E/2G) - 1$. But due to the variations in the previous moduli results, unreliable Poisson's ratio results were found in some cases.

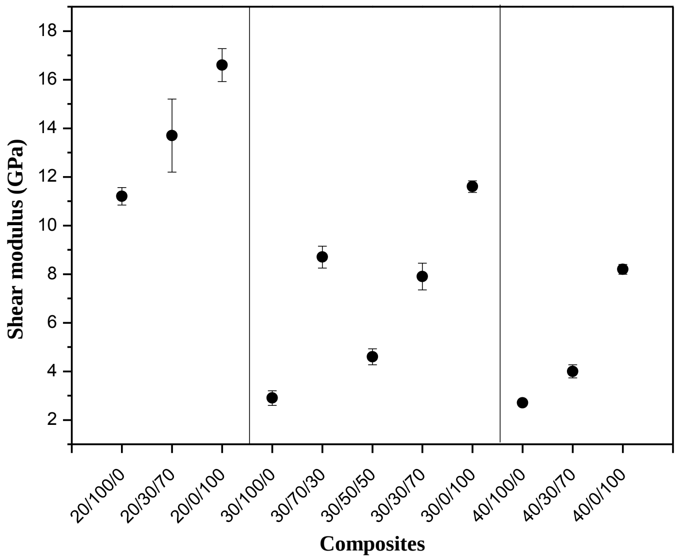

Figure 3 - Shear modulus of all composites studied measured by NDT.

Conclusion

In this present work was evaluated the hybridization effect of curaua fiber and glass one in polyester resin on its mechanical properties. The in plane shear strength, measured by Iosipescu method, did not show a clear trend probably due to experimental difficulties related to the characteristics of the specimens. Regarding the results from non-destructive tests, the elastic modulus obtained increasing upon incorporation of the more rigid fiber and for higher $\%V_f$ (up to 30 vol.%). The shear modulus presented the opposite behavior, lower shear modulus for higher $\%V_f$, that is strongly influenced by the specimen thickness, providing different acoustic response and consequently changing the shear results.

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