24th COBEM - 2017

24th ABCM International Congress of Mechanical Engineering
December 3-8, 2017, Curitiba, PR, Brazil

COBEM-2017-1034
MECHANICAL PERFORMANCE OF A NOVEL JUTE FIBER BIO-COMPOSITE USED AS A TRUNK TRAY MATERIAL

Roney Amarante Braga
Pontifícia Universidade Católica de Minas Gerais, Mechanical Engineering Department, 30535901, Belo Horizonte, MG, Brazil
roneybraga@yahoo.com

Fernando Neves Quintino dos Santos
Centro Federal de Educação Tecnológica de Minas Gerais, Energy Engineering Department, 30510000, Belo Horizonte, MG, Brazil
fernandonquintino@gmail.com

Hélio Augusto Goulart Diniz
Stella Marys Silva Pinheiro
Universidade Federal de Minas Gerais, Mechanical Engineering Department, 31270091, Belo Horizonte, MG, Brazil
helioufmg@gmail.com
stella_marys_@hotmail.com

Abstract. *The automotive industry is under pressure to reduce the weight of vehicles and consequently energy consumption. In this light, eco design has gained importance due to the attempt to incorporate materials of low environmental impact, in an attempt to replace those normally used. The objective of this study is to characterize the mechanical performance of a novel trunk tray of a passenger car, manufactured using a composite of jute fiber and epoxy resin. Tests of tensile and flexure strength, and global stiffness were performed. The trunk tray presented good geometric characteristics and higher global stiffness when compared to the usual polypropylene material. Maximum rupture stress, maximum flexural strength and flexural modulus decreased but were within acceptable ranges for automobile industry. Results showed that the novel material could replace the original one in polypropylene, effectively reducing weight and causing less environmental damage.*

Keywords: *bio-composite, jute fiber, trunk tray, mechanical performance*

1. INTRODUCTION

Environmental and economic concerns have encouraged the research on bio-composites. There is a particular interest in lignocellulosic materials, such as jute, sisal, coconut, banana and curaua, which are used as reinforcement in polymer matrices (Pires et al., 2012). These natural fibers have several advantages, such as low density, they are biodegradable, have acceptable mechanical properties, better thermal properties, low processing energy and global availability at low cost in different morphologies and dimensions (Davies et al. et al., 2004). Along with the development of new applications for these fibers, the job creation potential in the rural region can also grow a lot. However, it should be noted that in order to be a renewable resource, the harvesting of the fibers must be done in a balanced way with reforestation (Alves et al., 2010).

According to Gurunathan et al. (2015), the automotive and construction industries are the major consumers of bio-composites. Faruk presents several vehicle components used by vehicle assemblers, and concludes that the use of bio-fibers can reduce the weight of the vehicle by up to 30%. Alves et al. (2010) performed a life cycle analysis to replace a buggy bonnet by a jute fiber composite. Human health, environmental damage and natural resources were taken into account in the analysis, which concluded that fuel consumption reduced according to the weight reduction. However, the study pointed to unknown impacts in the production phase and hood scrap phase related to logistics and recycling. Witik et al. (2011) performed a steel bulkhead life-cycle analysis for two-seat vehicles, substituting it for other materials such as magnesium alloys or thermoplastic glass matrix archiving weight reduction, but concluded that not always the reduction in weight leads to environmental benefits. The authors concluded that the use of composites is better for reducing vehicle impacts, even if they are not recyclable. Bio-composites were not evaluated in their analysis.

The application field of bio-composites and its development are directly affected by vehicle assemblers, which keep results of their researches in secret. This paper offers a contribution for the research of bio-composites, proposing a new vehicle trunk tray, manufactured using a jute bio-composite fiber and epoxy resin. This fiber was chosen because it combines characteristics such as low cost and low density, in addition to being produced in the country. The new trunk tray was evaluated according to its mechanical characteristics and compared to the original one made of a polypropylene composite material typically used in this application.

2. MATERIALS AND METHODS

The trunk tray is usually made of a polypropylene composite and talc fiber, called PP-TD. In this work, a trunk tray made of PP-TD20 (20% talc), 3.0 mm thick, was used to manufacture a full scale mold, which would serve to create the new material tray. The mold was made using wood, polyester resin and fiberglass, with dimensions of 0.5 x 1.0 m². Figure 1 shows the trunk tray in PP-TD20 and Fig. 2 the mold.

Figure 1. PP-TD20 trunk tray

Figure 2. Trunk tray mold

Table 1 shows the materials used to manufacture the trunk tray. The jute fiber fabric, shown in Fig. 3, was cut into three parts of 0.5 x 1.0 m² to be used in the mold. A 10: 1 epoxy resin and hardener solution (epoxy resin: hardener) was manually prepared in 5 min, which allowed a 20 to 30 min working time until the polymerization process started. To prevent jute fiber from attaching to the mold, two release agents were used. Both release agents were supplied by Mundo da Resina e Fibras (MG). The first was a Polidesmo PVA, a polyvinyl alcohol based release agent. The second was a wax release agent, which is a mixture of carnauba wax, beeswax, paraffin and petroleum derivative solvent.

Table 1. Materials used to fabricate the new trunk tray

Materials	Specifications	Quantity	Supplier
Jute Fiber	Jute fabric 100% natural T10	1.0 x 3.0 m²	Sisalsul Fibras Naturais
Epoxy resin	RenLam M	3 x 1.40 kg	Mundo da Resina e Fibras
Realease Agent	Ren HY 951	3 x 0.12 kg	Mundo da Resina e Fibras

a) Macro view b) Detailed view

Figure 3. Jute fiber fabric

For the new trunk tray production, the mold was rigorously cleaned with a jet of compressed air. The remaining dust particles were removed with a water-wet mesh cleaning. After complete drying, three layers of release agent wax and a layer of polyvinyl peroxide PVA were applied throughout the models length to prevent the laminate part of releasing from the mold after curing.

The bio-fiber trunk tray was fabricated using a simple procedure as followed. Firstly, application of the first resin layer with a brush on the clean mold with release agent already applied. Secondly, placement of the first layer of jute fiber over the resin, followed by application of epoxy resin over the jute fiber using a brush, then elimination of air bubbles using the roller throughout the mold surface. This last step was repeated thrice for a total of tree layer of jute fiber.

After these steps, the mold remained for five days in complete rest for the polymerization and curing step. The curing was done outdoors at room temperature of approximately 25ºC. Figure 4 and 5 show the first jute layer positioning and the epoxy resin application, respectively. Figure 6 shows the new trunk tray front and back views, the front view already with the burrs removed. The final piece had a mass of 1.890 kg and an average thickness of 3.72 mm. The same piece made in PP-TD20 would have 1.444 kg, but as it is used with metal bars, the mass of the assembly can rise to 1.954 kg.

Figure 4. First jute layer positioning

Figure 5. Epoxy resin application

a) Front view b) Rear view

Figure 6. Trunk tray of jute fiber

Since some mechanical tests required specific dimensions, two types of reduced dimensioned samples were manufactured using the method described before. The difference is that a glass plate was used in place of the mold. Each piece of new material was 0.25 x 0.25 m². Figure 7 shows the different samples.

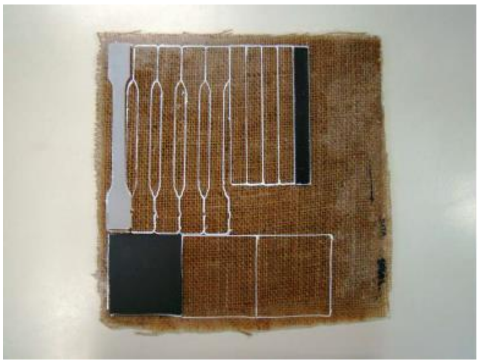


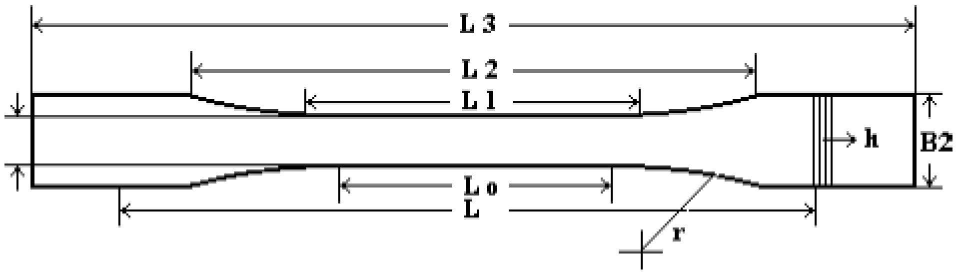
Figure 7. Sample's geometry

3. MECHANICAL CHARACTERIZATION

The analyses of the new material mechanical properties was carried out through mechanical tensile, flexural and global stiffness tests. The results of all the tests were compared with the PP-TD20 trunk tray equivalent tests.

3.1 Tensile strenght

Tensile tests were performed on five samples of same size. Figure 8 schematizes the geometry of these samples. The samples thickness and length were 4.41 mm and 12.44 mm respectively, with a variation of 5% for more and less, due to the nature of the material and the process. All tests were performed in a Universal Instron 4467 machine at a speed of 50,000/min with controlled ambient temperature and relative humidity of 23 °C and 70%, respectively. The tests followed ASTM D638 standard (2003).



Dimensions	(mm)
L	107
L_o	50
L1	60
L2	106
L3	150
B1	10
B2	20
h	4
r	60

Figure 8. Tensile strength test sample dimensions (ASTM D638 standard, 2003)

3.2 Flexural strenght

Five flexural tests were performed on samples of the same size. The machine used and conditions of room temperature and relative humidity were the same as for the tensile tests. The tests followed ASTM D790 standard (2003). Figure 9 shows the dimensions of the test used. The sample's thickness and length were 4.30 mm and 12.54 mm respectively, with variations of 5%.

Dimensions	(mm)
a	12,7
h	3,2
L	127

Figure 9. Dimensions of the flexure strength test sample (ASTM D709 standard, 2003)

3.3 Global stiffness

Global stiffness tests were performed on the PP-TD20 trunk tray as well as on the new material trunk tray. PP-TD20 trunk trays are usually used with metal bars that increase its stiffness; however, for this test it was chosen to perform without the bars to make a comparison with the jute fiber trays that do not use metal bars. This test consists in positioning the piece at its place of use, applying a force of 150.0 N with constant velocity in the central region of the tray and measuring the final elongation using an extensometer. The global stiffness is then calculated as the ratio of the force applied by the elongation. The tests were performed at room temperature of 23°C.

4. RESULTS

In this section we present the results of all mechanical tests, including a comparison of the results of the jute fiber material with the results of the PP-TD20 material.

Figure 10 shows the results of the tensile strength test. It was obtained a yield strength limit of 32.70 MPa, with a maximum deformation of 1.0%. This value corresponds to 95.8% of the PP-TD20 yield strength limit (34.15 MPa).

Figure 11 shows the results of the flexural strength test. The tensile strength and modulus of elasticity obtained were 42.82 MPa and 1389.18 MPa. These values correspond to 96.7% and 75.0% of the PP-TD20 tensile strength (44.28 MPa) and modulus of elasticity (1,853.00 MPa).

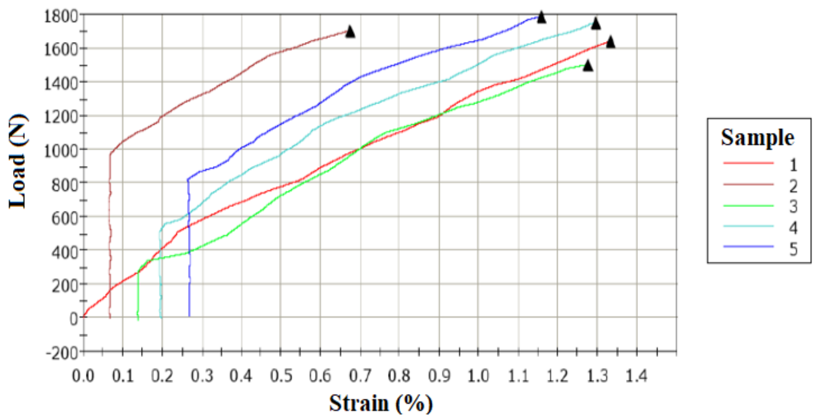


Figure 10. Tensile strength test results

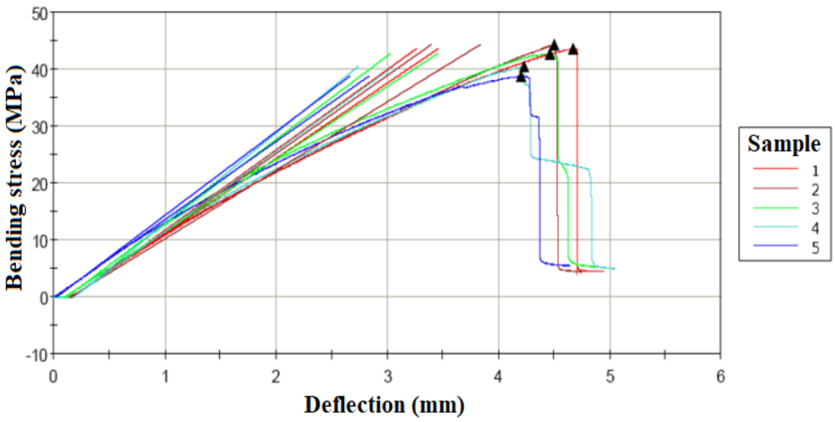


Figure 11. Flexural strength test results

Figure 12 shows the results of the global stiffness test. The new material presented rigidity of 10.006 N/mm, while the PP-TD20 had a rigidity of 8.916 N/mm, which means an increase of 12.22%. Although the value found for the jute fiber material is higher, it should be noted that PP-TD20 is usually used with metal bars that increases its rigidity.

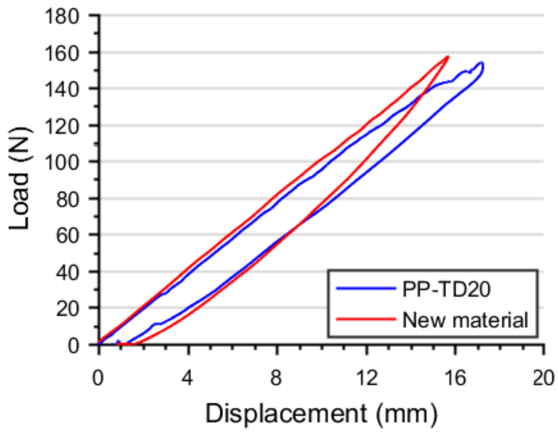


Figure 12. Global stiffness test results

5. CONCLUSIONS

A new bio composite of jute fiber and epoxy resin was created to be used as a trunk tray. This new material trunk tray was fabricated and mechanically analyzed. The tensile strength and flexural strength tests were realized using material samples and the global stiffness test was carried out on a full scale trunk tray.

The final part had a mass of 1,890 kg and average thickness of 3.72 mm, while the same part made in PP-TD20 has 1.444 kg, but as it is used with metal bars, the mass of the set rises to 1,954 kg. This means that it is possible to achieve a reduction of 3.27% in the mass of the part, which corresponds to a lower fuel consumption.

The jute fiber composite had yield strength limit of 32.70 MPa, tensile strength of 42.82 MPa and elasticity modulus of 1389.18 MPa, which represents 95.8%, 96.7% and 75% of the PP-TD20 values. However, the new material global stiffness was 10.006 N/mm, which is 12.22% higher than that of PT-TD20. It should be noted that in the global stiffness test, the metal bars were removed from the PP-TD20 for comparison purposes. If the test were performed with the bars, the stiffness would increase.

There is still a long way to replace the PP-TD20. Any new material proposed would need to have, besides technical requisites, a compatible production scale. At any rate, the bio-composite proposed is lighter, has better global stiffness and is more sustainable than the propylene composite currently used in the fabrication of trunk tray.

6. ACKNOWLEDGEMENTS

CEFET-MG, CAPES, CNPq and FAPEMIG for financial support.

7. REFERENCES

Alves, C., Ferrão, P.M.C., Silva, A.J., Reis, L.G., Freitas, M., Rodrigues, L.B. & Alves, D.E., 2010. “Ecodesign of automotive components making use of natural jute fiber composites”. Journal of Cleaner Production, Vol. 18, n. 4, p. 313-327.

ASTM D638 Standard, 2003. “Standard test method goes tensile properties of plastics”. ASTM International. American Society for Testing and Materials. <http://www.astm.org/cgi-bin/resolver.cgi?D638-03>

ASTM D790 Standard, 2003. “Standard test methods for flexural properties of unreinforced and reinforced plastics and electrical insulating materials”. ASTM International. American Society for Testing and Materials. <http://www.astm.org/cgi-bin/resolver.cgi?D790-17>

Davies, P., Bourmaud, A., Pajot, A. & Baley, C., 2011. “A preliminary evaluation of Matricaria maritimum fibres for polymer reinforcement”. Industrial Crops and Products Vol. 34, n. 3, p. 1652–1654.

Faruk, Omar. Cars from jute and others bio-fibers. <https://www.researchgate.net/publication/267389048_Cars_from_Jute_and_Other_Bio-Fibers>

Gurunathan, T., Mohanty, S. & Nayak, S.K., 2015. “A review of the recent developments in biocomposites based on natural fibres and their application perspectives”. Composites Part A: Applied Science and Manufacturing, Vol. 77, p. 1-25.

Jarabo, R., Monte, M.C., Blanco, A., Negro, C. & Tijero, J., 2012. “Characterisation of agricultural residues used as a source of fibres for fibre-cement production”. Industrial Crops and Products, Vol. 36, n. 1, p. 14–21.

Joshi, S.V., Drzal, L.T., Mohanty, A.K. & Arora, S., 2004. “Are natural fiber composites environmentally superior to glass fiber reinforced composites?”. Composites Part A: Applied Science and Manufacturing, Vol. 35, n. 3, p. 371-376.

Pires, E.N., Merlini, C., Al-Qureshim H.A., Salmória, G.V. & Barra, G.M.O, 2012. “Efeito do tratamento alcalino de fibras de juta no comportamento mecânico de compósitos de matriz epóxi”. Polímeros, Vol. 22, n. 4, p. 339-344.

Rana, A.K., Mandal, A. & Bandyopadhyay S., 2003. “Short jute fiber reinforced polypropylene composites: effect of compatibiliser, impact modifier and fiber loading”. Composites Science and Technology, Vol. 63, n. 6, p. 801-806.

Rout, J., Misra, M., Tripathy, S.S., Nayak, S.K. & Mohanty, A.K., 2001. “The influence of fibre treatment on the performance of coir-polyester composites”. Composite Science and Technology, Vol. 61, n. 9, p. 1303-1310.

Witik, R.A., Payet, J., Michaud, V., Ludwig, C. & Manson J-A.E., 2011. “Assessing the life cycle costs and environmental performance of lightweight materials in automobile applications”. Composites Part A: Applied Science and Manufacturing, Vol. 42, n. 11, p. 1694-1709.

8. RESPONSIBILITY NOTICE

The authors are the only responsible for the printed material included in this paper.