STUDY ON MECHANICAL PROPERTY OF THE HYBRID COMPOSITES FROM NATURAL FIBRES BY NUMERICAL AND EXPERIMENTAL METHOD

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ABSTRACT: The application of lignocellulosic fibers as reinforcements in composite materials has found increasing use in recent years, due to the attractive characteristics of natural fibers such as their low cost, high specific modulus, biodegradable, abundant and with many technical qualities. The hybridization of natural fibers can improve the physical, mechanical and thermal properties of composites. Natural fiber hybrid composites are very frequently used in the automotive industry. In this work, a computational and experimental analysis is carried out with the objective of comparing curauá fibers, jute and sisal fibers used in epoxy resin matrix composites for use in industry, determining the most appropriate hybridization effect by establishing the proportions and amounts of each fiber in a hybrid composite with better mechanical properties. To carry out the research, the Finite Element Method was first used, performing several models with different amounts of fibers which were later validated with mechanical tests. The number of Finite Element models and specimens performed was determined through the design of experiments using the Taguchi Method. As a result of the work, a greater strength of the hybrid composites made with greater amount of curauá fiber (20%), jute (10%) and lesser of Sisal fiber (5%) was obtained, both in the results obtained by the Finite Element Method and in the mechanical tests.

KEYWORDS: hybrid composites, finite element method, natural fibres, mechanical testing

INTRODUCTION

The application of lignocellulosic fibres as reinforcements in composite materials has found increasing use in recent years to replace synthetic fibres such as glass, carbon and aramid fibres due to the characteristics of natural fibres such as their low cost, low density, high specific modulus, economic and environmental advantages, biodegradable, abundant and with many technical qualities [1-3]. Many researchers and various industries have invested in biocomposites for many applications using local natural fibres such as Agave (Agave americana), Sisal (Agave sisalana Perrine ex Engelm), coconut (Cocos nucifera), jute (Corchorus capsularis), flax (Linum usitatissimum), curaua (Ananas Erectifolius), etc. as substitutes for synthetic fibers 4-6]. It is known that the mechanical performance of a composite material is strongly depends on the nature, orientation of the fibres, the nature of the matrix and also on the quality of adhesion between the two components 5]. In order to improve the adhesion of the fibre and reduce the water absorption, the surface of the fibre can be modified by physical or chemical methods 7-8]. Due to this, in this work, fibers treated with 5% by weight sodium hydroxide solutions with an immersion time of 4 hours were used, according to previous research recommendations [8-9].

In this work was used Epoxy Resin as a matrix, which is a thermosetting system widely used in the industry due to their low cost and adaptability to be transformed into large composite structures [8]. A computational and experimental analysis is carried out with the objective of comparing curauá fibers, jute and sisal fibers used in epoxy resin matrix composites for use in industry, determining the most appropriate hybridization effect by establishing the proportions and amounts of each fiber in a hybrid composite with better mechanical properties. The number of Finite Element models and specimens performed was determined through the design of experiments using the Taguchi Method and the results were statistically validated, which results corresponded with other works done and published previously.

METHODOLOGY

The vegetable fibers used in this work were obtained in Santarem, in the State of Pará (Northern Brazil, Amazon region). The matrix of the composite material was the epoxy resin (bisphenol-epichlorhydrin) with a density of 1.16 g/cm^3 and the epoxy hardener (3154, benzyl alcohol) with a density of 1.005 g/cm^3 supplied by Redelease company in São Paulo, Brazil. First, the design of the experiment was carried out using the Taguchi Method and the MINITAB 18 software using an L25 matrix with 3 factors and 5 levels as can be seen in Table 1. Following the Taguchi Matrix, a study was carried out using the Finite Element Method (FEM) through Solidworks software code. The FEM has been used in different areas of Engineering, including the evaluation of composite materials with plant fibers [10-13]. The dimensions of the models for both the pure resin and the composite with fibers correspond with the dimensions of the standard for the tensile force D638–14 Type I, as can be seen in Figure 1a. [14-15]. The contact (bonded) between the fibers and the resin of the specimen was ensured to guarantee the transmission of loads, simulating a correct bonding between the fibers and the matrix. To simulate the tensile test on one of the specimen heads, on both flat faces, fixed-type restrictions were placed, and at the other end, a force of 1150 N was applied in the area corresponding to the faces of the head of the Test body as can be seen in figure 1b.

The experimental part began with the washing and processing of the fibers and then the chemical treatment was carried out with 5 wt% sodium hydroxide solutions and 4 hours of immersion time for all fibers. Before being used in composites, the fibers underwent a drying process, the final step being drying at 100 Co for 50 minutes to completely eliminate moisture. Composite plates were made in a mold as shown in figures 2a and 2b, which were cut in a laser cutting machine as shown in figures 2c and 2d with the “Dog Bone” format according to the standard for tensile tests [13]. Before performing the tensile tests, the specimens were placed in an oven at 60 Co for 2 hours and then for 24 hours at room temperature. The tensile tests were performed on an Instron model 5984 universal testing machine with a load cell of 150 kN and a speed of 5 mm/min, as can be seen in figure 2e. The results can be seen in table 2.

Type of fibre	Level 1	Level 2	Level 3	Level 4	Level 5
A: Curauá Fibre weight fraction (wt.%)	0	5	10	15	20
B: Sisal Fibre weight fraction (wt.%)	0	5	10	15	20
C: Jute Fibre weight fraction (wt.%)	0	5	10	15	20

Table 1. L25 Taguchi with 5 levels 0 5 10 15 20

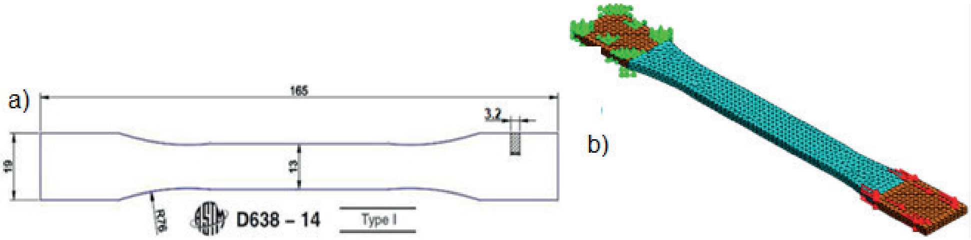

Fig. 1: Finite Element Model: a) Dimensions, b) Model with the mesh, loads and constraints.

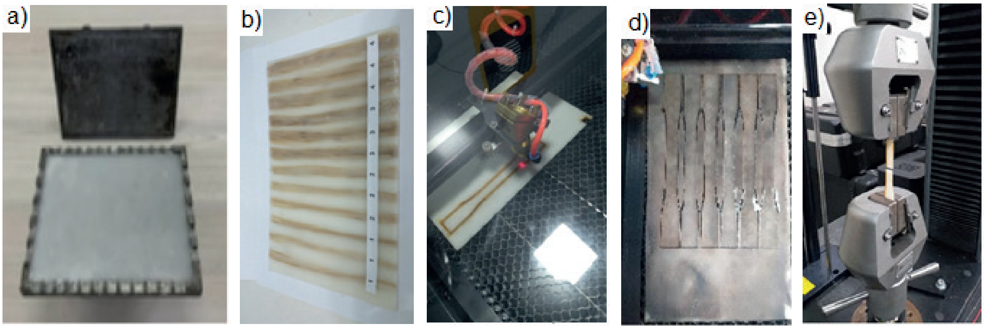

Fig. *2*: Manufacture of specimens: a) and b) molded composite plate, c) and d) cutting of specimens in a laser machine, e) Tensile test

RESULTS AND DISCUSSIONS

Table 2 shows the results obtained in all models analyzed by the Finite Element Method and the tensile tests for all specimens according to the Taguchi matrix. From the results of the tensile tests, it can be seen that when increasing the fiber content up to 35 %wt., increases the tensile stress, noting a greater increase with the increment of curauá fiber. Figure 3 shows several sections of specimens 1, 2, 14, 15, 24 and 25 modeled by FEM according to the Taguchi Matrix before processing (a) and after processing (b). The amount of fiber in each model corresponds to % by weight. It can be seen in figure 2b, that the Sisal and jute fibers are equally loaded (test body 2) and when introducing curauá fibers they absorb much more loads because they are more resistant (test body 15, figure 15b). The experimental data is transformed into a signal to noise ratio (S/N) to determine the optimal parameter configuration to maximise tensile properties. As Taguchi's analysis aims to maximise the tensile strength, the S/N ratio criterion chosen is the larger is better (LBT) [8]. For the analysis of the results, ANOVA for tensile strength was used and the regression equation (Equation 1) was determined. The standardized effect of the factors is examined by preparing a Pareto chart (Figure 4), which depicts the most influential factor in the response. The analysis suggests that the curauá fibre amount is the most effective factor, significantly contributing to the tensile strength.

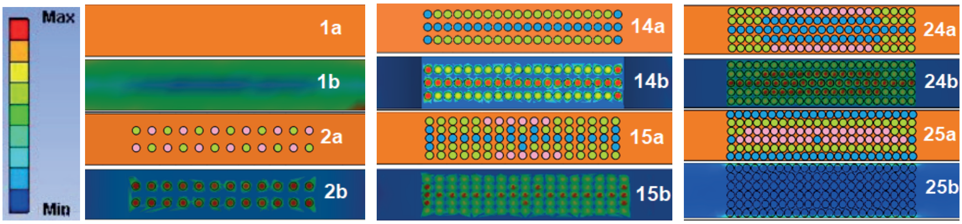

Fig. 3: Finite Element Model of 6 tests bodies

Regression Equation

Tensile Strength = (1)

$$35{,}70 + 9{,}18\ A + 8{,}40\ B + 4{,}01\ C - 0{,}2046\ A{*}A - 0{,}2023\ B{*}B - 0{,}2594\ C{*}C - 0{,}3977\ A{*}B - 0{,}0389\ A{*}C$$

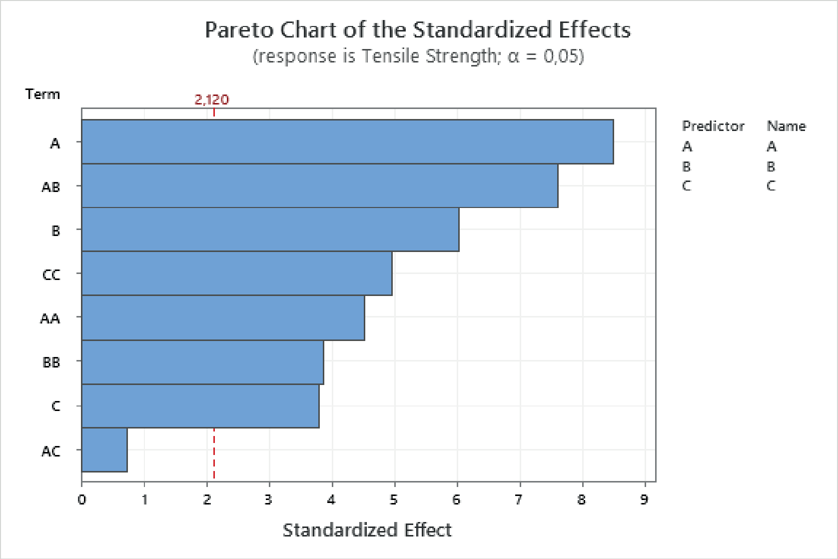

Fig. 4: Pareto chart of the standardized effects

Test Body	A (wt.%)	B (wt.%)	C (wt.%)	von Mises Stress (FEM) (MPa)	Elongation (FEM) (%)	Tensile strength (MPa)	Tensile strength (MPa)
1	0	0	0	**39.7**	0.82	36±0.94	-
2	0	5	5	143.3	0.78	92±0.67	39,83
3	0	10	10	101.5	0.66	102±0.67	41,54
4	0	15	15	77.99	0.72	125 ±0.66	39,91
5	0	20	20	66.06	0.98	98±0.67	40,76
6	5	0	5	176.3	0.76	97±0.67	38,63
7	5	5	10	118.9	0.67	104±0.67	40,79
8	5	10	15	96.61	0.71	127 ±0.66	41,46
9	5	15	20	84.29	1.24	98±0.67	41,17
10	5	20	0	105.5	0.65	121 ±0.66	39,83
11	10	0	10	121.6	0.64	106±0.67	38,47
12	10	5	15	96.51	0.7	128 ±0.66	40,73
13	10	10	20	72.54	1.18	98±0.67	41,40
14	10	15	0	105.3	0.654	124 ±0.66	41,22
15	10	20	5	89.53	1.27	136±0.84	40,05
16	15	0	15	91.64	0.69	125 ±0.66	38,63
17	15	5	20	80.35	1.07	98±0.67	40,79
18	15	10	0	102.1	0.64	128 ±0.66	41,46
19	15	15	5	85.80	0.73	140±0.84	41,17
20	15	20	10	74.16	1.28	92±0.67	39,83
21	20	0	20	77.80	1.02	98±0.67	38,47
22	20	5	0	95.63	0.61	131 ±0.66	40,73
23	20	10	5	83.87	1.27	143±0.84	41,40
24	20	15	10	71.34	1.27	92±0.67	41,22
25	20	20	15	116.0	1.45	61±0.55	40,05

Table 2: Results obtained from the computational and experimental part

CONCLUSIONS

Through the results of the computational part of the work, it can be seen that when increasing the amount of fiber, the von Misses stresses and deformations decrease, which improves the tensile strength of the specimens, which is verified in the results of the tensile tests. In the experimental part, it was found that when increasing the amount of fibers, the tensile effort increased up to an amount of vegetable fiber equal to 35 %Wt, the greatest increase being when placing curauá fibers.

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