ANALYSIS OF SOUND ABSORPTION COEFFICIENT OF COMPOSITE POLYURETHANE CASTOR OIL AND OF INDUSTRIAL WASTE

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Abstract. Acoustic materials are included in today's world, especially in the context of environmental comfort and sound isolation. However, at each moment, new applications and the need for improvement of properties of existing materials. Among the materials stand out acoustic insulation and sound-absorbent acoustic designs that meet in different aspects. The sound insulation is used when you want to prevent sound waves from spreading from one environment to another. They are heavy materials with high densities, such as concrete and glass. Sound absorbers are used to treat acoustic or acoustic environments, reducing the reflection of sound waves within an environment. Constitute porous materials, polyurethanes and "foam" open-cell or fibrous materials such as glass wool and rock wool. In this paper, we analyze the sound absorption coefficients in a frequency range that varies from 0 to 1000 Hz, the composite polyurethane castor and industrial waste in relation to the castor oil polyurethane and commercial sound absorbents. In the experimental procedure are presented specimens used in this proof composite material, produced from a hard resin oil from the seed of castor (Ricinus communis) and fiber from waste tires, and samples of castor oil and polyurethane, glass wool and rock wool. To obtain the rates of absorption of sound samples, we used the impedance tube method implemented by noise transfer function developed in the laboratory of acoustic testing of INMETRO.

Keywords: composite, acoustic, polyurethane

1. INTRODUCTION

In factories and industries generally or in any space where people are exposed to excessive noise, acoustic comfort is a factor critical to health and quality of life of users of these environments.

Since the resolution nº 1 of CONAMA of January 23, 1986, have emerged standards and actions to control excessive noise that interfere in health and welfare of the population. Thus, programs are designed to combat noise pollution in all its forms. The Program National of Education and Control of Noise Pollution - Silence - was established by CONAMA through Resolution nº 2 of March 8, 1990 and is coordinated by IBAMA that promote courses, campaigns and further incentive programs to reduce the noise by machinery, equipment, engines, etc., for use in industry.

Noise is an acoustic phenomenon that causes a hearing sensation unpleasant to the listener. High levels of urban noise are responsible for problems of sound pollution undesirable and common in large cities.

This question motivates the inclusion of building elements or materials that promote improvements in living conditions and comfort. At every moment, innovative products are developed in order to meet technical demands in relation the aspects commercial, economic and environmental.

The ability of sound absorption of materials is an essential property in relation to the comfort of acoustic environments and hence the levels of comfort are required in residential buildings, commercial and industrial.

The comfort of an acoustic environment involves the concepts of isolation and acoustic treatment. The acoustic isolation is different of the acoustic treatment, too called of acoustic absorption.

The acoustic isolation is the confinement of an environment through acoustic barriers. The acoustic insulating materials can prevent or at least hinder the passage of noise from one room to another. These materials are usually dense as concrete, steel or glass.

The treatment, also called acoustic conditioning, is the reduction or elimination of reverberation levels, ensuring a good level of speech intelligibility in an environment through sound absorption. Generally, sound absorbing materials are lightweight (low density), fibrous or open pores as carpets, fibers and polyurethanes. Gonçalves et al (2008) highlight the acoustic comfort as one of the key aspects to ensure quality of life for people in their workplace, showing noise control as a measure of prevention of occupational diseases as progressive loss of hearing.

According to Fernandes (2009), the sound is a vibration phenomenon resulting from fluctuations in air pressure. The human ear can perceive a considerable variation in air pressure (Gerges, 1992).

Halliday (1996) states that the sound spreads out uniformly in all directions, reducing its amplitude as it moves away from the sound source in free field conditions. When encountering an obstacle, part of the sound is reflected, another part is absorbed and an another part of the sound is transmitted through the obstacle. The amount of sound reflected, absorbed and transmitted depends on the wavelength and amplitude of the sound and the properties of the material making up the obstacle.

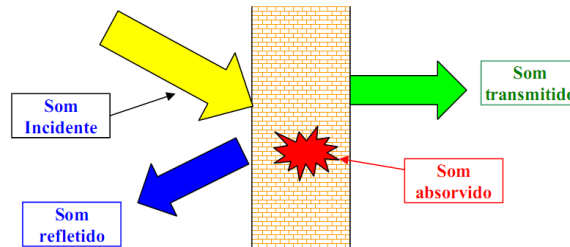Figure 1 represents these quantities sound when confronted with an obstacle.

Figure 1 - System sound propagation

Thus, we can define the sound absorption coefficient in equation (1):

$$\alpha = \frac{acoustic\ energy\ absorbed}{acoustic\ energy\ incident} \tag{1}$$

The value of sound absorption coefficient is always positive and varies between 0 and 1.

This paper presents a composite material made from expansive resin of oil castor and industrial residue. This innovative product consists of scraps of waste tires, recognized worldwide as urban waste, dispersed in a polyurethane matrix of plant origin, a renewable source and natural.

This research presents a comparison between a composite consisting of polyurethane matrix derived from castor oil and zest of scraps tires and acoustic absorbent synthetic such as polyurethane of petroleum, fiberglass and rock wool in regard to the absorption sound, obtained from impedance tube.

2. MATERIALS AND METHODS

Following are the materials and the experimental methodology employed in this work.

2.1. Materials

2.1.2 Polyurethane Resin expansive

The polyurethane derived from castor seed oil was obtained starting from an expansive rigid resin supplied by the company PROQUINOR - Northeast Chemicals Inc. under the trade name RESIN RESPAN ® D-40.

As can be seen in Figure 2, the resin is a two component polyurethane-based product of ricinoleic acid and its derivatives.
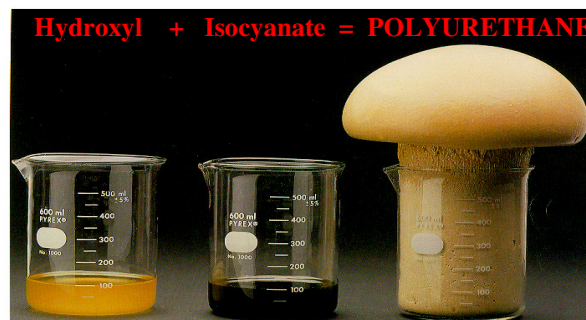

Figure 2 – Rigid resin expansive (PROQUINOR, 2007)

Hydroxyl molecules (polyol), lighter in color in Figure 2, react with the isocyanate group, of a darker color. The action of chemical catalysts promote expansion and the expansion of the solution accompanied by an increase in temperature, resulting in the polyurethane.

2.1.2 Zest of scrap tires

The residues used in this study are in the form of fibers obtained from the tire retreading process, as shown in Figure 3.

Figure 3 – fibers of tires retread

2.2. EXPERIMENTAL METHODOLOGY

The methodology of this study was adopted in order to measure the absorption sound index of the composite with polyurethane oil castor matrix and fibers of tires.

2.2.1 Preparation of the composite

The characterization of the composite derived from castor oil and tire shavings were fabricated specimens in the compositions 0%, 5%, 10%, 15% and 20% of residue added to the mixture. The specimen without the residue (0%) was used as a reference.

A mechanical mixer was used to homogenize the mixture. 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.

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 isocyanante) 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 4.
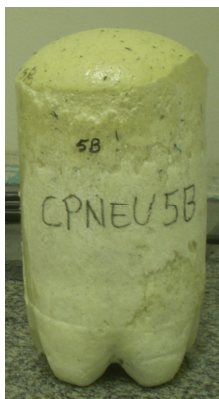

Figure 4 – Test specimen

2.2.2 Impedance tube method for measuring the index of Sound Absorption

The procedures of the impedance tube method for measuring the rate of sound absorption are described in ISO 10534-1 and ISO 10534-2. The absorption results are obtained by normal incidence of plane waves in the direction perpendicular to the samples. To establish a sound absorption coefficient of a given material, the pipe should be used in conjunction with a signal generator, a filter and a level meter. (Oliveira, 2005)

The sound absorption coefficient was obtained in this work by the impedance tube method of sound transfer function described in International Standard ISO 10534-2:1998.

The impedance tube and the whole apparatus is tube waves B & K 4002, shown in Figure 6, integrated to the data system, developed at Laena - Testing Acoustic Laboratory - belonging to INMETRO - National Institute of Metrology, Standardization and Industrial Quality Located on the campus of Xerém in Duque de Caxias / RJ.

This method uses a microphone located in the center of the cross section of the tube, as shown in Figure 5, which can be moved freely along its length. The position of capturing sound pressure inside the tube is determined by a probe, a car and a ruler with markings, as depicted in Figure 6. At the probe tip was adapted an electret microphone ¼ ". Measurements are made in P1 and P2 sequentially. The measurement system presented in figure 7, called CMF-22, includes an audio amplifier 2x70W compact, signal conditioning for microphones and converters A / D and D / A high-resolution.

The measurement control was made by software "Monkey Forest" by applying the technique of sine sweeps (MASSARANI et al, 2008).
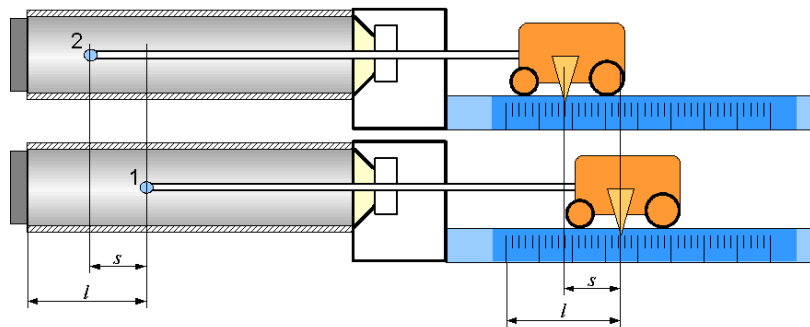

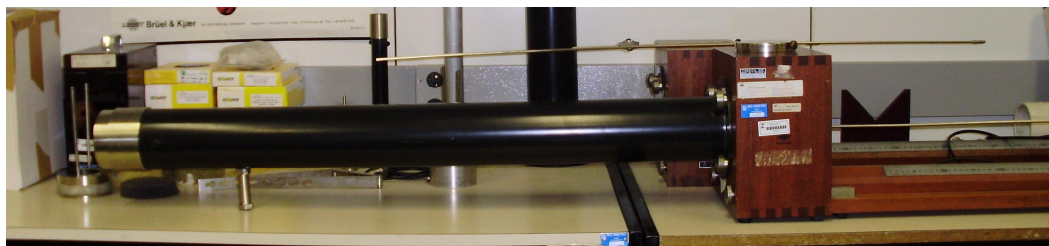Figure 5 - Move of the microphone along the impedance tube

Figure 6 - Impedance Tube

Figure 7 - System data

The absorption sound index are obtained for a frequency range contained between 0 Hz and 1000 Hz, limited by the cutoff frequency of the tube obtained from its length and diameter.

The specimen, shown in figure 8, has a cylindrical shape with a diameter of 100 mm consistent with the samples prepared previously, with 20 mm in thickness, as can be seen from figure 9.
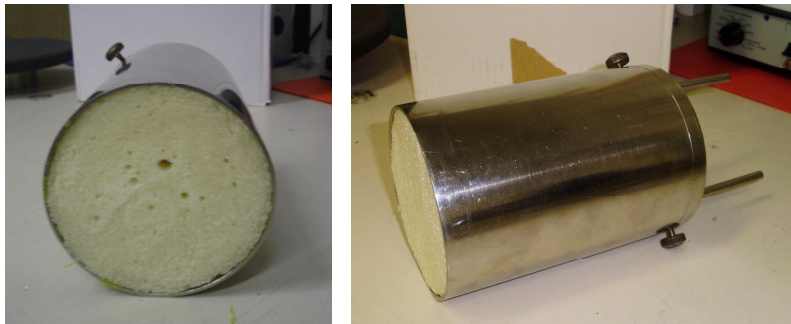
Figure 8 - sample holder with sample

Figure 9 - Test sample absorption

2.3. RESULTS AND DISCUSSION

The sound absorption levels measured by impedance tube method are presented through graphs, obtained from the software "Monkey Forest", developed by INMETRO.

In these graphs, the horizontal axis consists of the frequency 0-1000 Hz and the vertical axis values corresponding to sound absorption, ranging from 0 to 1, where zero corresponds to rigid materials with absorption of 0% and the 1 are absorbent materials with absorption of 100%.

Through these graphs shows the results for composites, and polyurethane castor oil, fiberglass and rock wool. For this purpose, we use the following tags: CP0 - Polyurethane castor; CP5 - composite polyurethane obtained from castor oil and 5% fiber from waste tires; CP10 - Composites with 10% residue; CP15 - Composites with 15% of residue, CP20 - Composite fiber with 20% tires; CPP - Polyurethane oil from a source; CPLV - glass wool and CPLR - Rock wool.

In figure 10 we observe the sound absorption of PU castor compared to commercial sound absorbents. In this graph, we can see that the polyurethane derived from castor oil seed absorbs up to 5% of sound waves, having a lower performance compared to other materials presented.
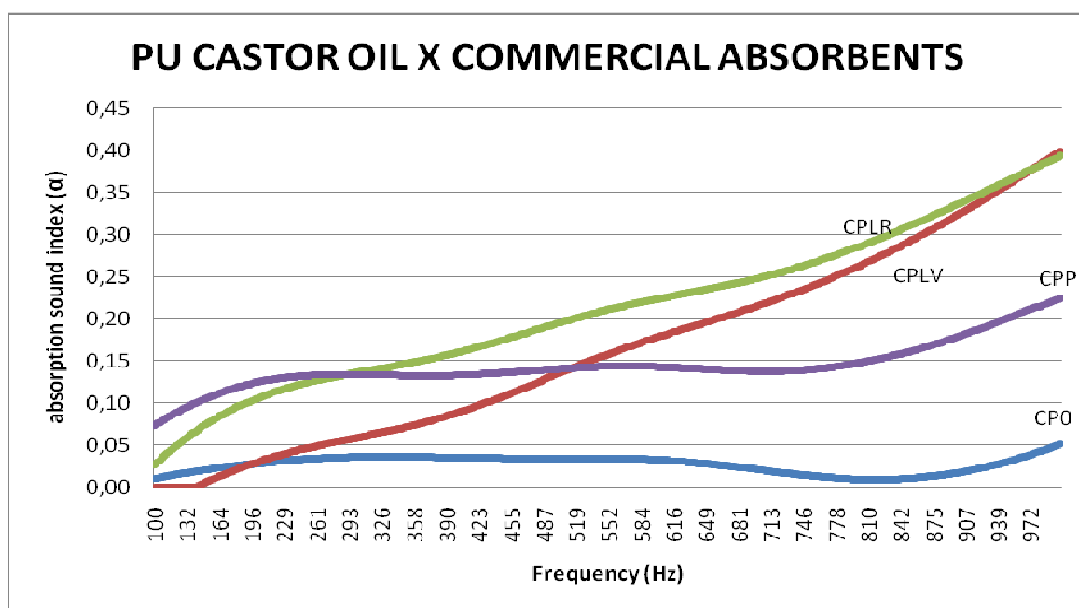

Figure 10 – Graph of sound absorption PU Castor oil (CP0), PU petroleum (CPP), fiberglass (CPLV) and rock wool (CPLR)

The polyurethane of petroleum origin is among the castor oil PU and mineral fibers that come to absorb 40%, as the case of rock wool. This result can be explained by the rigid structure of closed pores of PU castor tested. Polyurethane oil used in the test design was flexible with open pores showing sound absorption exceeding 20%. The open pores characteristic of flexible polyurethane, and the interstices or spaces in the existing structure of the mineral fibers promote better sound absorption due to twisting created by these cavities, which transform sound waves incident on the material in thermal energy.

Figure 11 shows the performance of the composites compared to the polyurethane of castor oil. And this chart we see that with the exception of the composite with 20% residue, which was very close to the behavior of castor oil polyurethane, other composites showed better results compared to the absorption of PU castor with emphasis on the composite with 15% waste , Who came to absorb three times more than the other materials in the vicinity of 1000 Hz.
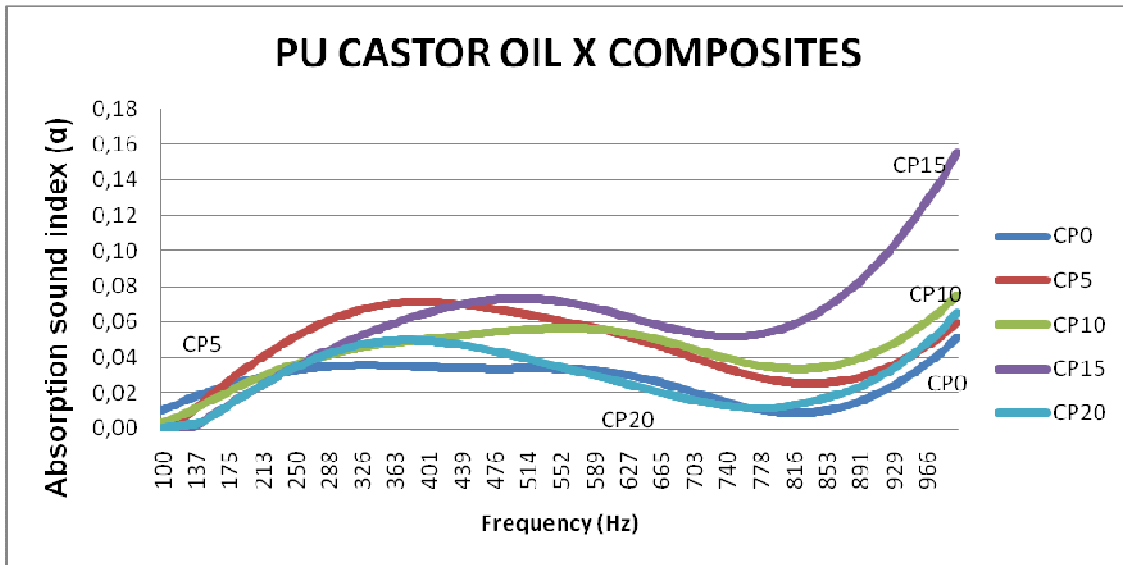

Figure 11 – Graph of absorption sound of the castor oil polyurethane and composites

In Figures 12 and 13 highlight the composite with 15% fiber from waste tires, which shows better result against the other compositions of the material developed in relation to the mineral fibers to polyurethane and castor oil. The graphs show that the composite with 15% of waste has sound absorption coefficient, higher than PU castor oil, about 15%, with only about 7% lower than PU oil. This leads us to assert that the performance of a new composite material using a flexible polyurethane can be equivalent or even superior to the PU oil.
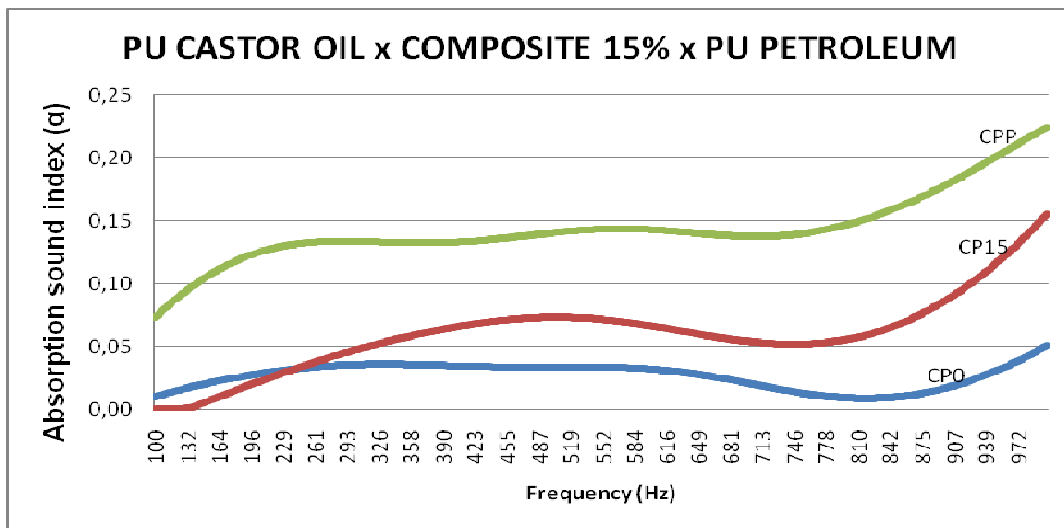

Figure 12 – Graph of absorption sound of the composite with 15% of residue (CP15), PU castor oil (CP0) e petroleum (CPP)
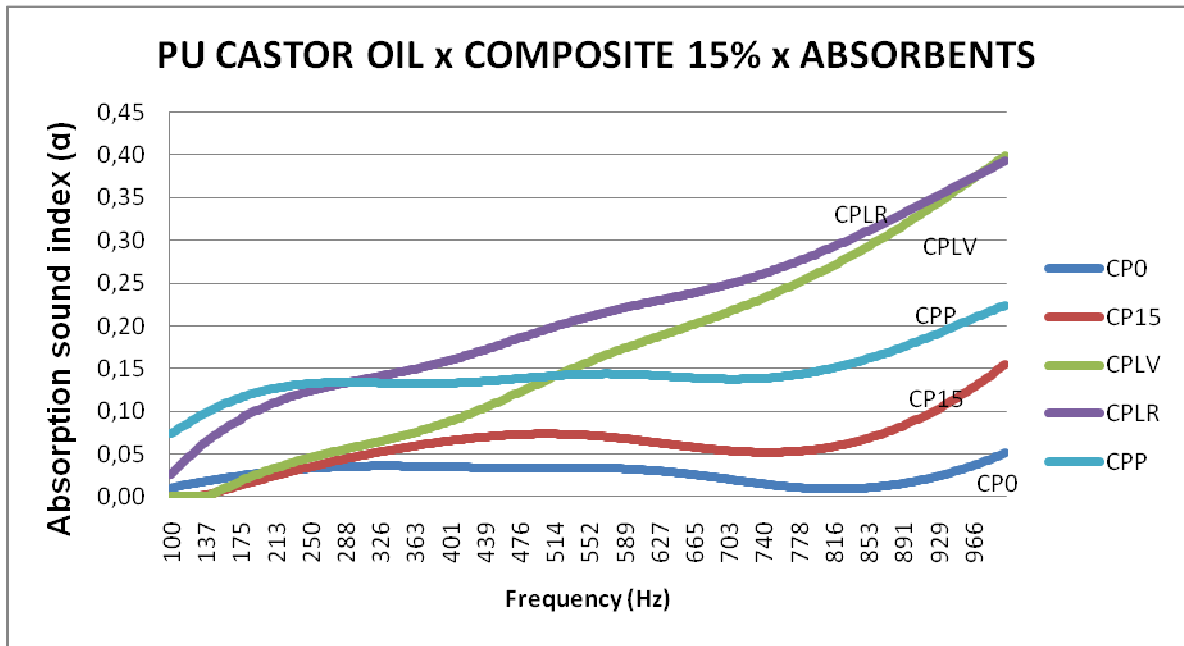
Figure 13 – Graph of absorption sound of the composite with 15% of residue (CP15), mineral fibers (CPLV e CPLR), PU castor oil (CP0) e petroleum (CPP)

We attribute the better performance of the composite with 15% of the waste, the relationship between the interfaces of fibers and resin waste tires expansive, which possibly resulted in greater interconnection between pores and the consequent increase of tortusiodade inside the material.

Figure 14 shows all the materials analyzed together in one graph showing the development of the frequency of sound absorption over the frequency range tested.
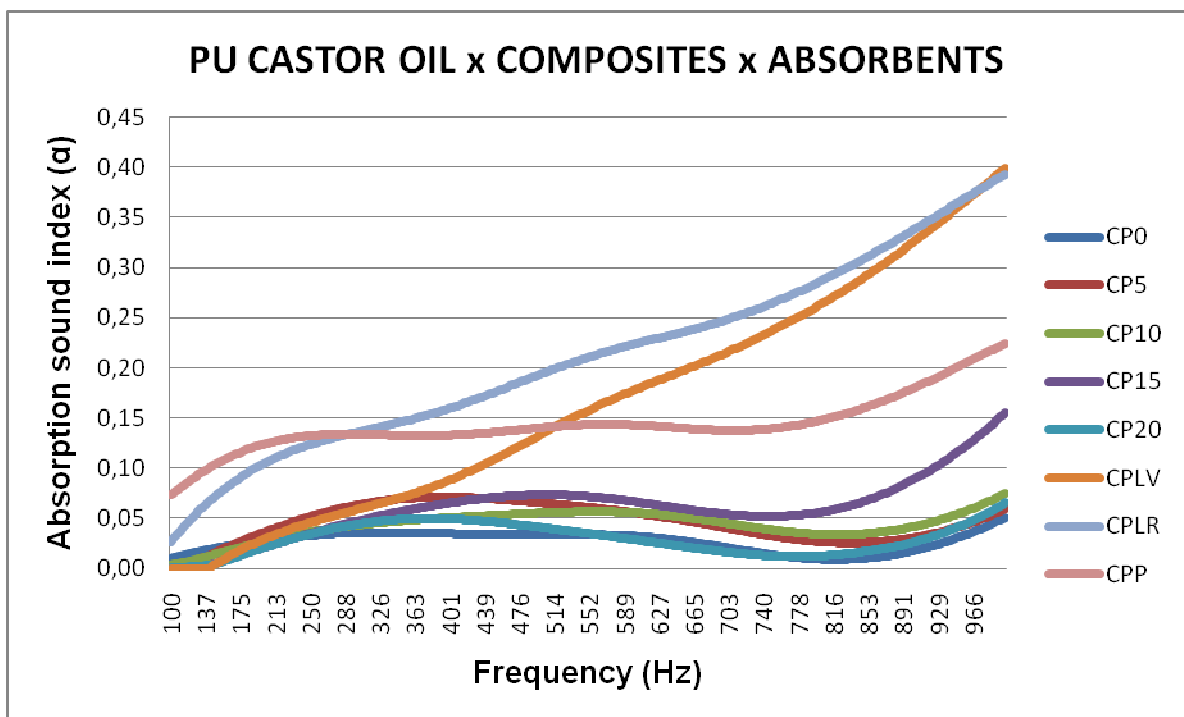

Figure 14 – Graph of absorption sound of the composites, mineral fibers, PU castor oil and petroleum

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