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SISAL AND GLASS HYBRID COMPOSITES WITH SHORT FIBERS

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Abstract. *Environmentalism and competitive edge pressure companies to produce more (quantity, quality), less (raw material, environmental, energy, etc.). The intensity of use of materials must take into account the cost of manufacture, use, reuse, recycling and final disposal. Should increase the conversion efficiency of natural resources and use right technologies in the environment and workers. This renders the products globally competitive because the satisfy these demands, the final cost will be less. In this context, the natural fibers, particularly sisal, are the great interest. It is plentiful, and renewable favorable in the aspect of resistance weight (specific modulus) which compared with others polymeric materials. The use of natural fibers in thermoplastic and thermoset composites avoids one of the major problems of the Brazil: the rural exodus. Better-paying field for cultures and byproducts, the farmers are more encouraged to stay active in the field. This work is confected polymer composites of short sisal and glass fibers; sisal fibers and glass fibers were acquired in Belém's downtown. The fibers had not pass to any treatment. The fibers were cut manually (scissors) in length of 5 mm, and were physically characterized through the optical microscopy, and mechanically characterized through tensile testing and microstructural through scanning electron microscopy. In the composites manufacture had been adopted a simple method using terephtalic unsaturated polyester and pre-accelerated resin with respect curing agent/resin 0.33% v/v combined with glass and sisal fibers of length 5 mm 5.41% mass fraction of fibers in the composite ratios sisal/glass fibers (25/75), (50/50) and (75/25). The composites mechanical characterization were through tensile testing and the fractured surfaces characterization were through scanning electron microscopy (SEM). The results of thefibers characterizations were efficient, the sisal fiber obtained 453.62 MPa tensile strength, 1.42 g/cm³ specific mass, and the glass fiber got 1685.76 MPa tensile strength, 2.40 g/cm³ specific mass. The results of sisal/glass composite mechanical characterization obtained 27.81 MPa for ratio sisal/glass (25/75); 26.87 MPa due to sisal/glass (50/50); 27.80 MPa due to sisal/glass (75/25). Microstructural analysis of both the composite and fibers were very effective to identify the peculiarities of fiber and the mechanisms of failure of fractured surfaces of composites manufactured.*

Keywords: *Hybrid Composites, Natural Fibers and Synthetic, Materials.*

1. INTRODUCTION

In recent years we can note an increasing research focused to materials development that combine with distinct properties. Then composite materials come increasingly gaining market share. Among the composites with improved properties are the polymer composites reinforced with synthetic fibers. However, the use of such fibers in polymer composites is associated with an increased wear of the equipment, high processing costs and high density.

The replacement of traditional materials by polymers in the industry has been gradually implemented over the past decades, having stepped up the pace of replacement in the last 20 years. The polymers have shown a high degree of reliability and many advantages over conventional materials. In addition to increased design flexibility and economy in production, its low density is essential to reduce fuel consumption.

Approximately to 100 kg of polymers employed in a vehicle 200 to 300 kg other materials no longer used, reflecting on the final weight of the car. Thus, estimating the useful life of a vehicle at 150,000 kilometers, can save 750

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liters of fuel due to the use of plastics. Furthermore, the use of polymers promotes the injection complex parts with high yield and quality without mentioning the corrosion resistance (HEMAIS, 2003 and SUDDELL, 2000).

The selection of materials geared for the future is essential nowadays due to the technological and economic aspects derived from the guidelines promulgated by the European Union legislation on the cars at the end of life, occurred in September 2000. As a result of this law, a quota was established recycling for scrapped vehicles, which will be 80% by the year 2006, rising to 85% by the year 2015, including a requirement for thermal utilization of 85% by 2006 and 95 % by the year 2015 (KLEBA, 2004; MARSH, 2003).

The glass fibers composites reached the market dominance by combining relatively low production cost and good physical properties. As the trend in the use of traditional materials is increasingly reducing the weight of metal materials, the lighter and lower cost materials that have a cost/benefit, have become increasingly important and popular as polymeric materials and its composites. Due to these facts, the full new materials characterization becomes crucial, as well as the importance of the domain to obtain the processing conditions of the same.

Vegetable fibers have been investigated for use as reinforcement in polymer matrix composites as combine properties that take into consideration aspects that go against this new world order, a strong ecological appeal, and features such as low cost, low specific mass, renewable source , biodegradability, the fact that it is non-toxic and non-abrasive, having good thermal properties and high specific module which makes them strong candidates for these potential applications (BLEDZKI and GASSAN, 1999).

The automotive industry began using natural fibers composites for technical and commercial reasons. Vegetable fibers appear as a valuable alternative to synthetic materials and its usage has grown dramatically in recent years. Vegetable fibers still have a potential for reduced vehicle weight by 40% compared with glass fibers, which are present in most automotive composites. The German automotive industry has increased its use of 4000 tons in 1996 to 15.500 tons in 1999 while the rest of Europe had its consumption increased from 300 tons to 6900 tons in the same period. Projections for 2005 and 2010 suggest that consumption of vegetable fibers in the European automotive industry to grow 50-70 thousand tons in 2005 to over 100000 tons in 2010 (SUDELL, 2002).

The study aimed to develop and investigate hybrid composites reinforced with short sisal and glass fibers. Practicing simple fabrication, the fibers being distributed and random variation of its mass fractions. Evaluating the mechanical and microstructural composites.

2. MATERIALS AND EXPERIMENTAL METHODOLOGY

2.1 Materials

The sisal and glass fibers used in the study were purchased from the metropolitan region of Belém-PA, without any treatment, glass and sisal fibers are illustrated in Figure 1 (a) and (b) respectively.

(a) (b)

Figure 1. (a) Sisal fiber and (b) Glass fiber

The polymer used in the study was the proportion of unsaturated polyester terephthalic 0.33% v/v curing agent.

2.2 Experimental Methodology

The sisal and glass fibers were physical, mechanical and microstructural characterized. It was assayed 100 (hundred) specimens of glass and sisal fibers to yield reliable results. The fiber specimens were prepared with paper holders called KRAFT but in literature it is known as TAB. The TABs are used to evenly distribute the load applied to the fiber being tested and also to protect the fibers from damage during the positioning of the jaws of the testing machine. The TABs KRAFT paper (weight 200 g/m²) with dimensions of 25 mm x 65 mm were bonded with cyanoacrylate (Loctite's SuperBonder) in the end of the usable length of the fibers, as recommended by ASTM D3822-96.

The fibers microstructure was analyzed through scanning electron microscopy (SEM), which found its surface appearance and cross section from tested specimens in tension and specimens embedded in acrylic matrix and prepared according to the metallographic procedures. To determine the fibers specific mass was used the pycnometer method with water as non-solvent, the material was immersed in water watching the displaced volume as the standard DNER

ME 084/95. The fibers were manually cut in 5 mm length to produce the composites. Figure 2 illustrates the glass and sisal fibers cut in lengths of 5 mm.

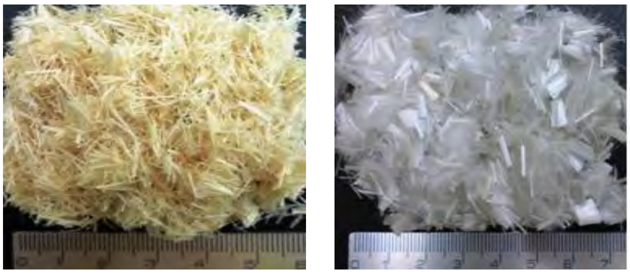

Figure 2. (a) Sisal fibers cut and (b) Glass fibers cut.

The specimens were fabricated by hand casting using silicone molds, no mold release and without pressure. The hybrid composites were manufactured based on RODRIGUES, (2008) fashioned composite sisal 5 mm in length at a rate of 5.41%.

It was established hybrid composite proportions reinforcement the following percentage ratio sisal/glass: (25%/75%), (50%/50%) and (75%/25%). For each length and proportions of the mass fractions of glass and sisal fibers 5 mm (5.41%). After established the reinforcement hybrid composites proportions were fabricated 2 (two) sets of 10 (ten) specimens for each percentage ratio of sisal/glass for mechanical characterization of hybrid composites in tensile test with the proportions curing agent/resin 0.33% (v/v). Figure 3 illustrates the sisal/glass hybrid composites.

Figure 3. Sisal/Glass hybrid composites.

The tensile tests were conducted according to ASTM D 638M. The specimens were manufactured from silicone molds in a 10 (ten) minimum number to testing resin reinforced with short sisal and glass fibers. The composites tensile tests were performed on universal machine Model KRATOS IKCL3 with data acquisition system with a load cell of 5 kN adopting speed of 5 mm/min and measuring useful length between grips of 60 mm.

After mechanical test completion, the specimens fracture surfaces were analyzed to study the failure mechanisms of each composition manufactured. The morphology of the fracture surface was analyzed through scanning electron microscopy.

3. RESULTS AND DISCUSSION

The sisal fibers were tensile strength, diameter, specific mass, moisture content, surface appearance and microstructure characterized. The results are shown in Table 1.

Table 1. Sisal Fiber physical and mechanical characterization

Material	Tensile strength (MPa)	Diameter (mm)	Specific mass (g/cm³)	Moisture contente (wet basis) (%)
	Average (Standard Deviation)	Average (Standard Deviation)	Average (Standard Deviation)	Average (Standard Deviation)
Sisal Fiber	**453,62 (± 91,98)**	**0,250 (± 0,032)**	**1,42 (± 0,01)**	**13,10 (± 0,5)**

The sisal fibers microstructural characterization was via scanning electron microscopy, showing microstructural peculiarities of external and internal surfaces of the fibers. As shown in Figure 4.

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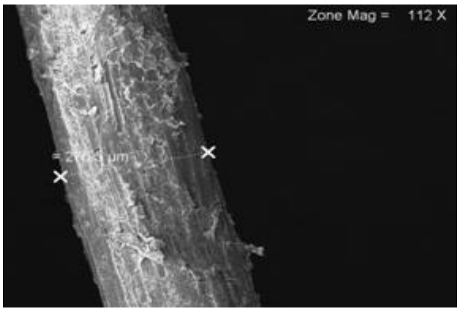

Figure 4. Sisal fiber scanning electron microscopy

The glass fibers were tensile strength, diameter, specific mass, surface appearance and microstructure characterized. The results are shown in Table 2.

Table 2. Glass fiber physical and mechanical characterization

Material	Tensile Strenght (MPa)	Diameter (mm)	Specific mass (g/cm³)
	Average (Standard Deviation)	Average (Standard Deviation)	Average (Standard Deviation)
Glass fiber	**1685,76 (± 108,05)**	**0,305 (± 0,02)**	**2,40 (± 0,01)**

The Figure 5 illustrates the glass fiber microstructural characteristics analyzed by scanning electron microscopy.

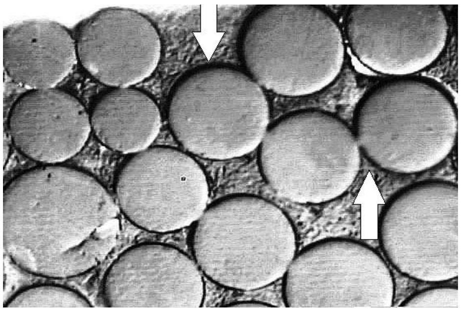

Figure 5. Glass fiber scanning electron microscopy

The Figure 5 illustrates a glass fiber embedded in acrylic matrix to verify its cross section, it can be seen that the fiber filaments has well defined (white arrows) typical of this type of synthetic fiber characteristics, giving the same, excellent properties for its applications.

The Table 3 shows the results obtained in the tensile test for the polyester hybrid composites reinforced with sisal/glass of 5 mm.

Table 3. Mechanical sisal/glass 5mm hybrid composites characterization

Sample type	**Ratio Reinforcements (%)**	**Mass fraction Reinforcement (F_M)**		**Tensile Strenght (σ) (MPa)**
	Sisal / Glass	Sisal	Glass	Average (Standard Deviation)
Sisal/Glass Hybrid Composites	(0/100)	0	3,52	33,80 (± 3,13)
	(25/75)	0,88	2,64	27,81 (± 2,73)
	(50/50)	1,76	1,76	26,87 (± 2,32)
	(75/25)	2,64	0,88	27,80 (± 2,95)
	(100/0)	3,52	0	16,98 (± 1,37)

The results in Table 3 indicate that, although the sisal/glass hybrid composites are reinforced by fibers 5 mm, which by several factors such as being short fibers, then the composite will have a greater amount of it, generating larger amount of fibers points, which causes nucleation of cracks and defects more probably to occur, directly impacting negatively on the mechanical properties of the composites. The results demonstrated the efficiency of reinforcement getting a 23% higher performance compared to bamboo/glass hybrid composites of 5 mm. Regarding the manufactured

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series (sisal/glass 5 mm) obtained performance very close to that shown with the difference between them around 3%. The sisal/glass hybrid composites 5 mm showed higher strength than the bamboo/glass hybrid 5 mm, which can be explained through the dimensions and shapes of sisal fibers are more refined, with better finishing, the bamboo fibers are rougher without good finish, so there was a better interaction between the sisal/glass fibers thus obtained a better layout and compression for natural healing of the composite, resulting in a sisal/glass hybrid with better finishing and less prone to defects, voids and bubbles, resulting in improved mechanical properties. The sisal/glass hybrid composites of 5 mm were on average 40% higher than the results found by (KHANAM et al., 2007). The Figure 6 illustrates the typical load versus displacement characteristic test bodies of the series of sisal/glass hybrid composites of 5 mm. It can be seen that the 2 (two) manufactured sets sisal/glass (75/25) and sisal / glass (50/50) showed similar among itself as to the level of maximum load in tension and the maximum elongation. In the sets sisal / glass (25/75) there was a level of loading and stretching quite high. Due to the greater proportion of glass fibers in the composite resulted in higher loading and deformation.

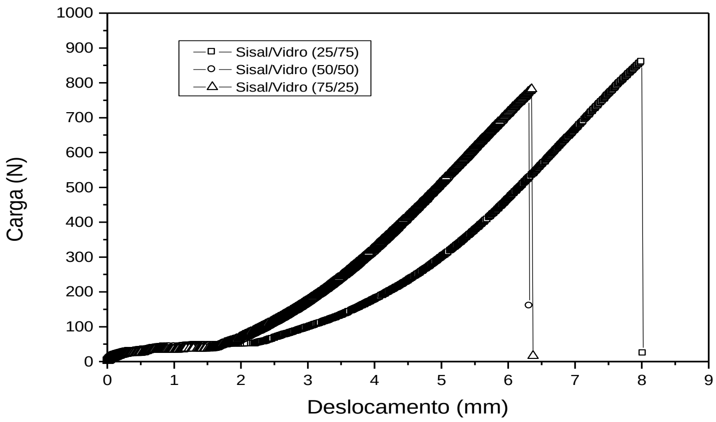

Figure 6. Graphic "Force versus sisal/glass hybrid compositess displacement"

The Figure 7 illustrates a composite reinforcement hybrid sisal/glass (25/75) an electron micrograph. In fractured surface can be verified presence of the pull out fibers (black arrows), and the supremacy of the disruption of the matrix fibers (white arrows).

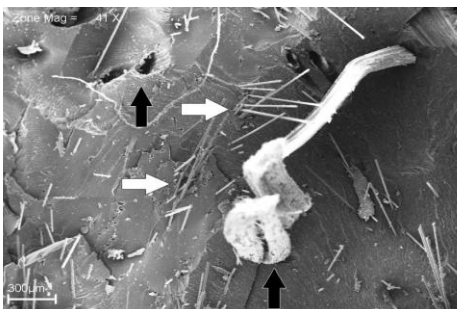

Figure 7. Sisal/Glass Hybrid composite fractured surface

4. CONCLUSIONS

In the fibers characterizations results were as predicted by the literature. Since sisal fibers are already used in composites engineering, as for example in the automotive industry and the glass fiber has already been established in the industry.

The sisal and glass hybrid composites results were similar. Overall fared well mechanical traction.

The simple manufacturing methodology was fairly efficient production of hybrid composites with good mechanical properties, and offer a low-cost material.

The sisal fibers because it was abundant in Brazil and are already applied in many situations, showed to be efficient in combination with glass fibers. For, due to its malleability and its finish is uniformly distributed over the entire area of the composite.

In the fractured surfaces microstructure in composites was noticed the predominant failure mechanisms for the disruption of composites. Introducing a good homogenization between the fibers (sisal and glass) and good impregnation with the polymeric matrix.

The hybrid composites development of natural fibers with synthetic fibers search for the combination to obtain specific characteristics achieved with this combination. Well, the main intention is to replace partially the large use of synthetic fibers (glass) in certain types of applications. Offering materials with good properties and estimate the economy and environment.

5. ACKNOWLEDGEMENTS

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6. REFERENCES

BLEDZKI, A. K.; GASSAN, J. Composite Reinforced with Celulose Based Fibers. *Prog. Polym. Sci., Elsevier*, v.24, p.200- 272, 1999.

DNER-ME 084/95- Departamento Nacional de Estradas e Rodagem (1995). Agregado miúdo – determinação da densidade real.

HEMAIS, C. A., Polímeros e a Indústria Automobilística. *Polímeros: Ciência e Tecnologia*, v.13, n.2, p. 107- 114, 2003.

KHANAM, P. N.; REDDY, M. M.; RAGHU, K.; JOHN, K.; NAIDU, V. Tensile, Flexural and Compressive Properties of Sisal/Silk Hybrid Composites. *Journal of Reinforced Plastics and Composites*, vol. 26, n. 10/2007.

KLEBA, I.; ZABOLD, J. Poliuretano com fibras naturais ganha espaço na indústria automotiva. *Revista Plástico Industrial*, São Paulo, n.75, p. 88- 99, nov. 2004.

MARSH, G. Next step for automotive materials, Materials Today, v.6, n.4, p. 36- 43, abr. 2003.

RODRIGUES, J. S. *Comportamento mecânico de material compósito de matriz poliéster reforçado por sistema híbrido fibras naturais e resíduos da indústria madeireira*. 2008. 35f. Dissertação (Mestrado Engenharia Mecânica). Programa de Pós-Graduação de Engenharia Mecânica – Universidade Federal do Pará, 2008.

STANDARD TEST METHOD FOR TENSILE PROPERTIES OF PLASTIC (METRIC). ASTM D 638, Annual Book of ASTM Standards, American Society for Testing and Materials, 1989.

STANDARD TEST METHOD FOR TENSILE PROPERTIES OF SINGLE TEXTILE. ASTM D 3822 **-** FIBERS, Annual Book of ASTM Standards, 1996.

SUDDELL, B. C., EVANS, W. J., ISAAC, D. H., CROSKY, A., A survey into the application of natural fibre composites in the automotive industry. *Natural Polymers and Composites*, 4, 2002, São Paulo.Anais...São Paulo, 2002.p. 455- 460.

SUDDELL, B. C., EVANS, W. J., ISAAC, D. H., CROSKY, A., A survey into the application of natural fibre composites in the automotive industry. *Natural Polymers and Composites*, 4, 2002, São Paulo.Anais...São Paulo, 2002.p. 455- 460.

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