COMPOSITE OF CASTOR OIL EXPANSION RESIN AND INDUSTRIAL RESIDUE FOR THE INSULATION OF THERMAL PIPELINES

Maria Cleide Ribeiro de Oliveira, cleideng@hotmail.com
George Santos Marinho, gmarinho@ct.ufrn.br
Universidade Federal do Rio Grande do Norte, Av. Sen. Salgado Filho, s/n. Lagoa Nova.

Abstract. *New materials for industry are developed considering the following criteria: cost, efficiency, safety and low environmental impact. They are fundamental in the design of new thermal insulation with advantages in terms of energy and the environment. Petrobras currently has about eleven thousand kilometers of pipelines that connect all the regions of Brazil (Transpetro). They carry oil and its derivatives to the most remote parts of the country. These pipelines are thermally insulated with rigid and flexible materials, such as rigid polyurethane foam and glass wool. The thermal insulation of pipelines is needed not only to conserve energy, but also to promote work safety and environmental questions. The union of castor oil expansion resin and industrial residue from the retreading of tires promotes the expectation of obtaining a composite material that results in innovation with efficient thermal performance, lower cost and environmental friendliness. In this study, an experimental procedure was conducted to evaluate the efficiency of the composite by determining thermal properties, namely: thermal conductivity (k), heat capacity (C) and thermal diffusivity (α) using a conductivity meter, and to analyze thermal insulation performance of industrials pipelines to satisfactorily meet technical requirements and environmental aspects and to reduce costs.*

Keywords*: Thermal insulation; Industrial residue; Composite.*

1. INTRODUCTION

The development of pipelines to carry hot or cold fluids has innumerous industrial applications, such as refrigeration and oil and gas distribution lines.

The study of techniques inherent to the transportation of oil and its derivatives through metallic pipelines is widely carried out in the petroleum industry, but there is a constant search for better solutions and methods that minimize maintenance costs and correct flaws or leaks in these pipelines. Their good performance is closely related to their composition and structure. The pipelines that carry oil, gas, fuels and other derivatives can be buried or above ground, or found in deep or ultra-deep waters. The study of the environment where pipelines will be placed establishes the work regime and characterization of the structure and of the materials that they are composed of. This being so, the aggressiveness of the environment, as well as its temperature and pressure conditions, in addition to forces acting on the pipelines, determine the most efficient materials in both the composition and repair of these conduits.

For buried pipelines, walls must be able to resist stresses and deformations inherent to their passage through underground environments, in addition to having the capacity to tolerate soil consolidations, internal pressures and pipeline-soil interaction.

In submersed pipelines, and in deep or ultra-deep waters, in addition to the forces and deformations inherent to the environment, the need for thermal insulation of the tube emerges owing to the considerable temperature difference between the fluid inside the duct and the external environment. Accordingly, pipelines located in deep waters require tubing that has good structural strength and that ensures continuous fluidity of the transported material without suffering the effects of external temperatures. Discontinuities or variations in temperature cause thermal losses and consequent formation of undesirable substances such as paraffin or hydrates that obstruct or even block the tubes, a situation that can be avoided by thermally insulating the duct.

The system known as pipe-in-pipe (PIP) consists of two steel concentric tubes with an annular space between them. This space may contain polymeric foam, inert gas or a vacuum. This conception provides excellent thermal insulation, but its application is impractical at very deep water levels. For these waters there are the so-called “sandwich-ducts”, similar to PIP, but with greater structural strength and their annular space filled by cement or polypropylene (Souza et al, 2007).

This study presents an alternative for filling the annular space using a composite of castor-oil expansion resin and industrial residue as thermal insulation. The conception of this new product aims at developing insulation that meets the thermal properties required for the thermal insulation of ducts, thereby contributing to the preservation of the environment, given that it is composed of a plant-based matrix and discarded tire shavings, classified as urban waste whose recycling is difficult, resulting in their being relegated to sanitary landfills and burning.

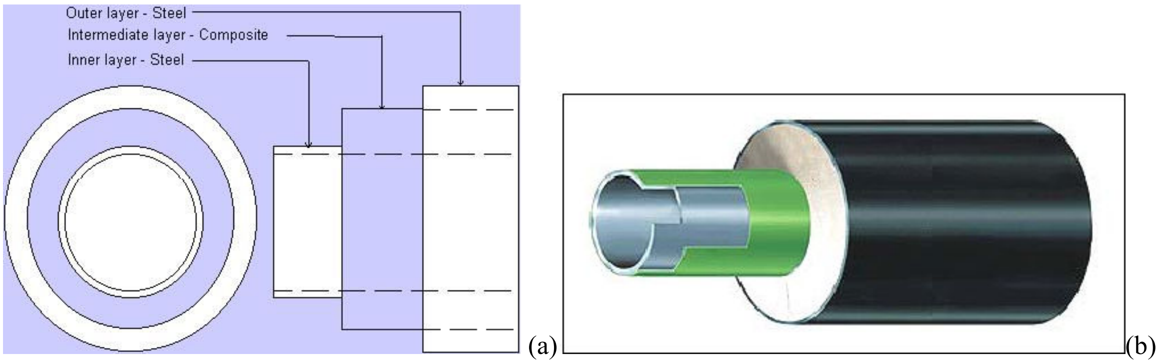

Figure 1 – (a) Pipe-in-Pipe System (Stefen, S. F.), (b) Duct with polypropylene foam (Castello, Xavier, 2005)

The materials that make up this composite are described below. The methodology is then explained, both for the materials and the manufacture of test specimens. Finally, the results and conclusions regarding the performance of the new composite material as thermal insulation are presented.

2. MATERIALS AND METHODS

The materials and experimental methodology used in the composite developed in this study are described below.

2.1. Materials Used

2.1.1 Expansion resin from castor seed oil

Figure 2 – Castor (*Ricinus Communis L.*)

The castor oil plant, typical of tropical regions, is drought resistant and propagated by seeds from which castor oil is extracted. The main component of this oil is ricinoleic acid, which has innumerable applications in agriculture, biomedicine and the automotive, textile and esthetic industries, among others.

The expansion resin used in this study is a ricinoleic acid-based polyurethane bicomponent, as shown in figure 3 (PROQUINOR). These components correspond to a hydroxyl group and an isocyanate that react, resulting in castor oil polyurethane (PU). The reaction promotes an expansion of the product accompanied by an increase in temperature. Table 1 shows the specifications of the resin used in this study. The polyurethanes are mainly in the form of rigid or flexible foams and elastomers with varying densities that generally determine the applications of this material.

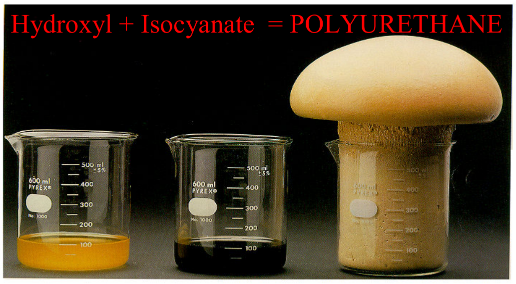

Figure 3 – Castor oil-based resin

Table 1 – Resin specifications

CHARACTERISTICS	SPECIFICATION
Polyol : Prepolymer ratio	1 : 1,63
Time that the mixture is initiating expansion	32 - 35 sec
Evolution time	58 - 65 sec
Density (mean)	30 -70 Kg/m3
Water absorption (mean)	0,48 %
Dimensional stability (mean)	0,098 %
Maximum reaction temperature (mean)	80ºC

2.1.2. Discarded tire shavings

In Brazil the annual reported production of tires is around 40 million units and it is estimated that at least 25 million are discarded per year (Miranda, 2006). In Natal, Brazil alone, where the present study was conducted, 20,449 tires are discarded monthly (Lopes et al, 2002). These figures reflect the impact caused by the discarding or burning of tires.

Availability of used tires:

USA: 250 million/year
Japan: 80 million/year
England: 27 million/year
Canada: 26 million/tear
South Africa: 7 million/year
São Paulo: 5.4 million/year

Figure 4 – Availability of used tires worldwide (Cunha et al, 2000, Kamimura, E., 2002)

The discarding of this urban waste is a worrisome environmental problem that has been affecting society for years. Concern about the environment motivated the National Environmental Council (CONAMA) to regulate, through Resolution no. 258, of 26 August, 1999, the discarding of used tires, assigning this task to the tire dealers. Among other questions, CONAMA decreed that, as of 1 January, 2005, for every four new tires produced in the country, tire manufacturers and importers were obligated to safely dispose of five used tires and for every three rethreaded tires imported, the importers had to dispose of four used tires (CONAMA, 1999).

Recycling tends to be the best option for used tires, either restoring them to their original state or as shavings or powder. The latter two states have given rise to innumerable studies seeking applications for this industrial residue.

The residue used in the experiments was in the form of shavings or fibers from the rethreading process, representing the possibility of recycling the tires, but not enough to prevent the discarding of tires in landfills, empty lots, rivers, lakes and the sea, or the release of CO^2 and other components into the atmosphere.

Rosa et al (2007), Meneguini (2003) and Marques et al (2006) studied the incorporation of tires into composites of concrete and plaster of Paris for use in the construction industry. Oda (2001) and Pinheiro (2004) researched the use of tire rubber in asphalt mixtures for use in pavement.

To characterize shavings or fibers, photographs and micrographs associated to granulometric composition were taken to enable configuration analysis of the particles used in the experiments. The photographs were taken with a 7.2 MP digital camera and the micrographs with a light optical microscope, as shown in figure 5. ABNT (Brazilian Association of Technical Norms) sieves were used for granulometry (figure 6).

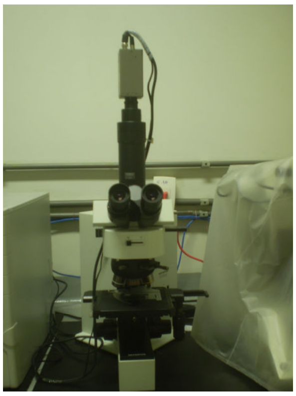

Figure 5 – Optical Microscope

Figure 6 – ABNT sieves

2.2. Composite sample preparation

To characterize the composite of castor oil expansion resin and tire shavings, test specimens molded into PET bottles were manufactured at compositions of 0 %, 5%, 10% and 15% of residue added to the mixture. A mechanical mixer was used to homogenize the mixture, as shown in figures 7 and 8. Initially, the tire rubber was mixed with the isocyanate component inside the mold and agitated for two minutes to ensure that the tire residue was mixed with the resin. The hydroxyl component was then added, homogenizing the mixture until the temperature of the material increased and it acquired a cream-like consistency.

Figure 7 – Isocyanate and residue mixture

Figure 8 – mixture is initiating the process of expansion

Homogenization is interrupted when the mixture is in a cream form and the process of evolving the material is initiated. This expansion occurs freely until the end of the reaction between the two components (hydroxyl and isocyanate) giving rise to castor oil polyurethane, now added with tire rubber.

After a period of at least 12 hours, the test specimen is demolded and the PET plastic is removed, resulting in the final test specimen shown in figure 9.

There were 12 repetitions of this experimental procedure to obtain 3 samples of each percentage to be tested, enabling the determination of mean results.

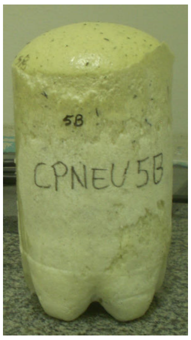

Figure 9 – Test specimen

2.3. Thermal properties of the composite

To analyze the thermal performance of the material an experimental procedure was carried out to determine the thermal properties: thermal conductivity, heat capacity and thermal diffusivity. Accordingly, the Quickline-30 thermal properties analyzer (figure 10) was used after an orifice was made in the test specimen for insertion of the device's probe (figures 11 and 12). Three readings were taken for each sample.

Figure 10 – Quickline-30 thermal properties analyzer

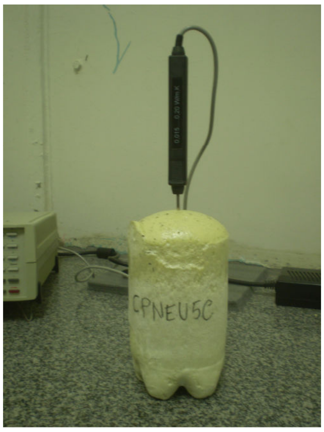

Figure 11 – Test specimen and Quickline-30 probe

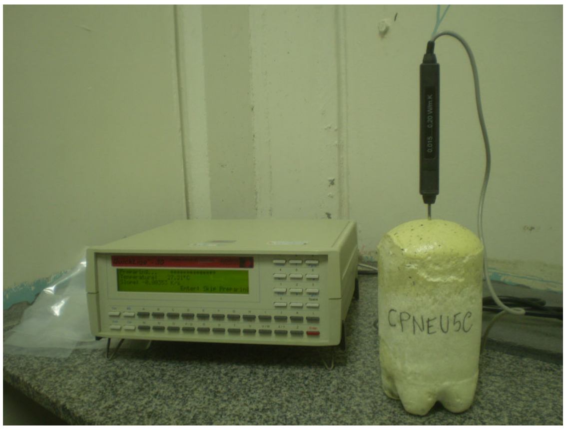

Figure 12 – Measurement of thermal properties

3. RESULTS AND DISCUSSIONS

3.1. Characterization of tire rubber

3.1.1. Fiber morphology

Figure 13 shows the images obtained from photographs and micrographs, where the format and arrangement of the fibers can be visualized, as well as the appearance of the surface area of the shavings.

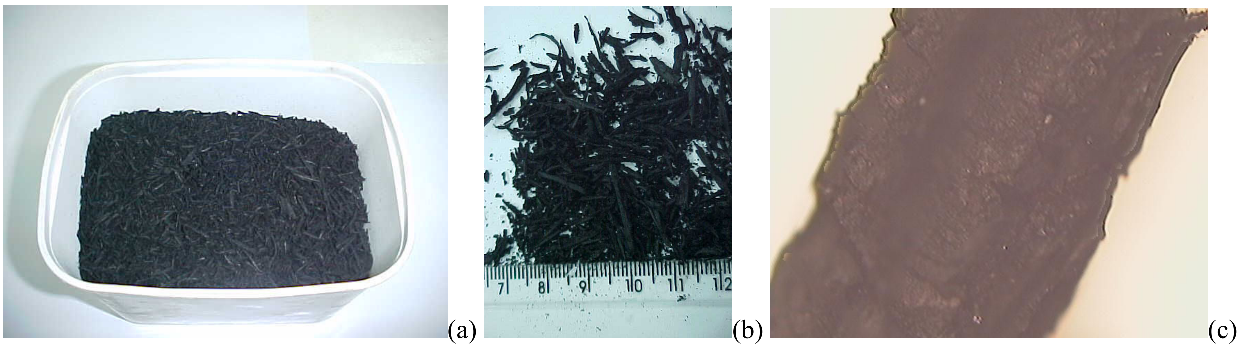

Figure 13 – (a) (b) Shavings (fibers) from discarded tires (c) Optical micrography of the residue

3.1.2. Granulometry

Table 2 illustrates the granulometric composition of the residue, showing fiber arrangement in the sieves. The greatest concentration was in sieve no. 16, indicating that the residue analyzed is composed of particles predominantly larger than 1.2 mm (between 0.6 and 1.2 mm) and a small amount of fine particles.

Table 2. Tire shavings granulometry

SIEVES		% RETAINED	ACCUMULATED % RETAINED
Nº	MM		
4	4.8	1.50	1.50
8	2.4	7.76	9.26
16	1.2	58.82	68.08
30	0.6	19.48	87.56
50	0.3	7.90	95.46
100	0.15	3.62	99.08
200	0.075	0.92	100.00
	< 0.075	0.00	100.00

3.2. Thermal properties of the composite

The mean values of the thermal properties shown in item 2.3 are presented below:

Tabela 3. Thermal properties of the materials

Material	**Thermal Cond**	**Thermal Cap.**	**Thermal Diffusivity**
	(W/mK)	**E+6(J/m^{3}K)**	**E-6 (m^2/s)**
0 % tire shavings	0.0333	0.0828	0.4019
5 % tire shavings	0.0334	0.0836	0.4012
10 % tire shavings	0.0351	0.0962	0.3671
15% tire shavings	0.0352	0.1017	0.3462

The data in table 3 show that thermal conductivity values varied minimally, always fluctuating around 0.030 W/m.K, the conductivity of the polyurethanes commonly used in duct insulation.

However, heat capacity increased considerably as residue was added to the composite, showing that the more tire rubber that is added to the composite material the higher heat capacity will be. Higher heat capacity means that the composite is more resistant to temperature changes.

4. CONCLUSIONS

The images obtained with photographs and micrographs show that the resin (matrix) tends to easily adhere to rubber fibers owing to the coarse surface of the tire shavings.

Granulometric composition demonstrates that the most of the residue particles are larger than 1.2 mm and smaller than 4.8 mm.

Analysis of thermal properties shows that the characteristics of the composite proposed in this study are favorable for use in the thermal insulation of pipelines. The advantages of this material are higher heat capacity, making the composite more resistant to heating, and environmental friendliness.

5. ACKNOWLEDGEMENTS

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