MECHANICAL PROPERTIES EVALUATION OF COMPOSITE DEPENDING ON WEIGHT CONCENTRATIONS OF NATURAL FIBER.

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Abstract: This study aims to evaluate the mechanical behavior of polypropylene-based natural fibers composites. For that, workpieces samples were formed according to the Technical Standards: D 3039/D – 3039/ M Test Method for Tensile Properties of Polymer Matrix Composite Materials and ASTM D 638-08 Standard Test Method for plastic tensile properties. The mechanical tests of stress versus strain and Young modulus were done in universal machine EMIC testing. Scanning electron microscopy images were used for getting images of the fibers in the cross section of the samples. Additionally, this work presents statistical analysis data obtained from the mechanical tests. It was noted that the adjustments of Stress versus Strain curves by polynomial functions allowed the estimation of the values of mechanical properties in different concentrations, in this way, reducing the necessity of more tests in others concentrations.

Key-words: Composite, Natural fiber, Mechanical tests, Statistical data analysis

INTRODUCTION

The constant concern for ecological, social, economic and the regulations of use of petrochemical origin of materials has stimulated the use of materials that do not cause damage to the environment. In this way, the advantages associated with natural fibers include low cost of raw materials, low density, high toughness, and biodegradability, also recycling, degradation and low weight (1). In this sense, various works aims to promote the development and possible applications of natural fiber in finished products observing the essential mechanical properties in the performance of composites (2). The demand for the use of natural fibers is increased because of its traditional applications, such as cloth, paper, ropes and cables. Along with this, some sectors of the industry have been used natural fibers in the composites for soundproofing and thermal, biodegradable packaging, vehicle parts, packaging of medicines and biocompatible coatings (3). Faruk et al. assigns a limiting factor for its widespread use by the existence of physical properties variations between the huge variety of qualities of natural fibers, mainly related to environmental conditions of cultivation and processing methods (4). In general, for adhesion improvement and chemical affinity are used alkaline treatments like mercerizing, acetylation, "maleated coupling" and also enzymatic (5). In this work, the feasibility of providing vegetable fiber from the fruit of the coconut and its use as reinforcement in polymer matrix composites are showed, thus by the understanding of synthetic fibers and natural could be an alternative for replacement. For that, among the variety of composite processing techniques such as compression molding, extrusion, thermoplastic direct method of softwood and high density thermokinect mixers, it has been used the process involves cleaning, grinding and drying the fiber before the injection in to the molding (6). The technical standards for regulatory testing based on American Standard Testing Materials (ASTM) were: tensile strength tests, impact resistance and morphology analysis of specimens tested through images by scanning electron microscopy.

MATERIALS AND METHODS

Fiber and polymer matrix

The matrix of the composite used in this work is according to the manufacturer as polypropylene PP-PX2507. Their physical and mechanical properties according to the related technical standard are: density – 0,905 g/cm^3, melt index - 40 g/10 min, tensile strength - 34 MPa and impact strength - 22 J/m. The glass fiber used in the composition of the samples according to the manufacturer is between 10 - 30 µm in diameter and 4 - 6 mm long. The tensile, impact and heat deflection temperature (HDT) workpieces were made by injection molding. In our explanation, the workpieces were labelled as polypropylene pure (PP), glass fiber (GF) and coconut fiber (CF). They were mixed in an extruder with doser for making the samples in the following concentrations 100% PP; 80% PP + 20% GF; 80% PP + 20% CF, 70% PP + 30% GF and 70% PP + 30% CF. For that, we used extruder COPERION - twin screw 36 mm and L/D = 44, temperature in the feed zone = 190° C, injection pressure: 320 bar, Injection time: 3.2 s, injection flow rate, 28 cc/s, mold temperature: 60° C and cooling time: 10 s. Mechanical properties of composite materials are strongly influenced by the interaction between the polymeric matrix and the reinforcing component. Identifies a pre-treatment of the fibers, seeking to remove impurities and improve adherence fiber/polymer matrix by a process cleaning with water or alkali treatment (mercerisation) with sodium hydroxide (NaOH) to 1% produce better final products. Narendar, R. and Dasan, K. P. (7) showed how the effect of chemical treatment in fiber surface modified the adhesion characteristics in the between fiber and matrix.

Equipment for testing and analyses

The mechanical properties was evaluated using universal machine Shimadzu AG-X trials with load cell model SPL - 10KN, P/N 340 - 43123, Cell Code No. N729705 9, with rate: 50 mm/min at 23° C temperature. Prior the tests, workpieces were stabilized for 4 hours at 23° C temperature. The Izod impact resistance test was conducted in an impact device XJ-25Z/50Z model. The angle that describes the machine during the impact trajectory corresponds to 153.72º with 3.5 m/s rate. The dimension of workpiece used in the impact test has 3.0 mm thickness with a groove in the middle of radius of 0.25 mm, 2.0 mm notch depth. The flexural strength test was made at a speed of 1.30 mm/min in EMIC model DL test 10000, operating load of 5000 N. The tests were performed on five specimens which were 48 hours 23° C and 50% humidity prior to testing. The load was applied at three points, the maximum load occurring exactly in the half distance between two fixed points. The density was determined by using Archimedes' principle of fluid displacement for in accordance with ASTM D792. Assays for Heat Deflection Temperature were performed on an Instron Testing machine HDT/VICAT and carried out with the test piece with 3 mm thickness. The specimen was immersed in glycerine at 28° C oil bath. Heat homogenization occurs 5 minutes of the specimen immersed in glycerine oil, and then the load was applied. Thermo gravimetric (TG) curves were obtained on a TA Q500 Thermo gravimetric module (MT Instruments) using alumina sample holder. The sample was heated from 23° C to 800° C with a heating rate of 20° /min and dynamic atmosphere of N_2 gas with flow rate of approximately 50 ml/min. The morphology in the cross section of the composite workpieces was observed using Scanning Electron Microscope (SEM), Shimadzu SSX-550.

RESULTS AND DISCUSSION

Due to the physical characteristics such as length, between 5 and 40 cm and diameter about 0.5 mm, this fiber when chemically treated, can be used as reinforcing filler in composites for applications at various situations. In the workpieces obtained here our samples were tested and demonstrated the physical behavior of stress versus strain as follow in the graph in Fig. 1.

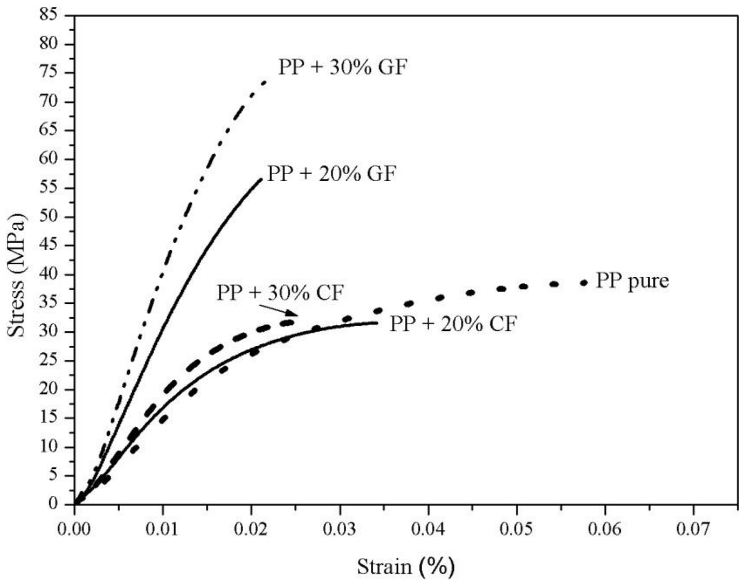

Figure 1 – Stress versus strain for each composition of glass fiber (GF), coconut fiber (CF) and Polypropylene matrix.

According to the tests, it can be noted that the coconut fiber composite has intermediate mechanical properties among no fiber (PP) and glass fiber. It is worth remembered that at least five workpieces were used for each composition, in the Fig. 1 it has been showed just one curve each as demonstration.

Different factors of molecular structures can explained the behaviour of natural and synthetic fibers inside the matrix, in which: It is known that, for higher molecular weights, polymers have high strength and low elongation at break, the strength and ductility of the polymers can be modified by the molecular orientation of the polymer chains. However, the yield stress and Young's modulus show the same tensile strength of the trend, but the increase in the parallel direction and decreased in the direction perpendicular to the orientation are not large as in the case of tensile strength. Fig. 2 is a comparison of the Young Modulus, Ultimate Tensile Stress and Izod Impact calculated for the composites with concentration changes.

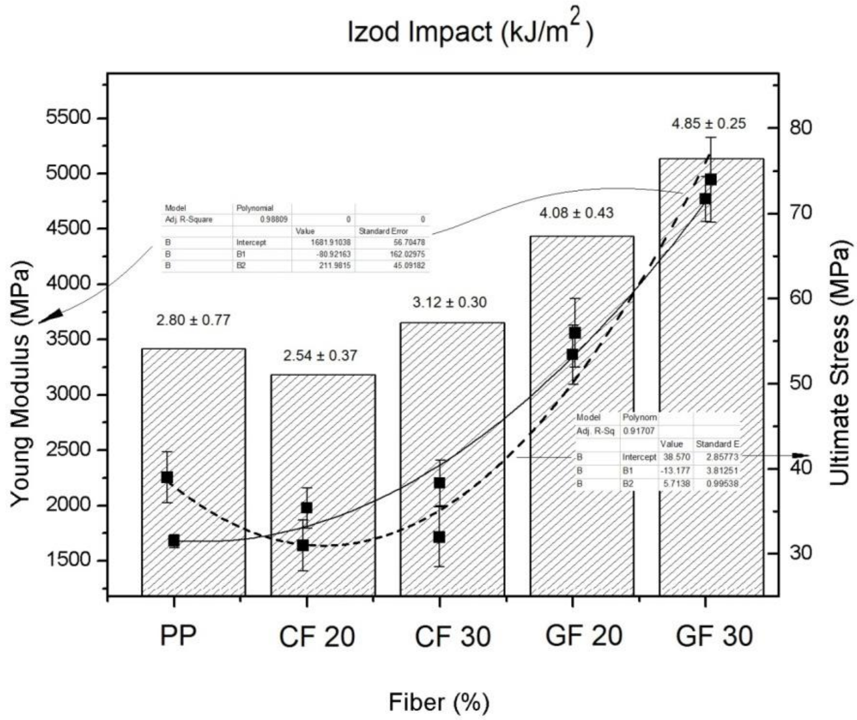

Figure 2 – Young Modulus, Ultimate tensile stress and Izod impact results from the composites.

The Young modulus, ultimate tensile strength and Izod impact increased with the increase of the fibers, as expected. Some reason for that can be explained, for example in reinforced polypropylene composites with glass fiber, by the influence of the high tensile strength and the impact resistance of glass fibers. In the other hand the net formed by coconut fiber must be the cause for a slight improvement in comparison with PP. Summary, it is observed that the coconut fiber has minor mechanical resistance in comparison with traditional glass fiber.

Following the previous results, Tab. 1 shows the behaviour of the composites for bending tests, HDT and densities. Again, the glass fiber showed a higher modulus and flexural strength, while the coconut fiber has behaviour close to polypropylene. The densities for all concentrations and fiber compositions are relatively equivalents, with a slight gap to the glass fiber by 30%. The test HDT/VI has shown that specimens with glass fiber have major resistance compared to the other fiber. In this test, the load is applied to the sensor located at the head station to indicate deflection of 0.25 mm, after which automatically heating the oil is stopped, with the objective of evaluating the flexure due to the temperature rise.

Table 1 – Module and flexural strength, density and HDT of the composite GF and CF in different concentrations.

Weight % (PP/Fiber)	Flexural modulus (MPa)	Flexural Strength (MPa)	Density (kg/m³)	Temperature (°C - HDT at 0,25 mm)
100/0	1579.00 ± 24.36	46.22 ± 0.52	904.8 ± 0.1	49.03 ± 1.85
80/20 GF	3812.04 ± 12.70	81.53 ± 1.38	954.8 ± 0.5	65.53± 1.95
70/30 GF	5325.79 ± 76.45	100.05 ± 2.13	1110.4 ± 1.4	86.20 ± 3.12
80/20 CF	1772.12± 51.90	65.59 ± 2.01	889.3 ± 2.9	54.06 ± 0.40
70/30 CF	2293.51 ± 53.98	49.97 ± 1.39	1004.2 ± 3.8	52.36 ± 2.28

The thermo gravimetry test showed the temperature records according to the residual mass to identify the degradation temperature of each sample by weight loss. The sample degradation onset temperature was determined by the onset temperature for each curve. From the moment that is determined mass loss of the initial sample, the temperature corresponding to this reduction is the initial temperature of sample degradation.

Table 2 – Results of the thermo gravimetric tests.

Weight % (PP/Fiber)	Faixa de Temperatura (°C)	Perda de Massa (%)	Temperatura de Máxima Decomposição (ºC)	Resíduos estáveis a 800º C (%)
100/0	23-800	99.26	470.74	1.047
70/30 GF	23-800	70.17	441.50	29.82
70/30 CF	20-200	1.462	108.34	7.485
	200-370	12.12	326.92	
	370-800	78.61	468.78	

The results from their studies helps to understand how the chemical treatment can influence the improvement of adhesion between coir and a polymer matrix, whereas the low affinity between them is a limiting factor in the use of coir on a large scale. The work done by Mir, S. *et al.* (2014) [8] sought the effect of chemical treatment, based on the mechanical properties of tensile, flexural and energy absorption on impact.

Micro structural analysis SEM was performed on samples after extrusion and test samples injected for the analysis of distribution and adhesion of fibers in the PP. Glass fibers showed more organization within the matrix, which is attributed to the fact that glass fibers have more weight than coir down, so the hopper of the extruder more easily in Fig. 3. Illustrate how the glass fiber was in the polymeric matrix. The uniformity of the glass fibers and the density favors the process of extrusion and injection molding, therefore the synthetic fiber material has more uniform distribution of fibers.

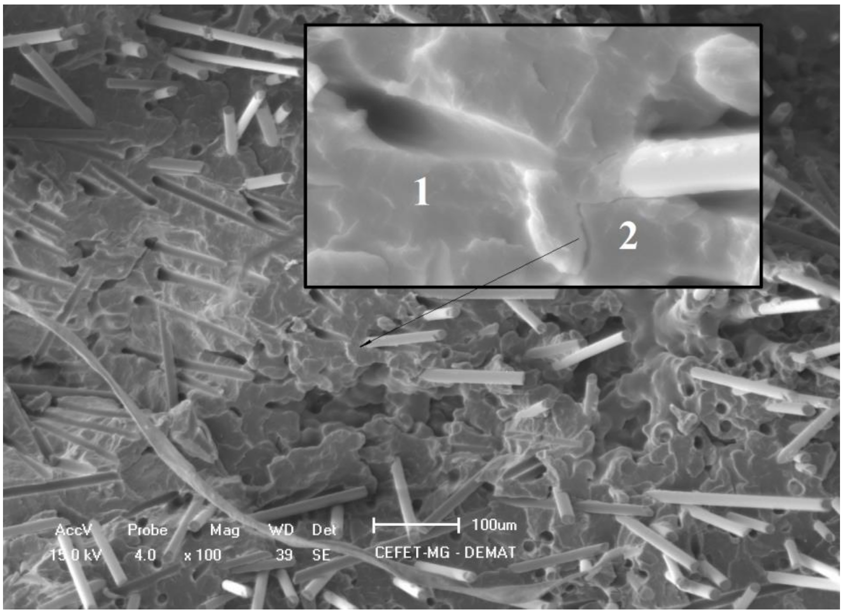

Figure 3 – Cross section of 30% Glass fiber composite in which can be seen the fibre distribution. In 1, a pore was created after the mechanical test due to the effect of pulling off. The detail in 2 is related to the small crack observed close to the fibre.

As the slip Coir the extruder hopper is more difficult, because it is lighter than glass fiber, coconut composite showed the most dispersed fibers without a more targeted organization glass fiber composite. The adhesion of a fiber in a polymeric matrix depends upon the chemical affinity between the matrix and the polymer, the additive used in the fiber to adhere to the matrix, the process of extrusion (extruder with a screw or twin screw), fiber size, preparation fiber, the extruder output and other factors. Fig. 4 shows how the coir became the polymeric matrix. In this figure coconut fibers are scattered, with voids in the polymer matrix structure. In this figure it can be seen that the coconut fiber was positioned just on the polymer, not adhering completely in the matrix. It is noted that the glass fibers in the matrix are uniform, with better adhesion to the polymer.

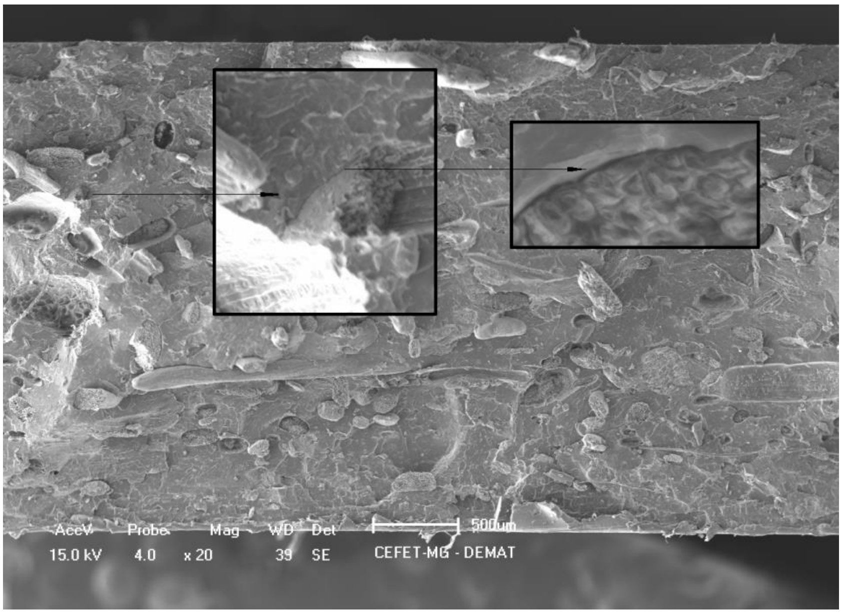

Figure 4 – The natural fiber observed in the cross section of the composite with coconut fiber broke during mechanical test as showed in the image.

In addition the concentrations of different concentrations for the fibers were tested and analyzed by numerically curves by polynomial fits. In this way it was possible to estimate the possible mechanical properties of the composites without the need for preparation of specimens. In Fig. 5 is being displayed simulation of concentrations between 15 and 35% for both fibers.

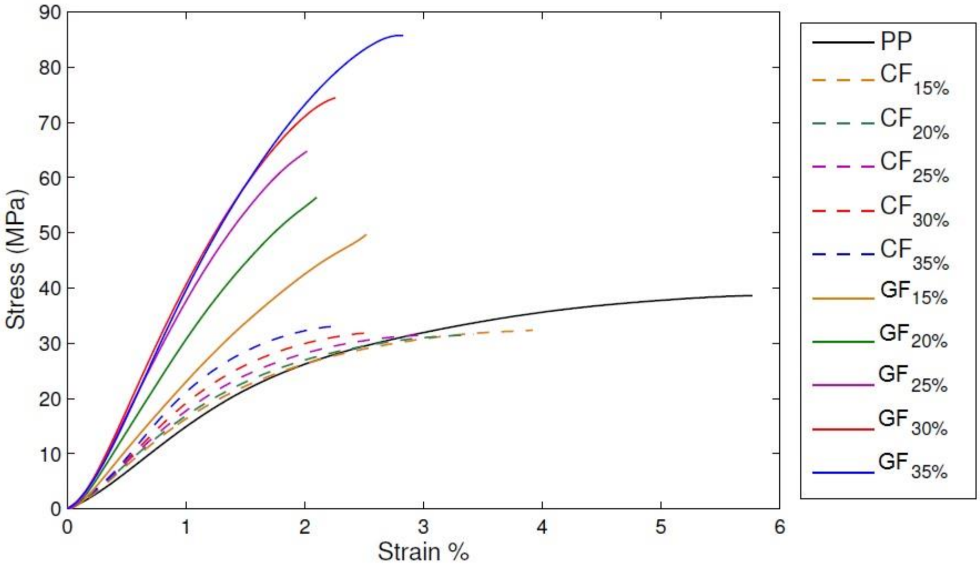

Figure 5 – Simulation of Stress versus strain curve for GF and CF fibres.

CONCLUSIONS

Through the characterization of the mechanical and thermal properties of the composite was possible to compare different fibers. In the tensile test of the CF composite it was verified that the CF broke (while GF did not) on the cross section of the workpiece, and this can explain the minor strength found. The polypropylene with glass fiber has more tensile strength, since the synthetic fibers has major resistance and then transmits this property to the composite. For both, increasing the fiber percentage demonstrated that favours the increase of tensile strength proportionally. Probably, due to the processing of coconut fibers, they showed low adhesion to the polymer matrix (additives were not used to join the coconut fiber in the polymer matrix) and, decreasing, thus, the composite resistance in the mechanical tests. The heat deflection temperature HDT test showed that the glass fiber presented highest resistance to bending and the coconut fiber composites is superior to pure PP. This way, the increase of the proportions of the fibers in the composite increases the strength. Thermo gravimetric analysis showed that adding fibers to the polymer did not increase the thermal stability of pure PP. When evaluating the thermal stability of PP, it was concluded that pure PP is more thermally stable, while for the addition of fibers, decreased the thermal stability. In the end, coconut fiber is an alternative for composite application, since the high strength resistance is not high required.

Acknowledgements

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