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Rear Bumper Laminated In Jute Fiber With Polyester Resin.

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Abstract
Today, a growing interest exists in the use of natural of fibers (sisal, coconut, banana, and jute), as reinforcement in composites. The aim of the present study is shows the use of jute fiber agglutinated with polyester resin in the automobile industry in the production of a rear bumper of hatch vehicle. A simplified mathematical model was used for evaluation of the flaw on trunk center cover submitted to dynamic loads. The traverse section of the referred bumper is simplified by a channel formation. This study shows that a rear bumper made using jute fiber agglutinated with polyester resin will be possible. The molded part obtained good visual characteristics, good geometric construction and surface without bubbles and imperfections in the fiber and resin composite. The mathematical model to failure criterion showed that the rear bumper in jute fiber will not resist to an impact equivalent at 4.0 km/h.
Keywords: Natural fiber, Jute, Rear Bumper, Composites, Resin.

I. INTRODUCTION

The development of materials ecologically correct and a better adaptation of processes for using these materials are fundamental tools in the search of alternatives to minimize environmental problems in the world (Dotan and Al-Qureshi, 1996). The use of raw materials of renewable sources is being object of several studies and researches, due to the potential in the substitution of derived petro-chemistry materials (Al-Qureshi, 2002).

The composites are materials consisting of two or more chemically distinct constituents, having a distinct interface separating them. One or more discontinuous phases therefore, are embedded in a continuous phase to form a composite (Geethamma, Thomas, Lakshminarayanan, and Sabu, 1998). The discontinuous phase is usually harder and stronger than the continuous phase and is called the reinforcement, whereas, the continuous phase is termed the matrix (Joshi, Drzal, Mohanty and Arora, 2004). Jute is a hydrophobic material and moisture absorption alters the dimensional and mechanical characteristics of jute fibers laminate (Mir, Zitoune, Collombet and Bezzazi, 2010), (Hachemane, Zitoune, Bezzazi, and Bouvet, 2013).

The natural fibers present a great potential application in the automobile industry, especially in the internal covering of automobiles, bus and trucks. The future perspective for the use of natural fibers is very good also in other areas. For instance, the textile industry is now with expansion international market. In the last years, use of natural fibers as, coconut, sisal, rami, sugar-cane pulp, jute and pineapple as reinforcement in polymeric material had an accelerated growth. They are source of renewable natural resource (Braga, 2006).

Natural fibers present low cost, are biodegradable, recycled, no poisonous and can be incinerated. They are being used as reinforcement in polymeric and substitute synthetic fibers partially as asbestos, Kevlar, boron, carbon, nylon and glass. In spite of these good mechanical characteristics, they present a high cost, are abrasive to the processing equipment's, possess high density, generate products with very high recycling cost, besides some of those fibers commit human health (ASM, 2001).

1.1 Resins

Matrices have as main purpose to transfer the stresses imposed on the composite material to the fibers, as well to serve as a support and protection of the fibers. Generally, composite matrices of thermosetting resins are used because they have great mechanical properties and dimensional stability. They are also resistant to chemical attack and have high thermal resistance (PIRES, 2009).
According to Bento (2006) the matrix has three main functions which are:

- To protect the surface of fibers from damage by abrasion that would lead to fracture;
- Adhere in the surface in order to transfer the force has applied to the same fiber;
- To separate the fibers each other in order to improve the resistance of propagation of transverse cracks to other fibers.

1.1.1 Synthetic resins

Synthetic resins are resins widely used in industrial scale. Macromolecules are obtained through chemical reactions in reactors using the appropriate monomers. Depending on the resin the obtainment appea occurs through of addition or condensation reactions. The best known synthetic resins are alkyd, vinyl, acrylic, polyurethane, phenolic, epoxy, amino, among others (Anon, 1997).

1.1.2 Natural resins

Resins are obtained in nature, the origin of plants, called biodegradable. These can be in a state fossil. Fossilized are extracted directly from the basement, and the recent direct from the plant. These natural resins are complex organic structures that can be found of phenolic derivatives, alcohols, esters, essential oils. Can be classified as low-acid, high acidity, shellac, gum elemi, as well as its physical and chemical characteristics. There are also animal origin resins such as the resin known as Shellac, which is exudation of an insect. (ASM, 2001).

Biodegradable break down into its simplest components by the activity of microorganisms on contact with soil, with moisture, the air and the sunlight, unlike what happens with the petrochemical resins, which remain long without modification. For a biodegradable plastic is considered, it must degrade within a period not exceeding 180 days, according to international standards.

The biodegradation process occurs under certain conditions when the micro environment fragment and use the materials as a food source. This process can take place in different environments, means, for example, soil, compost areas of water treatment plant, marine, etc. This process converts carbon energy for maintaining life. Biodegradation involves two steps.

- Long polymer chains are broken at carbon-carbon bond. Depending on the polymer, this process can be triggered by heat, moisture, microbial enzymes or certain environmental conditions. This process is called degradation, and you can observe it because the plastic becomes very resistant and therefore easily fragmented.
- The short carbon chains pass through the cell membrane of microorganisms and are used as a food source. This biodegradation is, that is, the carbon chains are used as a source of food and are converted into water, biomass, carbon dioxide or methane (depending on whether the process conditions occurring in aerobic or anaerobic conditions).

1.2 Fibers

There are some different ways to classify the fibers. The first distinction that can be made is between synthetic and natural fibers. Then, the natural fibers are divided into plants, animals and minerals. Finally, the vegetable fibers are separated according to their origin in plant fibers, seeds, fruit, stem, leaf, stem and cane. Examples of each type of fiber are also shown (Fig. 01) (Mohanty, 2002).

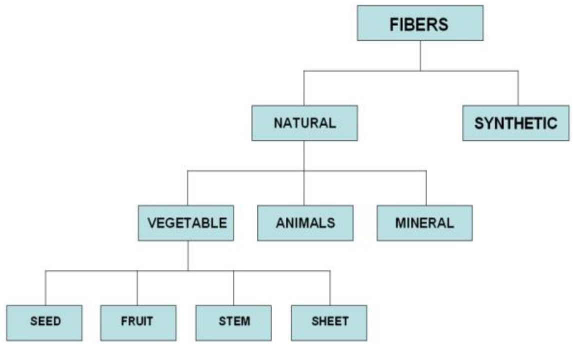

Figure 01: Classification of fiber and some examples.

The physical properties of some natural fibers is showed in Table 01. (Sathishkumar, 2013).

Fiber name	Density (g/cm^3)	Diameter (μm)
Agave	1.20	126–344
Bamboo	0.91, 0.6–1.1	240–330
Banana	1.35	60–80 50–250
Curaua	1.40	170
Jute	1.3–1.46	40 –350
Piassava	1.40	-
Ramie	1.50	50
Sisal	1.45	50–300

Table 01: Physical properties of some natural fibers.

Natural fibers consisted of cellulose micro-fibrils in an amorphous matrix of lignin and hemicellulose. The lignocellulose cell wall can be considered as naturally occurring composites structure of spirally oriented various chemical composites. Chemical compositions such as cellulose, hemicellulose, lignin, wax, ash, pectin, and moisture content vary with various natural fibers. The place of the plant growth, plant growth rate, and plant tissue determine the percentage of chemical compositions in fiber. The chemical composition of some natural fibers is reported in Table 02. (Sathishkumar, 2013).

Fiber name	Cellulose (%)	Lignin (%)	Hemi cellulose (%)	Pectin (%)	Wax (%)	Moisture (%)	Ash (%)	Microfibrillar angle (%)
Agave	68.42	4.85	4.85	-	0.26	7.69	-	-
Bamboo	26–43	1–31	30	-	-	9.16	-	-
Banana	83	5	-	-	-	10.71	-	11–12
Curaua	73.6	7.5	9.9	-	-	-	-	-
Jute	61–71.5	11.8–13	17.9–22.4	0.2	0.5	12.5–13.7	0.5–2	8
Piassava	28.6	45	25.8	-	-	-	-	-
Ramie	68.6–91	0.6–0.7	5–16.7	1.9	-	-	-	69–83
Sisal	78	8	10	-	2	11	1	20–25

Table 02: Chemical composition of some natural fibers.

1.2.1. Synthetic fibers

Synthetic fibers are fibers derived from synthetic polymers: polyamide (nylon), polyvinyl derivatives, polyolefin and polyurethane. Other polymeters with industrial interest are the synthetic fibers such as nylon, used in fishing net, used as yarn in the textile industry. It is mainly used to make clothing and other materials like bed sheets, pillows, scarves and more (Bento, 2006).

1.2.2. Natural fibers

Natural fibers, as shown in Figure 01, are subdivided into vegetables (cotton, coconut, flax, jute, ramie, hemp, sisal, pineapple, rice, bamboo), animals (wool and silk) and minerals (asbestos). Natural fibers are elongated structures of hollow cross section and rounded, are distributed over the entire plant can be classified according to anatomic origin as fiber stem, leaf fibers, fiber and wood fiber surface. Fibers occur in the stem phloem which lies on the inner bark of the stem, for example, the fibers of jute, ramie, flax, cotton, and palm fiber. The leaf fibers are extracted from the leaves of plants, we cite the sisal, pineapple, banana and palm. The wood fibers are obtained as in the case of the wood fibers of bamboo and fiber of sugar cane bagasse. The surface fibers form a protective layer of stems, leaves, fruits and seeds of plants such as fibers coconut and cotton fibers (Fagury, 2005).

The main advantages of natural fibers over traditional synthetic fibers are:

Abundant, low cost, low density, good specific properties, easy availability and handling, non-toxic, low abrasion equipment and molds, absorbing carbon dioxide through environment, biodegradability, renewable, low power consumption for production and mainly stimulate employment in rural areas.

Moreover, they also have disadvantages that hinder its application in many situations and environments, for example:

Low processing temperatures, marked variability in the mechanical properties, low dimensional stability, high sensitivity to environmental effects such as humidity, temperature variation, Suffer significant influences relating to soil, have cross sections of complex and non-uniform geometry and have modest mechanical properties over traditional structural materials. (Neto, 2006)

Although the mechanical properties of natural fibers are far below those of synthetic fibers, their density is approximately half of fiberglass, for example. (Silva, 2003).

1.2.2.1 Sisal fiber

Originally from Mexico, the "*Agave Sisalana Perrine*" is a plant used for commercial purposes. Sisal is grown in semi-arid regions. In Brazil, the major producers are the states of Paraíba and Bahia, in the latter, especially in the sisal region where is located the largest major producer of sisal and industrial world. The most widely cultivated species is "*Agave Sisalana Perrine*" and the average life cycle of the common sisal is 8 years, and at the end of the plant comes into bloom and die without fruit, and sisal hybrid fruits. (Ford Brazil, 2014).

1.2.2.2. Jute fiber

Originating in India, "*Corchorus capsularis*" or jute is a tough plant fiber similar to the string, an entirely ecological. From the family of tiliace, your plant, a woody herb, can reach height of 3 to 4 meters and its stalk thickness of about 20 mm, growing in humid and tropical (Fagury, 2005).

1.3 Mecanical properties

The mechanical properties of natural fibers such as tensile strength, modulus, and elongation at breaks have been determined after measuring the cross-sectional area and diameter of fiber. The sisal fibers were cut into four different gauge lengths for measuring the tensile properties with a 250N load cell. The test was conducted in displacement control at a rate of 0.1 mm/min. The mechanical properties of some natural fibers is reported in Table 03. (Sathishkumar, 2013).

Fiber name	Gauge length (mm)	Tensile strength (MPa)	Tensile modulus (GPa)	Elongation at break (%)
Bamboo	100	503	35.91	1.40
Banana	150	600	17.85	3.36
Curaua	10	158–729	-	5
Jute	60	393–773	10–30	1.5–1.8
Piassava	-	134–143	1.07–4.59	21.9–7.8
Ramie	-	220–938	44–128	2–3.8
Sisal	50	530–640	9.4–22	3–7

Table 03: The mechanical properties of some natural fibers.

II. METHODS

The natural jute fiber and the polyester resin were used tree layers of fiber composites are formed by stacking several thin layers of fibers impregnated with polymeric resin, also called slides.

Natural fibers like jute, sisal, hemp, flax, and ramie have mechanical properties better in many respects than PP or polyester. Natural fiber like jute is also known to have good adhesion with bitumen as evident from the widespread application of bituminized jute fabric. It is also relatively inexpensive and available abundantly in Brazil, India, Bangladesh, and some neighboring countries (Gassan and Bledzki, 1997).

The natural fiber used as structural reinforcement was the jute fiber. For construction of the experimental bumper three jute woven fabric were used. Each woven fabric was applied as only piece, without cuts, so that if could obtain the best possible structural characteristics (Braga, 2006).

The Polyester resin constitute a family of high molecular weight polymers resulting from the condensation of carboxylic acids with glycols, being classified as saturated or unsaturated resins depending on particular types of acids used that will characterize the type of bond between the carbon atoms in the chain molecular. Polyester is a term that means: poly (many, so many ester groups); ester (is a chemical function, an ester is obtained via the following reaction: acid + alcohol = ester + water) (Sabeel and Vijayarangan, 2008). Thus biacid molecules and give raise bialcool various molecules forming the polyester.

Was used 100.0 g of Poliester resin 10116 (1,0 % of Peroxide of Metil Etil Cetona) and 100.0 g of Polyester resin 10255 (1,0% of Peroxide of Metil Etil Cetona) totally polymerized, low reactivity, low viscosity, flexible, pre-accelerated. This resin:

- Reduces the shrinkage of the resins of rigid due to its low exothermic peak.
- Exceptional feature flexibility even with the addition of low levels.

Significantly increases the percentage of maximum elongation of rigid systems accommodating internal tensions.

A simplified mathematical model was idealized for evaluation of the bumper failure submitted to dynamic loads. The rear bumper used, is showed in frontal view with cut A-A (Fig. 02).

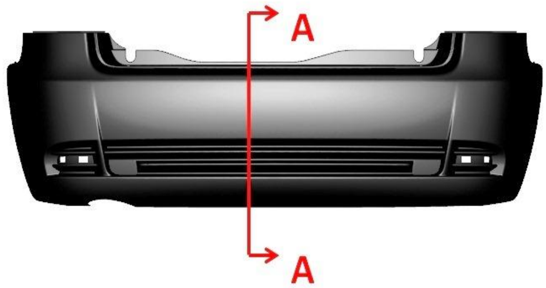

Figure 02: Frontal view of the rear bumper with cut A-A.

Was used a traverse section of the rear bumper and the simplified traverse section. To the mathematical model and calculation purposes, this cut A-A was simplified to a beam cross section in "U", (Fig. 03).

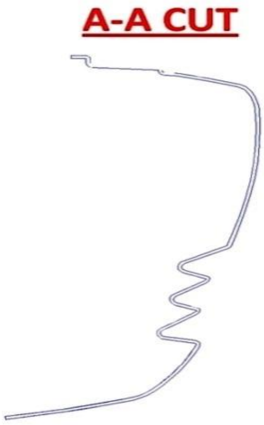

Figure 03: Traverse of rear bumper and traverse section used for calculations.

A layout simplified of a dynamic impact in the rear bumper used in mathematical model (Fig. 04).

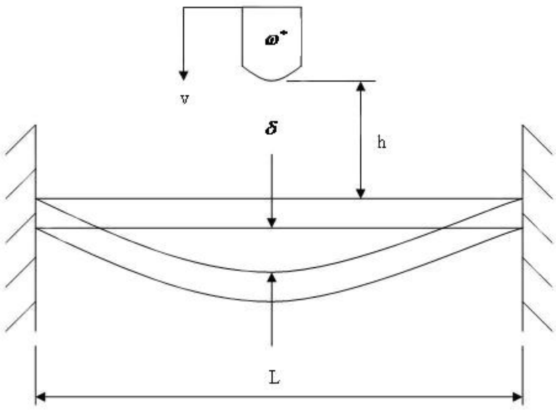

Figure 04: Simplified diagram of a dynamic impact in the rear bumper.

The work done in the impact on the bumper is determined by (Mendonça, 2005).

$$\omega^*.(h+\delta)=\frac{1}{2}.\omega_e.\delta \qquad (01)$$

Where ω_e is the static loading, applied in a same point in the bumper, causing a flexure δ. Then the work done is:

$$U_e=\frac{1}{2}.\omega_e.\delta \qquad (02)$$

It is necessary to express δ in terms of ω_e for the previous case, then:

$$\delta=\frac{\omega_e.L^3}{192.E.I} \qquad (03)$$

From Eq. (01) and Eq. (03):

$$\omega^*.(h+\frac{\omega_e.L^3}{192.E.I})=\frac{1}{2}.\frac{\omega_e{}^2.L^3}{192.E.I} \qquad (04)$$

Using:

$$\kappa = \frac{L^3}{192.E.I} \tag{05}$$

It is obtained Eq. (04), simplified:

$$\omega^*.(h+\kappa.\omega_e) = \frac{1}{2}.\kappa.\omega_e{}^2 \tag{06}$$

Solving Eq. (06):

$$\frac{1}{2}.\kappa.\omega_e{}^2 - \omega^*.h - \kappa.\omega.\omega_e = 0 \tag{07}$$

$$\omega_e{}^2 - 2.\frac{\kappa}{\kappa}.\omega^*.\varpi_e - \frac{2.h}{\kappa}.\omega^* = 0 \tag{08}$$

The Quadratic Equation for ω_e it is given:

$$\omega_e{}^2 - 2.\omega^*.\omega_e - \frac{2.\omega^*.h}{\kappa} = 0 \tag{09}$$

The solution is determined:

$$ax^2 + bx + c = 0 \tag{10}$$

Thus,

$$\omega_{e1}, \omega_{e2} = \frac{-(-2.\omega^*) \pm \sqrt{(-2.\omega^*)^2 - 4.(-\frac{2}{\kappa}.\omega^*.h)}}{2} \tag{11}$$

$$\omega_{e1}, \omega_{e2} = \frac{2.\omega^* \pm \sqrt{4.\omega^{*2} + \frac{8.\omega^*.h}{\kappa}}}{2} \tag{12}$$

Therefore:

$$\omega_{e1} = \omega^* + \sqrt{\omega^{*2} + \frac{2.\omega^*.h}{\kappa}} \tag{13}$$

$$\omega_{e2} = \omega^* - \sqrt{\omega^{*2} + \frac{2.\omega^*.h}{\kappa}} \tag{14}$$

Assuming $\omega_{e1} \geq \omega_{e2}$, Eq. (03) results:

$$\delta = \frac{\omega_{e1}.L^3}{192.E_c.I_c} \tag{15}$$

Where E_c is the Composite Elasticity Module.

Therefore:

$$\sigma = \frac{M.Y_2^1}{I_c} \tag{16}$$

$$M = \frac{\omega_{e1}.L}{8} \tag{17}$$

Resulting:

$$\sigma = \frac{\omega_{e1}.Y_2^1.L}{\lambda.8.I_c} \tag{18}$$

Where λ is safety's factor, from 1 to 3 values (Mendonça, 2005).

Assuming that the traverse section is a beam in "U", calculation of I_c made, in the following way. Outline for calculation of inertia moment of the bumper section (Fig. 05).

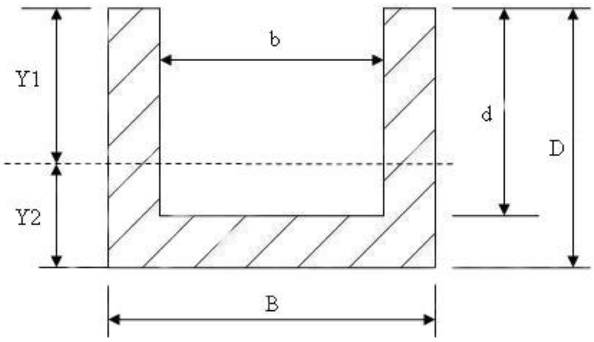

Figure 05: Outline for calculation of the section inertia moment of the bumper.

Therefore:

$$Y_1 = \frac{B.D^2 - b.d^2}{2.(B.D - b.d)} \tag{19}$$

$$Y_2 = \frac{B.D^2 - 2.b.d.D + b.d^2}{2.(B.D - b.d)} \tag{20}$$

So:

$$I_c = \frac{(B.D^2 - b.d^2)^2 - 4.B.D.b.d.(D-d)^2}{12.(B.D - b.d)} \tag{21}$$

The final expression for the tension developed in a bumper for an impact with constant speed, could be expressed in the following way.

$$\sigma_{max} = \frac{\omega_{e1}.Y_2.L}{\lambda.8.I_c} \tag{22}$$

Substituting Eq. (14) in Eq. (23):

$$\sigma_{max} = \frac{Y_2.L}{\lambda.8.I_c}\left[\omega^* + \left(\omega^{*2} + \frac{2.\omega^*.h}{\kappa}\right)^{\frac{1}{2}}\right] \tag{23}$$

where:

$$h = \frac{v^2}{2.g} \tag{24}$$

$$\kappa = \frac{L^3}{192.E.I} \tag{05}$$

Then the final equation of outline of a bumper submitted to a dynamic load gradually applied it will be of:

$$\sigma_{\max} = \frac{Y_2.L}{\lambda.8.I_c}\left[\omega^* + \left(\omega^{*2} + \frac{192.\omega^*.v.E_c.I_c}{g.L^3}\right)^{\frac{1}{2}}\right] \quad (25)$$

The theoretical composite elasticity module was obtained with law of the chemical mixtures (Al-Qureshi, 2002).

$$E_c = \beta.E_f.V_f + E_m.(1-V_f).\eta \quad (26)$$

Where E_f is the fiber elasticity module, E_m it is the resin elasticity module, V_f is the fiber volumetric Fraction, β is the fiber alignment efficiency factor ranging from 0 to 1, according to the type and construction of the conjugated (Al-Qureshi, 2002). And η is the adhesion factor between the fibers and the matrix, ranging from 0 to 1. In this case, the alignment efficiency factor (Al-Qureshi, 2002) is 0.5 because the direction is bi-directional. The variation alignment of fiber efficiency factor is showed in the Table 04.

Direction	Factor (β)
Uni-directional Longitudinal	1.0
Uni-directional Traverse	0.0
Bi-directional	0.5
Random in the plan (woven fabrics)	0.375
Random in the plan (pitted fibers)	0.2

Table 04: Alignment fiber efficiency factor Variation.

The Mathematical model to failure criterion used was if the stress of the material / composed is larger than the calculated stress, the part will resist to impact, otherwise, it won't resist and will break.

$$\sigma_{\max} = \frac{Y_2.L}{\lambda.8.I_c}\left[\omega^* + \left(\omega^{*2} + \frac{192.\omega^*.v.E_c.I_c}{g.L^3}\right)^{\frac{1}{2}}\right] \quad (25)$$

$\sigma^m_{\max} < \sigma^c_{\max}$ → The Bumper will break with impact.

$\sigma^m_{\max} > \sigma^c_{\max}$ → The Bumper won't break with impact.

$\sigma^m_{\max}$ is the theoretical ultimate tension strength of the Material / Composed and $\sigma^c_{\max}$ it is the calculated ultimate tension strength.

2.1 Calculations

2.1.1 Rear bumper in jute with polyester resin

Data for calculations for a rear bumper made of jute fiber is showed in Table 05.

Denomination	Value	Unit
D (Rear bumper height)	300,00	mm
B (Rear bumper widht)	500,00	mm
D	295,00	mm
B	490,00	mm
L (Rear bumper length)	1500,00	mm
e (Average thickness)	5,00	mm
g (Gravity acceleration)	9810,00	mm/seg
v (Speed)	4,00	km/h
v (Speed)	1100,00	mm/seg
β (Alignment)	1,00	-
λ (Safety factor)	3,00	-
η (Factor of adhesion between the fibers and the matrix)	0,30	-
W (Vehicle weight)	1000,00	Kg
Ef (Fiber jute elasticity module)	10500,00	MPa
Vf (Volumetric fraction of fiber)	0,20	-
Em (Resin elasticity module)	350,00	MPa

Table 05: Data for calculations for a rear bumper made of jute fiber.

Using equation 19, the value of Y_1, is:

$$Y_1 = \frac{B.D^2 - b.d^2}{2.(B.D - b.d)} = 216.30 \ mm$$

Using equation 20, the value of Y_2, is:

$$Y_2 = \frac{B.D^2 - 2.b.d.D + b.d^2}{2.(B.D - b.d)} = 83.70 \ mm$$

Using equation 23, the value of I_c, is:

$$I_c = \frac{(B.D^2 - b.d^2)^2 - 4.B.D.b.d.(D-d)^2}{12.(B.D - b.d)} =$$

$$I_c = 51846101.87 \ mm^4$$

Using equation 24, the value of h, is:

$$h = \frac{v^2}{2.g} = 61.70 \ mm$$

Using equation 05, the value of k, is:

$$\kappa = \frac{L^3}{192.E.I} = 0.000298981 \quad \frac{mm}{N}$$

Transforming the value of k to $\frac{mm}{kg}$:

$$\kappa = \frac{L^3}{192.E.I} = 0.000029898 \quad \frac{mm}{kg}$$

Using equation 13, the value of ω_e, is:

$$\omega_e = \omega^* + \sqrt{\omega^{*2} + \frac{2.\omega^*.h}{\kappa}} = 65237.60 \ kg$$

Using equation 26, the value of E_c, is:

$$E_c = \beta.E_f.V_f + E_m.(1 - V_f).\eta = 1134.00 \ MPa$$

Therefore, using equation 22, the value of σ_{max}, as follows:

$$\sigma_{max} = \frac{\omega_{e1}.Y_2.L}{\lambda.8.I_c} = 17.00 \ \frac{kg}{mm^2}$$

Transforming the value of σ_{max} to MPa:

$$\sigma_{max} = \frac{\omega_{e1}.Y_2.L}{\lambda.8.I_c} = 166.70 \ MPa$$

Therefore:

σ^c_{max} = 166.70 MPa

The Stress has to be between 27.26 to 32.70 MPa, according to the literature.

In this case, with this composite jute +polyester resin, the rear bumper **will break** at an impact to 4 km/h.

2.1.2 Rear bumper in sisal with polyester resin

Data for calculations for a rear bumper made of jute fiber is showed in Table 06.

Denomination	Value	Unit
D (Rear bumper height)	300.00	mm
B (Rear bumper widht)	500.00	mm
D	295.00	mm
B	490.00	mm
L (Rear bumper length)	1500.00	mm
e (Average thickness)	5.00	mm
g (Gravity acceleration)	9810.04	mm/seg
v (Speed)	4,00	km/h
v (Speed)	1100.00	mm/seg
β (Alignment)	0.50	-
λ (Safety factor)	3.00	-
η (Factor of adhesion between the fibers and the matrix)	0.30	-
W (Vehicle weight)	1000,00	Kg
Ef (Fiber jute elasticity module)	23500,00	MPa
Vf (Volumetric fraction of fiber)	0,20	-
Em (Resin elasticity module)	350,00	MPa

Table 06: Data for calculations for a rear bumper made of jute fiber.

Using equation 19, the value of Y_1, is:

$$Y_1 = \frac{B.D^2 - b.d^2}{2.(B.D - b.d)} = 216.3 \ mm$$

Using equation 20, the value of Y_2, is:

$$Y_2 = \frac{B.D^2 - 2.b.d.D + b.d^2}{2.(B.D - b.d)} = 83.7 \ mm$$

Using equation 23, the value of I_c, is:

$$I_c = \frac{(B.D^2 - b.d^2)^2 - 4.B.D.b.d.(D-d)^2}{12.(B.D - b.d)} =$$

$$I_c = 51846101.87 \ mm^4$$

Using equation 24, the value of h, is:

$$h = \frac{v^2}{2.g} = 61.7 \ mm$$

Using equation 05, the value of k, is:

$$\kappa = \frac{L^3}{192.E.I} = 0.000139295 \quad \frac{mm}{N}$$

Transforming the value of k to $\frac{mm}{kg}$:

$$\kappa = \frac{L^3}{192.E.I} = 0.0000139295 \quad \frac{mm}{kg}$$

Using equation 13, the value of ω_e, is:

$$\omega_e = \omega^* + \sqrt{\omega^{*2} + \frac{2.\omega^*.h}{\kappa}} = 95105.40 \ kg$$

Using equation 26, the value of E_c, is:

$$E_c = \beta.E_f.V_f + E_m.(1 - V_f).\eta = 2434.00 \ MPa$$

Therefore, using equation 22, the value of σ_{max}, as follows:

$$\sigma_{max} = \frac{\omega_{e1}.Y_2.L}{\lambda.8.I_c} = 24.80 \ \frac{kg}{mm^2}$$

Transforming the value of σ_{max} to MPa:

$$\sigma_{max} = \frac{\omega_{e1}.Y_2.L}{\lambda.8.I_c} = 243.00 \ MPa$$

Therefore:

σ^c_{max} = 243.00 MPa

The Stress has to be between 163.00 to 445.00 MPa, according to literature.

But, in this case, with this composite sisal + polyester resin, the rear bumper **won't break** at an impact to 4 km/h.

III. EXPERIMENTAL

The present experiment had as objective to build a rear bumper in resin polyester ortoftalic and jute fiber, in real scale, using a mold made in wood, polyester resin and fiberglass. The material composite formed by the resin ortoftalic and the jute fiber used in the lamination of the bumper was evaluated at laboratory, and tests of tensile and flexure strength were realized. This experimental stage also had the purpose of obtaining practical data to comparative evaluation with the theoretical results (Braga, 2006).

The mold construction was in order to obtain the proposed bumper in polyester ortoftalic resin and jute fiber, a mold was built having as base the rear bumper of a vehicle hatch. This mold was elaborated using as material: wood, polyester resin and fiberglass. It is a real scale mold with removable structure in two laterals, with purpose of facilitating the removal of the component (Fig. 06).

Figure 06: Mold of the rear bumper in real scale.

For construction of the bumper, research was made in order to obtain a composite of polyester resin (ortoftalic) and jute fiber (Fig. 07) that presented good elongation characteristic. To obtain this condition a mixture of resins with 80% of resin rigid ortoftalic and 20% of resin flexible ortoftálic was chosen.

The employed resins were the resins Resapol 10116 (rigid ortoftalic) and Resapol 10255 (flexible ortoftalic). Fiber of jute was used as structural reinforcement for bumper woven fabric (Braga, 2006).

Figure 07 : Continuous Woven fabric in Fiber of Jute.

Development of bumper lamination stages:

- Stage 1: Preparation of the mold

The Mold of the rear bumper was strictly clean, being used jet of compressed air, and for removal of remaining dust particles cleaning was made with mesh humidified in water. After it was completed dried, stripping solution was applied on all extension.

- Stage 2: Preparation of the reinforcement woven fabric with fiber of jute

With a woven fabric of Jute's fiber, three similar woven fabric were cut in length and width, in order to be perfectly adjusted to the mold. These jute woven fabric were removed of the continuous woven fabric in its length direction.

- Stage 3: Preparation of the resin

The resin used for lamination of the bumper was prepared through the mixture of 80% of ortoftalic rigid resin and 20% of ortoftalic resin flexible. For each 1000 grams of mixture resin, 10 grams of peroxide of metaletilceton was used as catalyst. In this condition it was obtained a gel point of 25 minutes, temperature of 25ºC.

- Stage 4: Lamination of the rear bumper

1. Application of the first resin layer with brush on the previously prepared mold.
2. Positioning of the first woven fabric of jute fiber on the resin, in the direction of length of the mold (designated as A direction).
3. Resin application on the woven fabric of jute fiber, using a brush.
4. Elimination of air bubbles using a roller, by every surface of the mold.
5. Repeat these steps for second and third woven fabric of fibers.

Polymerization stage and cure, accomplished to the air in room temperature of 25ºC. After 48 hours, the Bumper was removed of the mold. The external side and the internal side of the ortoftalic polyester resin and jute fiber bumper after the mold shakeout is showed (Fig. 08).

Figure 08: External surface of ortoftalic polyester resin and fiber of jute Bumper.

Preparation of specimens for tensile tests, the material composite used in the experiment was obtained through the preparation of a plate with the same employed characteristics for the bumper lamination.

The resin was prepared through the mixture of 80% of ortoftalic rigid polyester resin and 20% of ortoftálic flexible polyester resin. For each 1000 grams of mixture of resin, it was used 10 grams of metiletilceton peroxide as catalyst. Three woven fabric of the same jute fiber were employed as reinforcement in the bumper lamination.

Preparation of polyester resin and fiber of jute plate after 168 hours, estimated time (by the manufacturer) for cure of the composite plate, specimens were extracted of this plate. They were used in tests of flexure, and tension.

IV. RESULTS AND DISCUSSIONS

The tension strength Tests were realized according to the ASTM D 638 standard (ASTM D 638 Standard, 2003) and a Universal machine Instron 4467 was used.

Specimens used in tension strength tests were obtained from flat composite plates using machining technique. Five specimens were obtained from A direction (sense of length of the continuous woven fabric) and 5 specimens from B direction (sense of width of the continuous woven fabric).

This procedure was accomplished with the intention of detecting any significant difference in the tension strength characteristics due to production direction of the continuous woven fabric. The dimensions of these specimens were according to ASTM D 638 standard. Tests were obtained using velocity of 50 mm/min, in room controlled temperature of 23°C and 50% of air relative humidity. The results of the tensile strength tests of specimens built in the A direction are shown in the Table 07 and in the figure 09 and the results of tensile strength tests of specimens built in the B direction are shown in the Table 08 and in the figure 10. The media tensile strength to both specimens in A direction and B direction configurations were considered satisfactory.

	Width (mm)	Thick (mm)	(Max. Load) (N)	Tensile Strength (Mpa)
1	4.61	9.45	1249.00	28.67
2	4.72	9.41	1372.00	30.89
3	4.48	9.07	1063.00	26.26
4	4.68	9.22	1306.00	30.27
5	4.58	9.57	1226.00	27.97
Aver.	4.61	9.34	1243.20	28.79
D. S.	0.09	0.20	115.47	1.88
C. V.	2.02	2.12	9.29	6.54
Min.	4.48	9.07	1063.00	26.16
Max.	4.72	9.57	1372.00	30.89

Table 07: Results of tensile strength tests of specimens - A direction

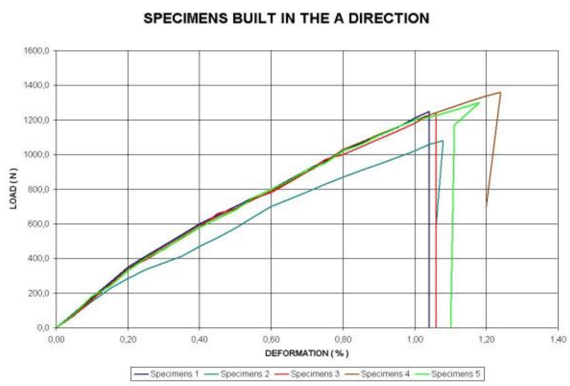

Figure 09: Results of tensile strength tests of specimens built in A direction.

	Width (mm)	Thick (mm)	(Max Load) (N)	Tensile Strength (MPa)
1	5.08	8.89	1205.00	26.68
2	4.78	9.72	1075.00	23.14
3	5.31	9.38	1158.00	23.25
4	4.63	9.12	1055.00	24.98
5	4.78	9.58	1259.00	27.49
Aver.	4.92	9.34	1150.40	25.11
D. S.	0.27	0.34	86.05	1.97
C. V.	5.58	3.61	7.48	7.85
Min.	4.63	8.89	1055.00	23.14
Max.	5.31	9.72	1259.00	27.49

Table 08: Results of tensile strength tests of specimens - B direction

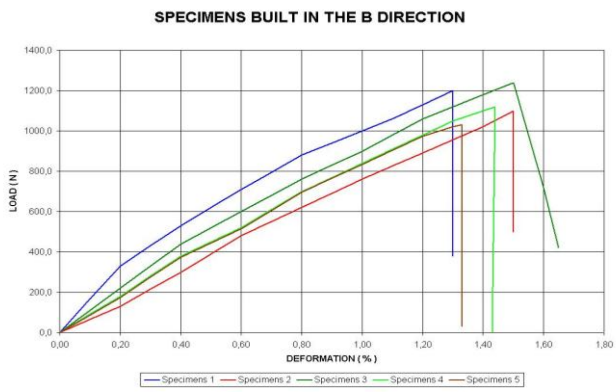

Figure 10: Results of tensile strength tests of specimens built in B direction.

The specimens laminated in the A direction, presented a tensile strength average 14.7% better that the specimens laminated in the B direction.

The composite elasticity module in A direction was 1096.8 MPa and B direction was 826.67 MPa. Therefore 32.6% better.

Tests of flexure strength were obtained according ASTM D 790 standard (ASTM D 790 Standard, 2003) and a Universal Machine of model Instron 4467 was used.

Specimens used in flexure tests wore been obtained from flat composite plates by machining technique. Five specimens has been obtained from A direction (direction of length of the continuous woven fabric) and five specimens from B direction (direction of width of the continuous woven fabric). This procedure has been realized with objective to detect any meaningful difference in the flexure strength characteristics due to different direction of continuous woven fabric produced. Dimensions of specimens to the flexure strength tests were according ASTM D 790 standard.

Tests wore been obtained using velocity of 50 mm/min, in room controlled temperature of 23°C and 50% of air relative humidity.

Results of flexure strength tests with specimens in the A direction are shown in Table 09 and the results of the flexure strength tests, with specimens in the B direction are shown in Table 10. The media flexure strength to both specimens in A direction and B direction configurations were considered satisfactory.

	Width (mm)	Thick. (mm)	(Max. Load) (N)	Flex. Str. (MPa)
1	13.41	5.23	278.50	57.86
2	13.77	5.47	249.50	46.14
3	13.68	4.56	187.80	50.31
4	13.44	5.15	195.00	41.68
5	13.30	5.18	199.90	42.68
Aver.	13.52	5.12	222.14	47.74
D. S.	0.20	0.34	39.80	6.59
C. V.	1.46	6.57	17.92	13.81
Min.	13.30	4.56	187.80	41.68
Max.	13.77	5.47	278.50	57.86

Table 09: Result of flexure strength tests - specimens in A direction.

	Width (mm)	Thick. (mm)	(Max. Load) (N)	Flex. Str. (MPa)
1	12.96	4.47	148.90	43.82
2	13.49	4.91	212.80	49.86
3	13.39	5.45	227.80	43.65
4	13.42	4.76	169.10	42.38
5	13.12	5.48	240.10	46.44
Aver.	13.28	5.01	199.74	45.23
D. S.	0.23	0.44	39.08	2.98
C. V.	1.70	8.80	19.57	6.59
Min.	12.96	4.47	148.90	42.38
Max.	13.49	5.48	240.10	49.86

Table 10: Result of flexure strength tests - specimens in B direction.

The specimens laminated in the A direction, presented a flexure strength average 5.5% better that the specimens laminated in the B direction.

V. CONCLUSIONS

The Bumper after mold shakeout, presented good geometric constitution, and woven fabric of fiber jute fiber were perfectly involved by the resin, with absence of voids or bubbles in an apparent way. The characteristics of the finishing experimental component were: mass = 7.956 KG and medium thickness = 5.0 mm. Calculated composite elasticity module in A direction was 1134.0 MPa. Laboratory tests results showed Ec = 1096.8 MPa, in another words, 96.7 % of the calculated value. Using the Equation 26, the $\sigma^{c}_{\max}$ (calculated for jute) will be 166.7 MPa and the $\sigma^{m}_{\max}$ is 28.79 MPa (average, shows in the Table 3). Then the rear bumper will break with the real impact at 4 km/h. Even doubling the thickness of the rear bumper of jute fiber, tension tensile strength moves to 117.8 MPa, this is not sufficient to support a frontal impact of 4 km / h. We could change the inertia moment of the material, making some longitudinal ribs in the molded Bumper, like this he would resist better to the front impact, without breaking. Another alternative would be to use a new polymer matrix a higher percentage of flexible resin with better mechanical properties, for making the composite with better elongation characteristics, to increase the ultimate tension strength. The test of the real impact at rear bumper has not possible, but due to calculations and laboratory tests, we believe that it really would break on impact at 4.0 km/h.

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