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CHARACTERIZATION OF NATURAL FIBRE REINFORCED HYBRID COMPOSITES

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Abstract: *With the increase in the use of composite materials in several industrial applications (such as in the aeronautics, automotive and defense industries), the need for the development of materials with low density and equivalent mechanical properties to existing composites, but with reduced costs and better relation between resistance and ductility. Thus, a new classification for these materials has appeared, named hybrid composites, which are characterized by the presence of more than one type of reinforcement that will give the final laminate characteristics similar to the materials that compose it. Among the existing hybrid matrix polymer composites are those reinforced with synthetic, natural or with both types of fibres. In particular, hybrid composites reinforced with mixed or only natural fibres have gained great visibility in recent years due to characteristics such as: low environmental impact,reduced carbon emission levels during their production process and low density, despite having low interfacial adhesion in matrices polymer. In this way, this work aims to characterize two types of hybrid composites reinforced with natural fibres (jute + sisal, jute + curauá) and a jute laminate by tensile, flexural and impact tests in the untreated and alkalinized conditions. Afterwards, scanning electron microscopy images were performed in order to verify the influence of the application of superficial chemical treatment on the fracture type of the composites studied. It is expected that at the end of the research the alkaline composites present higher results in relation to the untreated composites and, in particular, that the hybrid composites present better mechanical properties in relation to the laminate of only jute.*

Keywords: *Hybrid composites, natural fibres, jute, sisal, curauá.*

1. INTRODUCTION

The use of composite materials in the aeronautics, automobile, packaging and civil construction industries is constantly growing due to its low density combined with excellent mechanical properties. However, these types of materials present a direct correlation between the strength and hardness, resulting in brittle fracture behaviour [1]. Such behaviour becomes a limiting factor in some types of applications that require a good mechanical resistance and ductility of the material.

In order to solve this limitation several researches were developed. Among the solutions found are: change in the properties of the matrix composing the composite through the addition of nano-structured materials or through chemical modification, and the implementation of hybridization techniques (Swolfs *et al.*, 2014; Hui *et al.*,2010; Fratzl *et al.*, 2007; Ku *et al.*, 2011; Jawaid *et al.*, 2011; Dicker *et al.*, 2014).

Hybridization in composite materials consists of the presence of two or more types of reinforcement in the matrix thereof. In the diagrams of Fig. 1 and Fig. 2 a classification of composite materials and hybrid composites is, respectively, presented.

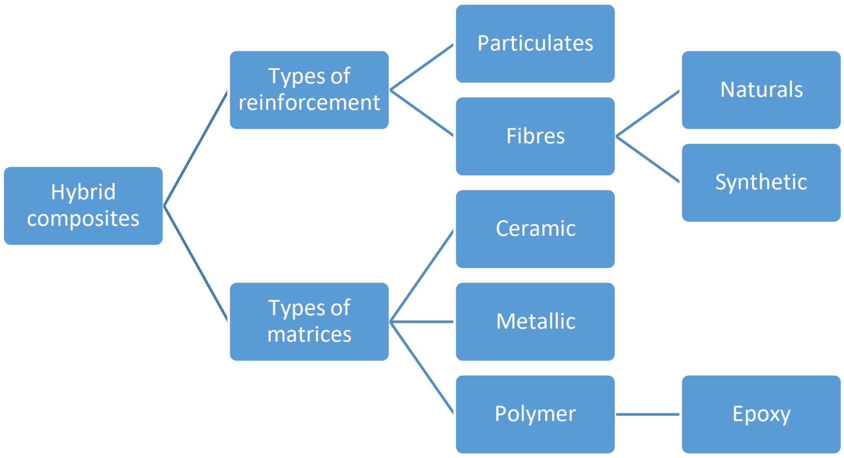

Figure 1: Classification of composite materials.

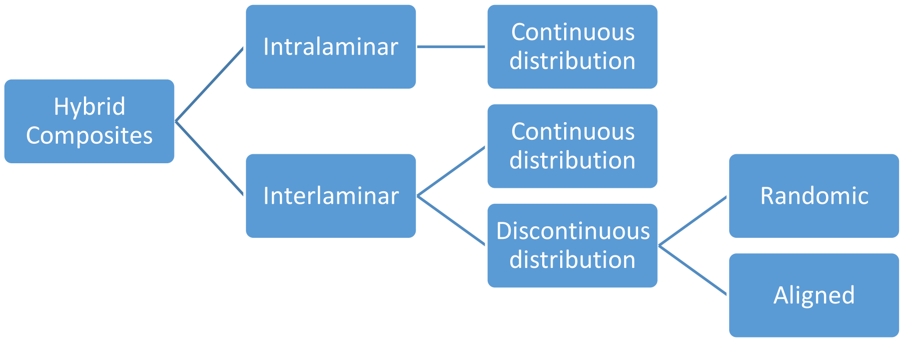

Figure 2: Classification of hybrid composites.

Hybrid composites can also be classified according to the type of reinforcing fibre used in their manufacture. Thus, hybrid composites reinforced with synthetic, natural or mixed (natural + synthetic) fibres can be produced.

With the increasing interest in the research and use of hybrid composite materials, the visibility in the application of natural fibres as reinforcement of these materials, either partially or totally, has increased. This is due to the fact that natural fibres present as main characteristics: low environmental impact and energy consumption during their production, reduced density, and good resistance to fatigue and impact. However, it presents some limitations such as low interfacial adhesion in polymer matrices, and greater sensitivity to humid environments and exposure to UV rays (Pickering *et al.*, 2016; Nunna *et al.*, 2012; Mittal *et al.*, 2016).

The main objective of this work is to investigate the influence of the application of the hybridization technique on the mechanical properties of hybrid fibers reinforced with natural fibers (jute, jute + sisal and jute + Curauá). The effects of the chemical treatment of alkalinisation of the fibers in the characterization of the materials will also be analysed.

2. EXPERIMENTAL PROCEDURE

The following materials were used for the production of the studied intralaminar hybrid composites: bidirectional jute fabric and sisal yarn (supplied by Sisalsul, São Paulo - Brazil), curauá yarn (supplied by Permatec, Santarém - Brazil) and a bi component epoxy resin, in the proportion of 26g of hardener per 100g of resin - AR260 / AH260 (supplied by Barracuda Advanced Composites, Rio de Janeiro - Brazil).

The fabrication of the fabrics to be used in the lamination of the hybrid composite, the yarns of the sisal and curauá fibres were sewn between the voids of the jute fabric, according to the detail of Fig. 3, in such a way that a hybrid fabric configuration was obtained (60% jute and 40% the other fibres).

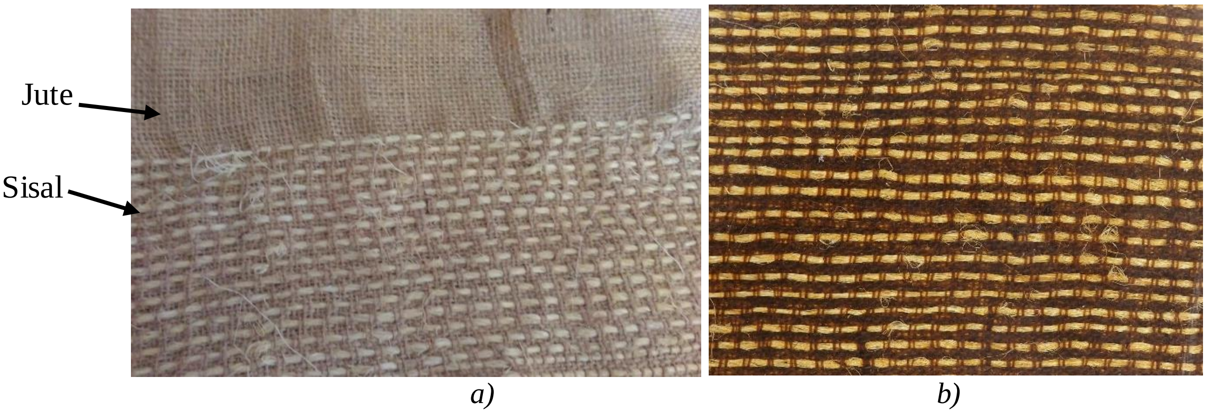

Figure 3: (a) Fabrication of hybrid jute fabric + sisal and (b) hybrid jute +sisal after lamination

Soon after the fibres were washed and submitted to the superficial chemical treatment of alkalinisation, in which the fibres were immersed in alkaline solution (concentration of 2% NaOH) for 2 hours and finally dried in an oven at 100 ° C, also for 2 hours.

Finally, for the production of the composite materials the hand-lay-up method was used. After that the laminate was put in a hydraulic press at a pressure of 120 kgf / cm² and at a temperature equivalent to 80° C for 6 hours until the total cure of the resin. The volumetric percentage of reinforcing fibres used is equal to 30%, a reasonable value considering a manual manufacturing process.

The following ASTM standards were used for the tensile, flexure and impact tests and standardization of the test specimens: D638, D790 and 6110. It is worth noting that all the composites were produced with two layers of fabric for the tensile tests and three layers for bending and impact tests.

The tensile and flexure tests were performed on an Instron 5966 with a load cell of 10 kN, in conjunction with a 25mm extensometer (hydraulic, multiaxial machine - Instron, Paraná-Brazil) present in the composite and adhesive laboratory of CEFET / RJ, according to Fig. 4. The impact tests were performed using the Wolpert machine, present at the metallurgy laboratory of CEFET / RJ.

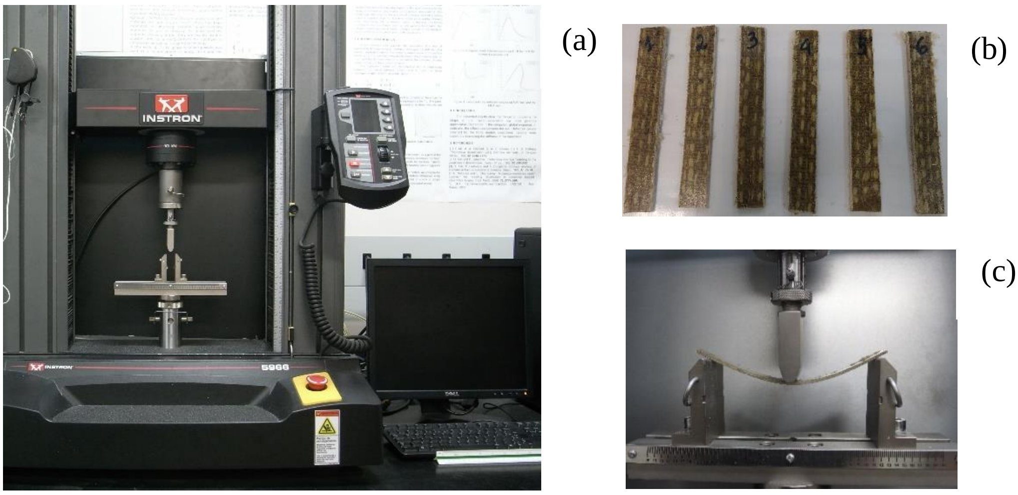

Figure 4: a) Instron 5966; b) Samples; c) Details flexural test

3. RESULTS AND DISCUSSIONS

The tensile test of the reinforced composites based on natural fibres (jute, jute + sisal and jute + Curauá) was carried out in the condition without superficial chemical treatment and with alkaline treatment. The velocity rate used in the tensile test was equal to 1mm/min.

The results can be seen in table 1 and in the graph of Fig. 5.

Table 1: Tensile test results.

Type of composite		Load (N)	Tensile stress (MPa)	Elongation (%)	Young's modulus (GPa)	Density (g/cm³)
Resin		745	28 ± 2	10	3.8	1.15
Jute	without treatment	1122	39.1 ± 7.4	25	4.2	1.15
	Alkalinized	1201.2	30 ± 4	7	5.5	1.11
Jute + Sisal	without treatment	3039.78	75.99 ± 4.1	12	9.7	1.3
	Alkalinized	2762.90	69.10 ± 7.2	6	10.7	1.28
Jute + Curauá	without treatment	1753.8	68.5 ± 5.6	20	6	1.33
	Alkalinized	2840.2	71 ± 7.2	12	10.7	1.31

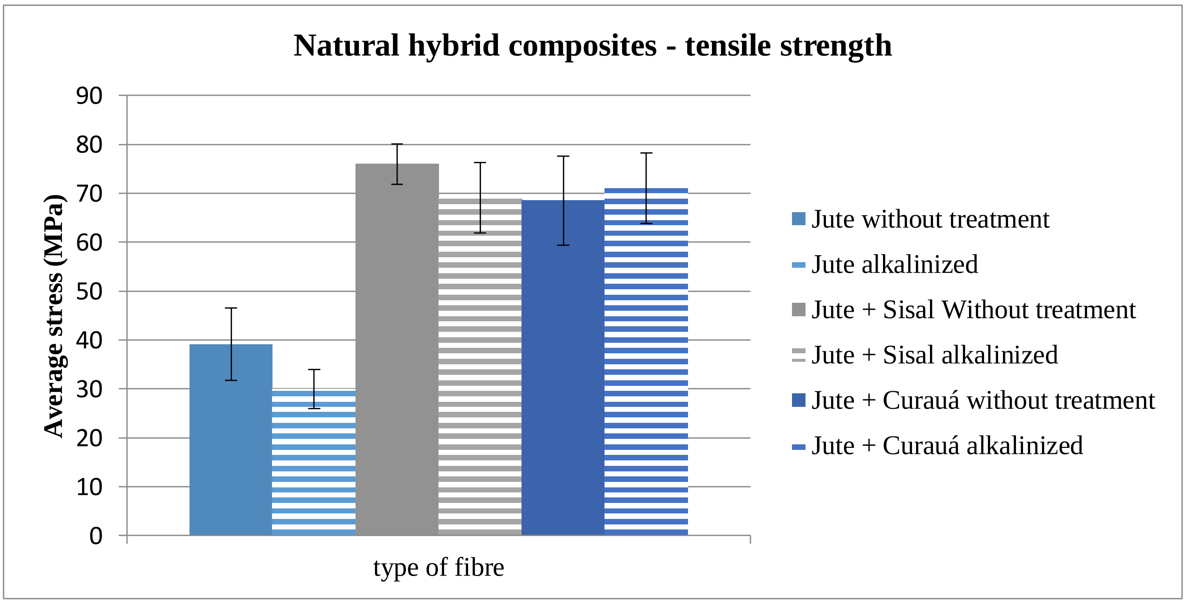

Figure 5: Natural hybrid composites - tensile strength.

As can be observed from the tensile tests, hybridization of the jute fabric had positive effects on the tensile strength of the composites in both cases. The jute + Curauá hybrid had an increase of 73.9%, while the jute + sisal composite had a 94.34% increase in its strength. This effect has already been addressed in previous work on interlaminar hybridization (layers of different types of fibres) in natural fibre composites (Nunna *et al.*, 2012; Jawaid *et al.*, 2011).

The superficial chemical treatment of alkalinisation reduced the mechanical strength of the jute composite and jute + sisal hybrid composite. While in the jute + Curauá hybrid composite, the alkaline treatment provided a slight improvement (3.5%) of its mechanical properties and can be considered irrelevant.

Therefore, it can be concluded that the suggested alkaline treatment was aggressive for the jute fabric used (which makes up about 60% of the fibre volume present in the composite), which gave a reduction in the tensile strength of the laminate.

In relation to the impact of the hybridization type on the mechanical properties of hybrid composites reinforced with natural fibres, higher values of tensile strength for intralaminar hybrid composites (proposed in this work) were observed for those interlaminates, widely studied in the literature (Boopalan *et al.*, 2013; Costa *et al.*, 2008; Kim *et al.*, 2010).

Then, flexural and impact tests were carried out to verify the influence of hybridization and alkaline treatment on the improvement of the flexural strength and on the percentage of energy absorption to the impact of the composite produced. The results obtained are shown in Fig. 6 and 7.

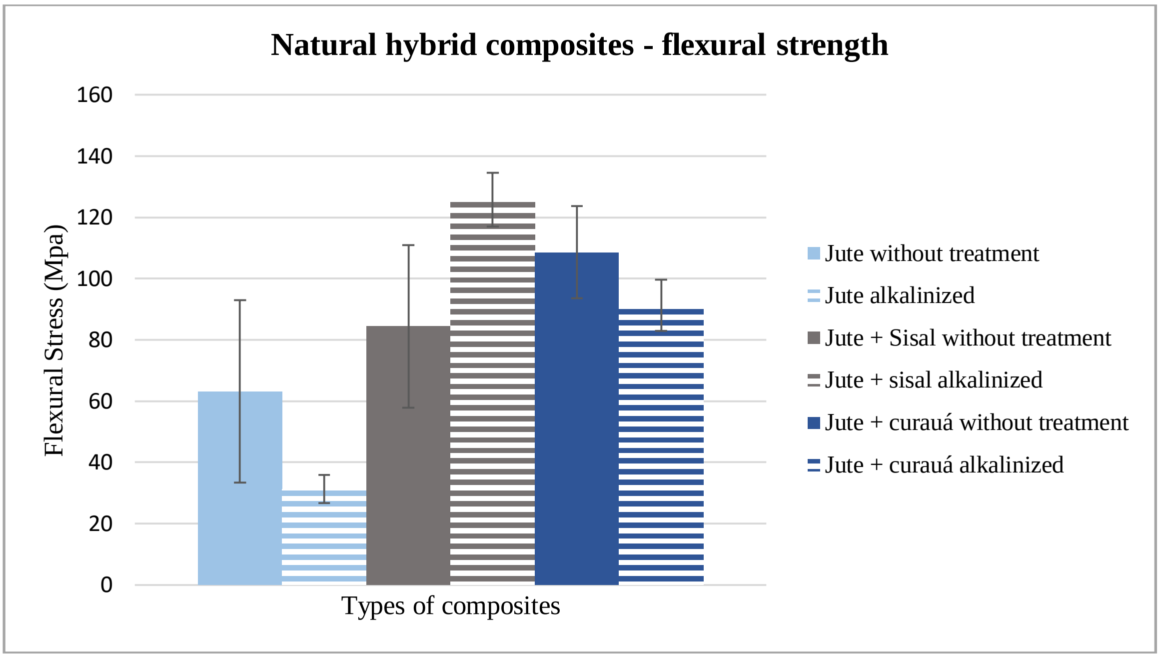

Figure 6: Natural hybrid composites - flexural strength.

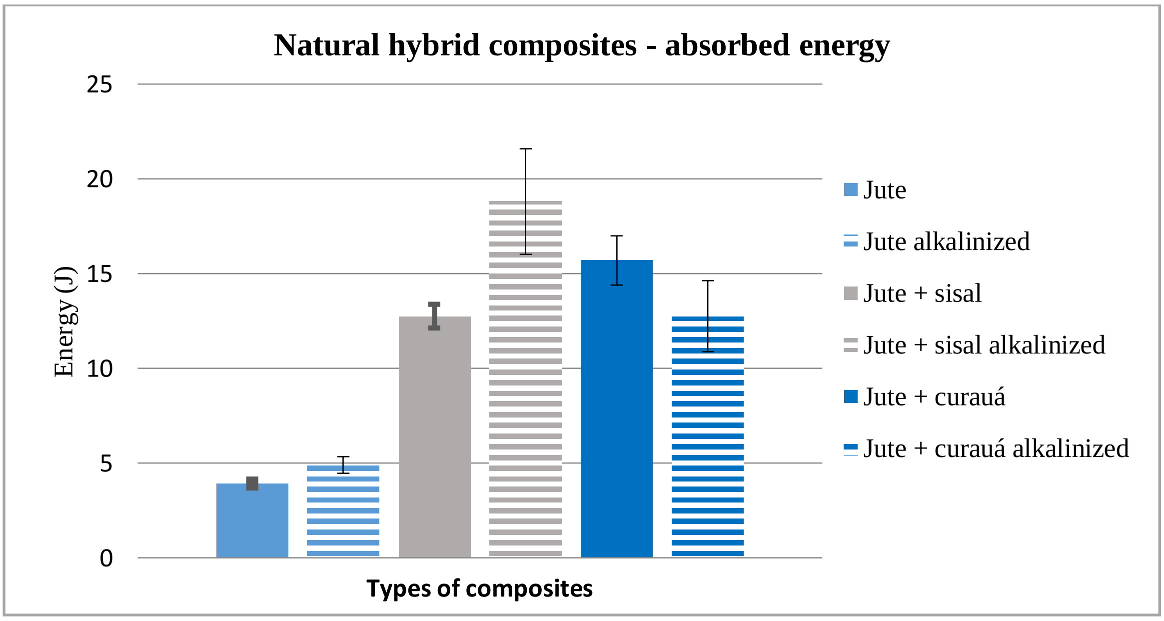

Figure 7: Natural hybrid composites - absorbed energy in impact.

According to Fig. 6, hybridization provided an improvement in the flexural strength of both hybrid composites (jute + sisal and jute + Curauá), with an increase of about 50% for the laminate of jute + Curauá and 33% for jute + sisal compared to jute composite only. This improvement in mechanical properties was of less significance when compared to that obtained in the tensile test, because in this case the higher strength fibres added to the jute fabric were not aligned in the direction of force application. In this case, the natural fibre with greater resistance to propagation of the failure by flexion was the jute fabric.

It is also possible to observe that the composite that presented the best result in the flexural tests was the jute + sisal alkalinized hybrid. This composite also presented lower dispersion of results, demonstrating a greater reproducibility of its properties.

In relation to the impact test, the jute + sisal alkalinized hybrid also showed better performance and higher energy absorption capacity, followed by jute + Curauá without treatment and alkalinized composite.

The higher the performance for energy absorption at impact the higher is the interfacial adhesion between fibre / matrix, so that stresses are well distributed and the fibres are responsible for resisting the stresses until their rupture occurs and the pull-out of the fibre (Ornaghi Jr. *et al*., 2011).

4. CONCLUSION

The intralaminar hybridization process proposed in this work had positive effects on the improvement of mechanical properties of the composites reinforced with natural fibres. Another relevant factor, especially in flexion and impact tests, was the use of superficial chemical treatments such as alkalinisation.

Among the studied composites, it was observed that for the tensile tests the alkaline treatment had little effect on the mechanical properties. In such a way that the hybrid composites of jute + sisal and jute + curauá, under the conditions without treatment and alkalinized, both presented average resistance to traction equivalent to 70MPa.

As for impact and flexural tests, the hybrid composite that presented the best result was the jute + sisal alkalinized, indicating, therefore, that the alkaline treatment provided an improvement in the interfacial adhesion between fibre / matrix of this composite (Ornaghi Jr. *et al*., 2011, Bouguessir *et a.l*, 2016).

Thus, it was concluded that the intralaminar hybrid composite that presented better mechanical properties was the jute + alkalinized sisal.

5. ACKNOWLEDGMENTS

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7. AUTHORAL RESPONSIBILITY

"The authors are solely responsible for the content of this work."