23rd ABCM International Congress of Mechanical Engineering
December 6-11, 2015, Rio de Janeiro, RJ, Brazil

FLAMMABILITY OF THE COMPOSITE: NATURAL LATEX ENHANCED WITH PLAIDS STRAW COCONUT

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Abstract. *Composite produced from Plaid straw coconut and natural latex, with percentages of coconut plaids in the proportions 15%, 25% and 35% of the total volume of the compound in order to analyze the fire and burning speed without use retardant. The coconut webs were treated with 2% sodium hydroxide (NaOH). The assays were performed according to UL94 standard. In the UL94 vertical test samples were not classified because of the self-sustainability of the flame. It was also found that even cannot be classified according to the UL94 standard. The composites were far lower burn rate to a prescribed resolution CONTRAN No. 675, which requires liners employed by the automotive industry have a flame propagation velocity of 250 mm/min.*

Keywords: *composite, natural fiber, flammability*

1. INTRODUCTION

With the emergence of new technologies, has grown the need to use new materials, and this has intensified research on the collection and use of materials from renewable sources, is to reduce production costs and / or environmental impact. In this context, it was found that the sheath of the straw coconut (coconut blanket or cloth), may be utilized as feedstock for the production of a composite that can be used as a thermal and acoustic insulator.

In applications where the material used is in touch or on the verge of contact with substances or heated or inflamed bodies, it is necessary to determine the flammability, in order to avoid unwanted combustion. This has encouraged the development of formulations capable of retarding combustion and decreasing the flame propagation speed and/or reduce smoke emissions.

The increasing demands of safety standards in some applications, the flammability (flame resistance), is in one of the barriers to use of some polymers (Rabello, 2000).

According Kiliaris and Papaspyrides (2010), like most organic products, polymers are flammable and during the heating, there is the release of small molecules which act as fuels in the presence of fire.

The flame resistance of a rubber artifact depends fundamentally on its composition and the presence, in varying dosage of a type of additives called "flameproof agents." The flame retardant agents are substances that, in case of combustion, emit substances (for example, halogens or water vapor), substances that tend to "drown out" the combustion. Some rubber compositions are by themselves, flameproof. This is the case of rubbers based on polychloroprene, chlorobutyl, bromobutyl, chlorosulfonated polyethylene, which have halogen (chlorine or bromine) in the elastomer base.

In rubbers which have no intrinsic flame retardant resistance is generally incorporated flame retardant additives, such as hydrated alumina or antimony oxide and a halogen carrier (such as a chlorinated paraffin).

The literature has cited quite often the employment of aluminum hydroxide, which acts as flame retardancy and smoke suppression in polymeric matrices, because of its low cost and low toxicity (Canaud et al., 2001).

But, they are used in large quantities also has activity as fillers, generally jeopardizing the mechanical behavior of the composite (Siqueira et al., 2001).

It is known that in different circumstances, the specifications on the use of products of rubber or rubberized, should include heat resistance requirements and/or flame resistance (flammability). In some cases, in addition to the above requirements, standards also set requirements regarding the type, volume and toxicity of the gases released on combustion.

Given the above, it becomes evident the need to conduct flammability tests in the composite under study, aimed to provide information about specific use of this product.

This paper presents the results obtained in the flammability test as well as polymeric composite burning rate using the plaid sheath straw coconut as reinforcement and natural latex as a matrix, without the use of flame retardant. Composites were produced with 15% blanket percentage, 25% and 35% of the total compound volume.

The plaid of coconut straw sheath was selected for this work in order to analyze its properties and possible ways to use and give it a more noble destiny to this material, since the agribusiness coconut and / or dry, most of the burn times or discards it improperly in the environment.

2. MATERIALS AND METHODS

2.1 Materials

It was used as latex matrix liquid natural rubber, acquired in the State of São Paulo, Brazil.

Originally latex used was extracted from rubber trees (Hevea brasiliensis), and have as major components poly-cis-isoprene having syndiotactic sui generis properties when compared to most synthetic rubbers (Tanaka and Sakdapipanich, 2001). Tab. 1 presents the latex composition provided by the manufacturer.

Table 1. Composition of the latex used.

Composition	Percentage
Eraser	59.37 %
Water	37.96 %
Proteins	1.6 %
Lipids	0.23 %
Salts	0.40 %
Ammonia	0.68 %

As reinforcement material used an extracted natural plaid coconut straw sheath (nucifera coconut), commonly coconut cloth call. Figure 1 shows the materials used.

Figure 1. (a) Extraction of rubber latex; (b) Plaid straw coconut

2.2 Methods

The plaids were washed with water, dried in the sun and selected. Fig. 2 shows the process of cleaning and selection.

Figure 2. Cleaning the plaids: (a) Preliminary cleaning; (b) drying in the sun; (c) Selection of plaids

Once selected, the plaids were subjected to an alkaline treatment, which aims at the removal of lignin and hemicellulose, and thus provide a better interfacial adhesion between fiber and matrix.

The alkali treatment consisted in immersing the coconut plaids NaOH solution and distilled water with a mass concentration of 2% NaOH for 1 hour period. Fig. 3 shows the alkaline treatment.

Figure 3. Alkaline treatment

It was determined the densities of the plaids of coconut and latex through a Digital Densimeter mark GEHAKA, DSL model 910, which uses Archimedes' principle (buoyancy) and is suitable for solid and liquid.

In these assays were used 12 different samples of coconut plaids with dimensions of 2 cm x 2 cm, according to the requirements of ASTM D 792. Fig. 4 shows the density tests performed.

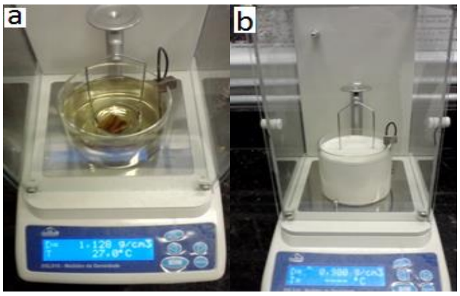

Figure 4. (a) Plaids density test; (b) Latex density teste

2.3 Manufacturing Process

The manufacture of composite is carried out by manual lamination process (Hand Lay Up). For the preparation of the specimens was built a cast acrylic, with internal dimensions of 250 mm x 26 mm x 10 mm with upper and lower lids, fastened with screws, as shown in Fig. 5.

Figure 5. Shows the mold made

Using the data obtained in determining the density of natural latex (0.980 g/cm^3 of coconut blankets (1.1051 g/cm^3), there was some experiments to determine the maximum percentage that blanket the mold bear, and so set percentage of the components used in the manufacture of composites under study. The formulations of composites for the preparation of specimens were defined as percentage of the total volume of the mold as described in Tab. 2. These compositions were set up to the limit of 35% of coconut blanket.

Table 2. Compositions of proof bodies

Raw Materials	Compositions of the composite (% volume)		
	CP-15	CP-25	CP-35
Plaids of coconut	15	25	35
Latex	85	75	65

The manufacture of composites and of the specimens were performed as follows: With the properly cut and heavy plaids and heavy latex, gave up early manufacturing of the specimen, with alternating placement plaids and latex in the mold .

With the aid of a metal spatula, the plaids are pressed inside the mold, with aim of improving impregnation process and eliminate bubbles. After placing all plaids and all the latex in the mold, this was capped, and after two days the specimen was removed from the mold.

After the curing process, the samples were cut into smaller samples with dimensions 125 mm x 13 mm x 10 mm. Fig. 6 shows the samples used in the horizontal flammability test.

Figure 6. Test specimens used

2.4 Flammability test

In this work the flammability tests were carried out according to UL-94 standard, which guides the tests using two methods: UL-94 HB (Horizontal Burning), the object is tested in a horizontal position on the flame and UL-94 V (Vertical Burning), the object is burned in an upright position, with greater exposure.

The horizontal flammability test according to the UL-94 HB (method A) consists of flame impinging on a specimen with dimensions of 125 mm ± 5 mm long, 13 mm ± 0.5 mm wide and a minimum thickness of 3 mm and a maximum of 13 mm.

The horizontal burning test is applied to materials which continue to burn and propagate the flame, even after removal of the initial flame. It is used in order to classify UL-94 HB polymer material by burning speed the material. In this test the samples should have the length 125 mm and must be marked to 6 mm, 25 mm and 100 mm from the edge to be burned. The Fig. 7 shows the scheme for the horizontal flammability test.

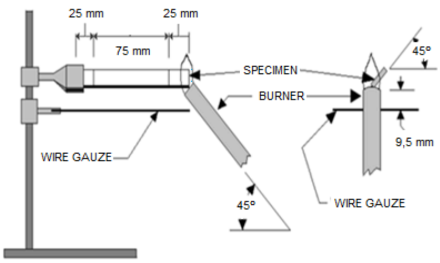

Figure 7. Schematic representation of the horizontal flammability test

The sample should be determined by marking the hook free end, and is fixed to the hook with its longitudinal axis placed horizontally and the transverse axis inclined at 45 °.

The flame must be applied to the free end of the sample for a period of 30 seconds. If the specimen continues to burn after removal of the flame, must be registered in the time required for combustion reaches the 25mm mark, to continue combustion, registering the time required to reach 100 mm mark.

In this test 24 samples were used, each 8 three studied composites (15%, 25% and 35%).

Classification HB is assigned if the following conditions are met:
• The combustion speed is not greater than 38 mm/min for samples with thicknesses between 3 mm and 13 mm.
• The combustion speed is not greater than 75 mm/min for specimens of thickness less than 3 mm.
• The combustion must self-extinguish before being hit 100 mm.

The flammability test (UL-94 HB) aims to determine the linear burning rate (V), in millimeters per minute, for each specimen, and it makes use of Eq. (1).

$$V = 60L/t \qquad \text{Equation (1)}$$

Where:
V = Linear burning rate in mm/min;
L = Length damaged in the specimen, in millimeters;
t = Time in seconds.

The vertical flammability test according to UL-94 V (method B) consists of flame impinging on a specimen with dimensions of 125 mm ± 5 mm long, 13 mm ± 0.5 mm wide and a minimum thickness of 3 mm and a 13 mm. The specimens should be labeled 6mm at one end of the sample to be fastened to the hook. At the other end will be marked 10 mm coming into contact with the flame when the test started.

With the specimen vertically caught in the hook support, the test begins by placing the flame at the free end of the sample with the marking 10 mm for a period of 10 seconds. After 10 seconds the flame must be removed if it goes out, the flame is reset for another 10 seconds. If there is self-sustaining flame in the sample will not be possible to classify it according to UL-94 V. We used this assay 30 samples, 10 samples of each of the 3 studied percentage (15%, 25% and 35%).

The tests shall be carried out in two series, with five test pieces for each series. If there is no self-sustaining flame, the material is characterized by the following ratings:
• Classification V0 - when the sum of the durations of calls is not greater than 50 seconds, the cotton layer does not ignite drip material.
• V1 rating - when the sum of burning times is not more than 250 seconds and no burning of cotton by dripping or sparks emitted;
• V2 rating - when the sum of burning times is not more than 250 seconds, but the layer of cotton by dripping the material ignites. Fig. 8 shows the scheme for the vertical flammability test.

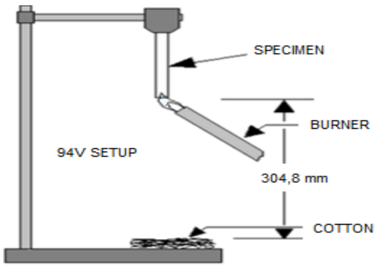

Figure 8. Schematic representation of the vertical flammability test

3. RESULTS AND DISCUSSION

3.1 Vertical Flammability Test of UL-94 V

Vertical Flammability Test carried out in the composite with 15% of coconut plaid volume (CP-15), Fig. 9.

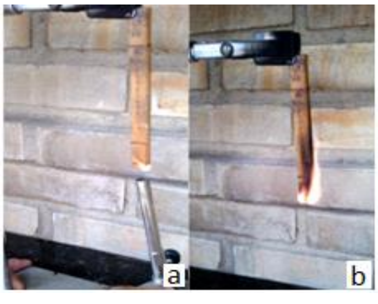

Figure 9. UL-94 V test the CP-15 composite: (a) flame application for 10 seconds; (b) self-sustaining burns.

Vertical Flammability Test carried out in the composite with 25% of coconut plaid volume (CP-25), Fig. 10.

Figure 10. UL-94 V test the CP-25 composite: (a) flame application for 10 seconds; (b) self-sustaining burns.

Initially the flame was applied for 10 seconds after removal of the flame the fire was quenched. In the second application of the flame is self-sustaining burning, and burning the sample fully.

Vertical flammability test performed in the composite with 35% of the coconut plaid volume, Fig. 11.

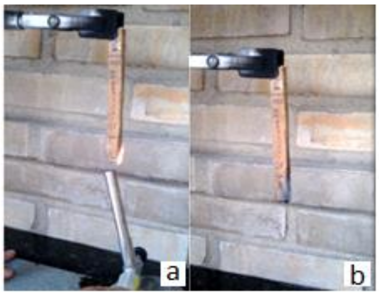

Figure 11. UL-94 V test the CP-35 composite: (a) Flame Application for 10 seconds; (b) The flame goes extinguished.

It is observed in the vertical flammability test that composites with 15% and 25% coconut plaids, then underwent a self-sustaining ignition combustion in the first application of the flame, which prevents the material under analysis are classified according to the UL-94 V.

But during the first application of flame, the set of specimens with 35% coconut plaids, held the flame for 5 seconds, self-extinguished.

However in the second application of the flame (as instructed on standard) is self-sustaining flame in the samples, which also prevents it from being classified according to UL-94 V.

3.2 Ensaio de inflamabilidade horizontal UL-94 HB

Horizontal Flammability Test carried out in the composite with 15% of coconut plaids volume (CP-15), Fig. 12.

Figure 12. UL-94 HB test the CP-15 composite: (a) Flame application for 30 seconds; (b) Sample completely burned

Horizontal Flammability Test carried out in the composite with 25% of coconut plaids volume (CP-25), Fig. 13.

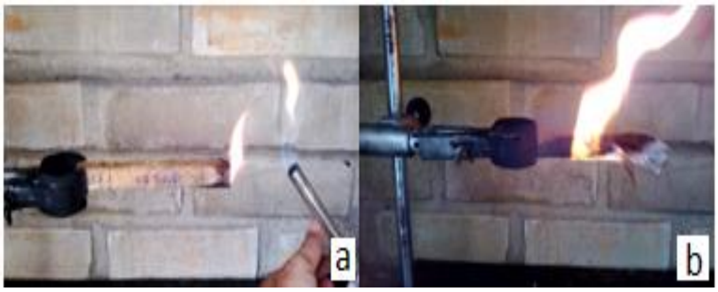

Figure 13. UL-94 HB test the CP-25 composite: (a) Flame application for 30 seconds; (b) Sample completely burned

Horizontal Flammability Test carried out in the composite with 35% of coconut plaids volume (CP-35), Fig. 14.

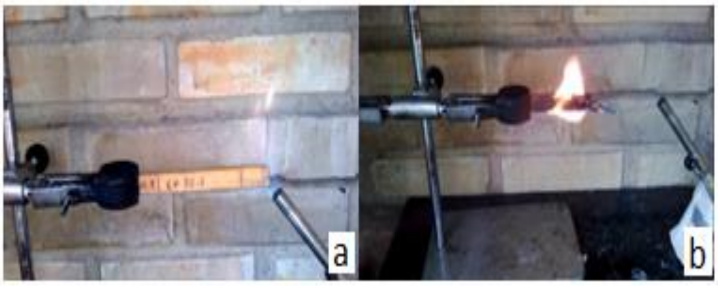

Figure 14. UL-94 HB test the CP-35 composite: (a) Flame application for 30 seconds; (b) Sample completely burned

Analyzing the results of flammability tests horizontal, it can be seen that the average burning time of the samples increases with increasing percentage of the plaids in the composite formulation. As a result, decreases burning rate, hindering the spread of flames and facilitating their extinction. The average burn time and the average speed of burning composites can be seen in Fig. 15.

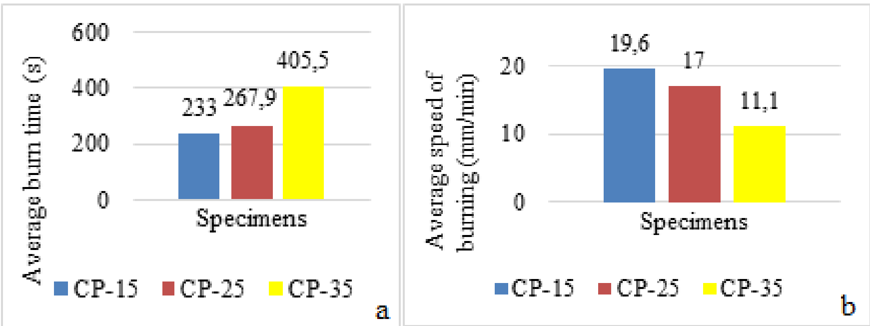

Figure 15. (a) Average length of burns; (b) Average speed of burning of composites.

The higher burn rate (19.6 mm/min) was observed in the composite specimens with 15% of plaid and 85% latex. However, the lower burning speed (11 mm / min) was observed in samples with 35% of plaid and 65% latex.

According to Resolution No. 675-CONTRAN in Brazil require that internal coatings used in the automotive industry have a flame propagation velocity of 250 mm / min. Already in countries with advanced research in the field, this value and 80 mm / min. Compared with these data we can say that the studied composite showed much lower values than required, as the higher average burn rate was 19.6 mm/min, seen in composite samples with 15% plaid.

It was also observed that after the support calls in all samples analyzed, occurred continuous drip of dark liquid, and smoke and soot. Furthermore, it was found that the burning rate and the emission of smoke and dripping are directly proportional to the percentage increase in the latex used in formulating the composite.

A resin system primarily determines the overall behavior of the fire, while the reinforcement has a certain influence on the burning characteristics of the material, although this is less in comparison with the resin. The general behavior of burning a composite, is the sum of the components (resin and fiber), plus any positive or negative interactive effects.

According as Horrocks and Kandola (2005) inorganic fibers fuse or soften while the organic fibers can degrade into small products depending on their thermal stability. According Kandola and Horrocks (2001) cellulosic fibers can ignite at lower temperatures and burn rapidly.

The literature has cited quite often the employment of aluminum hydroxide, which acts as flame retardancy and smoke suppression in polymeric matrices, because of its low cost and low toxicity (Canaud et al., 2001).

Analyzing the flammability of reinforced unsaturated polyester composite fiber pineapple, Ribeiro et al. (2013) found burning velocities (31.47 mm/min) (17.79 mm/min) making use of flame retardant (alumina) in percentage of 20%, and 40% respectively.

Referring to higher burning rate obtained during the horizontal inflammability test (19.6 mm/min), it can be concluded composites analyzed may obtain classification according to UL 94 HB standard, which provides that the maximum burn rate should not exceed 38 mm/min for samples with thicknesses between 3 and 13 mm.

4. CONCLUSIONS

According to this research, it can be said the coconut plaid can be utilized as a reinforcing material in biodegradable composite formulation. And so, give yourself a better destination for this material most often is burned or disposed of improperly in the environment.

According to the results obtained in flammability testing, we can say that the composite (plaid/latex), it is a material that can be used in automotive liners, or even in heated environments. Given that the highest average burn rate found (19.6 mm/min) is far below the (250 mm/min) required by Resolution No. 675-CONTRAN.

Moreover, the composites can be classified according to UL 94 HB standard, which provides that the maximum burn rate should not exceed (38 mm/min) for samples with thicknesses between 3 and 13 mm.

5. REFERENCES

ASTM D 792-98, Standard Test Methods for Density and Specific Gravity (Relative Density) of Plastic by Displacement.

BRASIL.,1986. Ministério das Cidades. Conselho Nacional de Trânsito. Resolução n°. 675 de 08 de setembro de 1986. Dispõe sobre requisitos aplicáveis aos materiais de revestimento interno do habitáculo de veículos e dá outras providências. Diário Oficial da União, Seção 1, página 13534, 09 de setembro de 1986.

Canaud, C., Visconte, L. L. Y., Nunes, R. C. R., 2001. Propriedades Mecânicas e de Inflamabilidade de Composições de Borracha EPDM Carregadas com Negro de Fumo e Hidróxido de Alumínio. Polímeros: Ciência e Tecnologia. v. 11, n. 1, p. 35-40.

Horrocks, A. R., and Kandola, B. K., 2005. "Inflamabilidade e Resistência ao Fogo de Compósitos" em Projeto e Fabricação de Textile C omposites, Long AC, Ed, Editora Woodhead Ltd, Cambridge, capítulo 9, p 330.

Kandola, B. K., and Horrocks, A. R., 2001. "Compósitos" em *materiais à prova de fogo,* AR Horrocks, D. Price, Eds, Woodhead Publishing Ltd, Cambridge, capítulo 6, p 182.

Kiliaris, T., and Papaspyrides, C. D., 2010. Prog. Polym. Sci., 35, p.902.

Ribeiro, L. M., Ladchumananandasivam, R., Galvão, A. O., Belarmino, D. D., 2013. Flamabilidade e retardância de chama do compósito: Poliéster Insaturado Reforçado com Fibra de Abacaxi (PALF). Revista Holos, Ano 29, Vol 1, p.115-126.

Rabello, M., 2000. Aditivação de Polímeros, Artliber Editora Ltda, São Paulo.

Siqueira, B. G., Visconte, L. L. Y., Nunes, R. C. R. et al., 2001. Propriedades mecânicas e resistência à chama de composições SBR/negro de fumo/ hidróxido de alumínio. Polímeros: Ciência e Tecnologia, Rio de Janeiro, v. 11, n. 3, p. 89-93.

Tanaka, Y., and Sakdapipanich J. T., 2001. Chemical structure and occurrence of natural polyisoprenes. In: Koyama T, Steinbüchel A (editors), Biopolymers, Polyisoprenoids. Wiley-VCH, Weinheim, Germany. 2: pp.1-25.

UL-94 HB., 2001. “Test for flammability of plastic materials for parts in devices and appliances”, Underwriters Laboratories.

UL-94 V., 2001. “Test for flammability of plastic materials for parts in devices and appliances”, Underwriters Laboratories.

6. RESPONSIBILITY NOTICE

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