Analysis of mechanical properties of hybrid composites reinforced with jute / fiberglass in epoxy matrix

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Abstract**—*The study of vegetable fibers has been usual for the manufacture of many utensils in industry in general. Vegetable fibers are considered for their high renewability, high degradability, and low cost. In this work, the mechanical properties of the tensile and flexural strength and the modulus of elasticity of hybrid composites of jute fibers with fiberglass in an epoxy polymer matrix were evaluated. The fibers were treated in a 5% by weight NaOH solution and subjected to tensile tests in a universal testing machine according to the ASTM D3039 and D790 standards. The composites with the best performance were jute + fiberglass hybrids, with 113% for the tensile strength and 32% for the elastic modulus. In the bending tests, the results showed a performance of 111% for the maximum stress and 20% in the highest breaking stress for the hybrid composites.*

Keywords**— *jute, composites, mechanical properties, vegetal fibers.***

I. INTRODUCTION

The importance of using jute fiber has increased in recent decades worldwide, resulting from important properties such as low weight, low cost and are environmentally sustainable [1]. The main goal in using jute fibers is to replace synthetic fibers, which are more expensive and difficult to dispose of.

Composites are a combination of two or more materials with the objective of obtaining properties superior to those of the individual materials [2]. Two distinct phases can be observed. A continuous (matrix), a dispersed (reinforcement), interspersed by the contact region between the two phases, called the interface. The matrix can be metallic, polymeric or ceramic. The fibrous reinforcement phase (fiberglass, carbon, vegetal) or particulate [3].

The use of composites is very old and authors report since antiquity, dating from 1,800 B.C. The use of vegetable fibers as reinforcement in composites with clay [3]. Modernly, studies of composites with vegetable fibers reinforcing polymer matrices for use in various sectors of the industry. From plant fibers, specific parts such as fibers (jute, flax, ramie, hemp), seeds (cotton, coconut), leaves (jute, pineapple), cane fiber (rice, corn), core fibers (hemp, kenaf, jute).

Tensile strength, flexural tension and modulus of elasticity are the main properties analyzed in these composites.

The main difficulties in using vegetable fibers in polymeric matrices is the incompatibility between fibers and resins. However it can be partially solved with chemical treatments like silane, acetylation, mercerization [3]. The main constituents of vegetable fibers are cellulose, hemicellulose, lignin and vary according to the species considered [4]. In the literature, many plant fibers are being studied in order to replace conventional carbon, glass and kevlar fibers, such as bamboo, coconut, sisal, jute, hemp, piassava, banana, cotton, etc.

1. The jute fiber

Jute fiber is obtained from the plant *Corchorus capsularis*, a woody herb from the family *Tillloideae*. Jute plants are easily found in India, but can also be found in the state of Pará, Brazil. It has an average composition of 64% cellulose, 9.7% resistance to traction, flexion, and modulus in jute composites with fiberglass were carried out by Braga et al [5] and the results resulted in an increase in density, strength tensile strength and tensile strength.

Many studies have aimed to analyze the properties of jute fibers.

Sanjay et al [6] highlighted the main mechanical properties of vegetable fibers, among them, the elastic, flexural, impact, interlaminary and hardness properties. Mohamed et al [7] evaluate the various applications of plant fibers, highlighting chemical treatments, the mechanical properties associated with the origin of the fibers.

The performance of the mechanical properties of a jute composite with epoxy resin was better than the jute composite with polyester. The jute fiber was treated with 5% NaOH had a better result than that treated with 10% [8]. Monteiro et al [9] analyzed the relationship between the diameter of the jute fiber and the tensile strength. The results showed that the resistance decreased with increasing diameter, attributed to premature rupture of thicker fibers before thinner fibrils.

The analysis of the effect of fiber length in random orientation of jute fibers was the object of study by Bisaria et al [10] and concluded that it reached the maximum in tensile and flexural strength with the fiber of 15 mm and 20 mm in length for impact property.

Server et al [11] investigated the stacking sequence in linen / fiberglass and jute / fiberglass composites and the results showed that there is no effect on the tensile strength and modulus as to the sequence, but when the fiberglass is found in the outer layers the result was superior.

Sanjay et al [12] also conducted work analyzing the stacking sequence of jute, kenaf and fiberglass fibers. The results showed a significant improvement in the flexion and traction properties.

Misra et al [13] conducted work analyzing hybrid composites of coconut fiber with jute and fiberglass. In this work, composites with treated coconut fiber resulted in greater resistance to traction and flexion than untreated composites.

2. Fibers Treatments

The fibers need treatments for adhesion with the matrix to be effective. These treatments aim to remove the pectin and waxes that prevent the adhesion of the fibers to the matrix [15]. These treatments can be chemical or physical. Many authors have published works addressing different ways of treating fibers.

Mwaikambo et al [15] studied alkalinization in hemp, sisal, jute and kapok.

Corrales et al [16] analyzed the application of fatty oil (oleyl chloride) in jute fiber. Merlini et al [17] analyzed the effect of alkaline treatment on jute fibers, showing superior performance in treated fibers.

Anna Dilfi et al [18] studied treatments with 3-glycidoxypropyltrimethoxysilane (KH560), alkaline (NaOH) and composition of the two treatments. The results showed that the treatments with compounds of the two treatments performed better for the flexural and modulus tension when compared with the isolated treatments in jute fiber composites reinforcing epoxy matrix. Razera et al [19] carried out work with a jute fiber composite in a phenolic matrix showing the best result with treating the fibers with 10% NaOH for tensile strength.

II. MATERIALS AND METHODS

A medium viscosity epoxy resin code 969 MVORGIBX and epoxy hardener code 289 ORGBACMIBX, purchased from IBEX Químicos e Composites. As reinforcement, jute fibers in the form of mesh purchased from the company SisalSul, fiberglass in the form of mesh and grass of 300 g / m², purchased from the company IBEX were used. For the treatment of fibers, sodium hydroxide (NaOH) J T Baker was used.

2.1. Fiber treatment

The jute fiber was washed with distilled water, dried in an oven for 24 hours, at 40ºC. It was placed in a solution of 5% by weight of sodium hydroxide in distilled water for 5 days at room temperature and the fibers were washed to remove excess solution and placed for drying for 24 hours.

2.2. Preparation of composites

The composites were grouped in the following constitutions, all in an epoxy matrix: untreated jute fiber, treated jute fiber, untreated glass fiber jute, treated glass fiber jute.

The composites were manufactured molded in a flat plate format in a 2: 1 epoxy matrix (resin: hardener) with dimensions 250mmx20mmx4mm. In hybrid composites, a layer of jute mesh and two layers of fiberglass mesh, in the form of sandwich, with the jute in the middle, were used. For the manufacture of the composite, the following sequence was considered: the resin mixture was poured into a glass plate mold.

The layer of fiberglass was placed, then a layer of jute fiber, and then another layer of fiberglass and again resin for complete coverage of the fiber.

After molding, the composites remained at rest in the air for 24 h, when they were demoulded and later cut to make the specimens. Fig. 1 shows the composite ready to be cut.

Fig.1: Jutel fiber composite

2.3. Caracterization

2.3.1. Mechanical Tests

The tensile and flexion tests were conducted in a Time Group universal testing machine, model WDWEB according to ASTM D3039 and ASTM D790 standards. For the tensile test, the velocity of 2 mm / min was used and for the flexion tests, the three point flexion test speed was 2 mm / min, with a distance of 50 mm between the points.

2.3.2. Density

After being cut and sanded, the specimens were measured for dimensions of width and thickness, the masses were measured at a temperature of 24ºC and the average densities of the specimens were calculated. Densities were calculated from measurements of dimensions of width, thickness and length. The width and thickness were measured with a pachymeter in three positions on the specimen defined at the ends and in the middle. The masss of each specimen was measured on a semi-analytical balance. The density was calculated according to the equation

$$\rho = \frac{m}{V} \tag{1}$$

where ρ is the density (g / cm³), m (kg) the mass of the and V (cm³) the volume of the specimen respectively.

III. RESULTS AND DISCUSSIONS

2.4. Average densities

The average densities of the manufactured specimens are shown in Table 1

Table 1: Average density specimens

	Jute	Jute+ Fiber Glass
Average density ρ(g/cm³)	1.128±0.032	1,167±0.032

These table results correspond to the averages of the analyzed specimens.

2.5. Tensile Tests

The average results of the tests are shown in Table 2. The values maximum stress (T_M), rupture stress (T_R) and module (E) are shown.

Table 2: Average results of tensile tests

	T_M (MPa)	T_R (MPa)	E (GPa)
Jute treated	22.432±2,000	18.598±4,144	2,632±0.227
Jute+Fiberglass treated	47.806±1.664	40.144±6.686	3.473±0.327

In general, hybrid composites containing fiberglass-treated jute fiber performed much better. Jute composites with fiberglass increased 113% compared to composites with only jute in relation to maximum tensile strength (T_M). The tensile strength (T_R) increased by 115% when glass fiber was added to the composite and the module increased by 32%, approximately when glass fiber was added to the hybrid composite. Fig. 2 shows the average behavior of composites containing only jute.

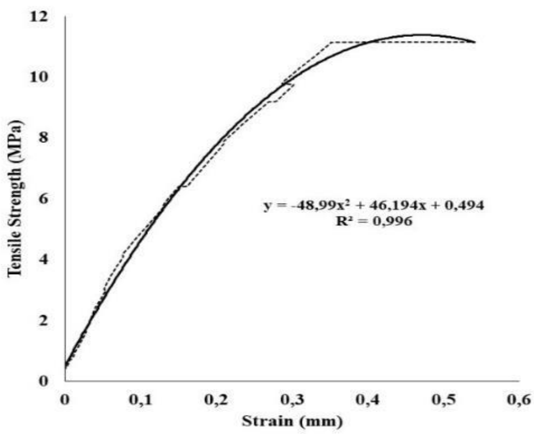

Fig.2: Tensile Strength x Strain curve jute untreated

In Fig. 3, the graph shows the average behavior of hybrid jute and fiberglass composites subjected to traction. The solid line corresponds in the graphs to the trend lines of the

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average results of the tests performed. The results showed very good correlations between deformation and stress applied to the composite.

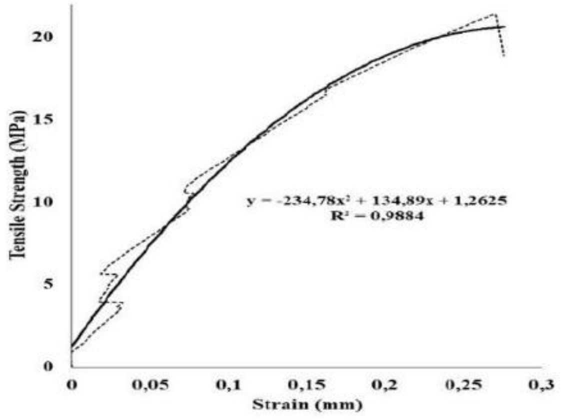

Fig.3: Tensile Strength x Strain curve jute treated

And in Fig. 4 and Fig 5 are presented the average behavior of hybrid composites of jute and fiberglass, untreated and treated, respectively.

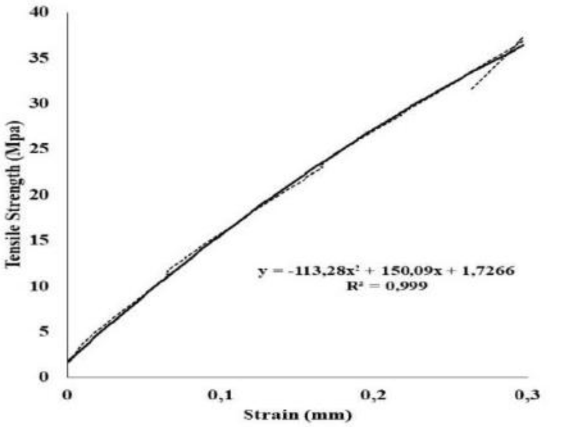

Fig.4: Tensile Strength x Strain curve jute/glass untreated

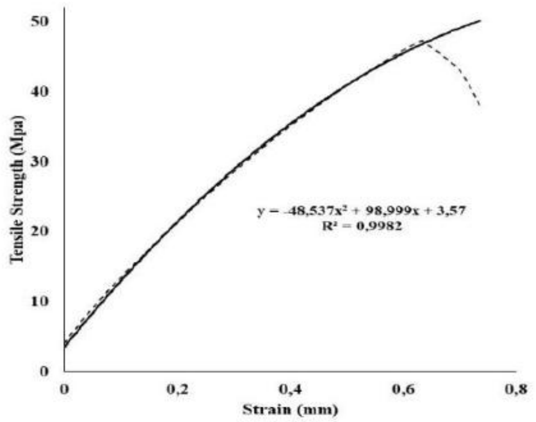

Fig.5: Tensile Strength x Strain curve jute/glass treated

2.6. Bending tests

The average results of the flexion tests are shown in Table 3 below.

Table 3: Average bending test results

	T_M (MPa)	T_R (MPa)
Jute treated	2.383±0.070	2,954±0.186
Jute + Fiberglass treated	5.038±0.235	3.534±0.304

Fig. 6 and Fig. 7 show the behavior of bending tests in composites with only jute.

The results show that hybrid specimens performed better than non-hybrid composites. The maximum strength (T_M) for the fiberglass composite had an increase of 111%. The tensile strength was 20% higher in jute fiber and glass fiber hybrid composites.

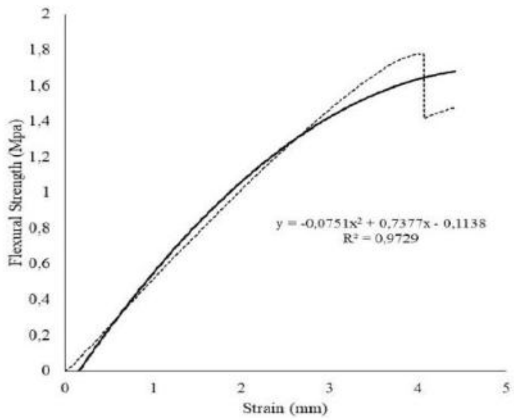

Fig.6: Flexural Strength x Strain curve jute untreated.

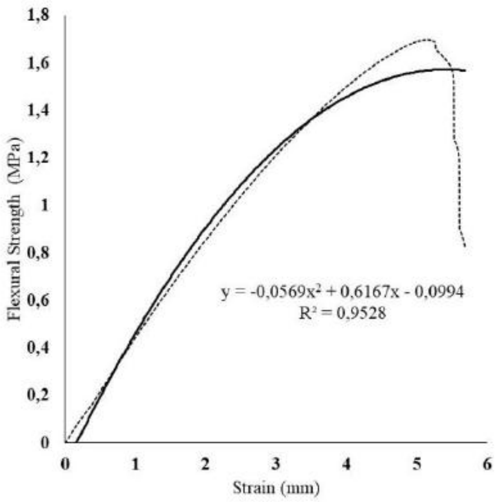

Fig.7: Flexural Strength x Strain curve jute treated.

In Fig. 8 and Fig 9 are presented the average results of the behavior of the hybrid jute composites with fiberglass, where the stresses were higher in the hybrid composites.

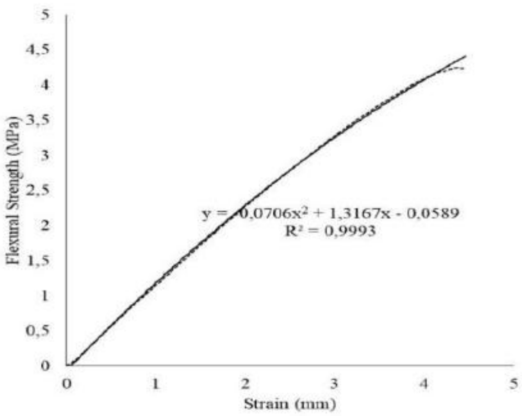

Fig.8: Flexural Strength x Strain curve jute/glass untreated.

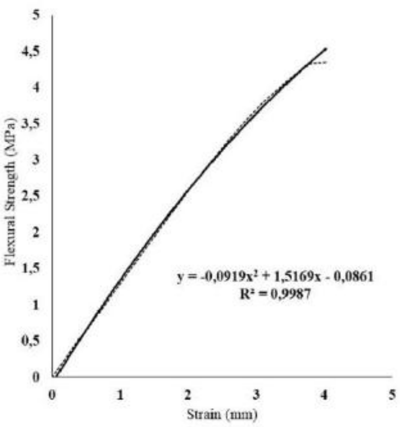

Fig.9: Flexural Strength x Strain curve jute/glass treated

IV. CONCLUSIONS

Vegetable fibers have recently been used as important substitutes for fiberglass and carbon in industry products. This work aimed to analyze the mechanical properties of composites containing jute fiber by analyzing the contributions of hybridization with glass fiber in an epoxy matrix. The results showed that hybrid composites containing jute and fiberglass performed better in the tests of tensile and flexion and modulus of elasticity than composites with only jute fibers. This study points out that from the point of view of stresses in jute composites there is an important contribution to performance when associated with fiberglass.

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