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Study of a sustainable solution: A methodology to analyse the vibrational absorption comparing PET wool and glass wool

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ABSTRACT

This work aims to expose a methodology from a vibrational perspective for a comparative analysis between different materials. Also, it proposes the use of the results to substantiate the replacement of the currently used materials for vibrational absorption in structures by ecologically sustainable materials. For this, polyethylene terephthalate (PET) wool was selected, which is a material produced from a recycling process of PET mainly found in disposable bottles, in detriment of glass wool, which is largely used in industry. The two materials can be used for thermal, acoustic and vibrational absorption in structures. This paper seeks to

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compare quantitatively and qualitatively the vibrational characteristics, such as the transmissibility index of PET wool and glass wool. The methodology involved the analyses of the data obtained through a setting with two known masses, eight known springs, a shaker, a signal generator, a power amplifier, two accelerometers and a sample of each studied material with the same geometry. Data was captured using Catman Easy software and treated with MatLab. From this analysis, the vibrational characteristics can be added to the other properties of PET wool and contribute to the greater use of it in industrial and domestic levels.

Keywords: Vibration, Sustainability, PET wool.
I-INCE Classification of Subject Number: 46

1. INTRODUCTION

Sustainability, according to Boff (2012), is the act of conserving natural capital, allowing it to be refined and enriched for future generations. Feil and Schreiber (2017) define: "Sustainability is a term that expresses concern about the quality of a system that relates to inseparable integration (environmental and human), and evaluates its properties and characteristics, covering the aspects environmental, social and economic."

In this bias, waste is one of the key issues that distances humanity from reaching an ideal level of sustainable development. In this scenario, the use of disposable products, especially made of Poly-Ethylene Terephthalate (PET), is antagonistic to the sustainable, as these have a very long degradation time compared to the shelf life of the products.

In this perspective, the Brazilian government issued Decree 7,746, dated June 5, 2012, which addresses, among other issues, the practices of sustainable national development (BRAZIL, 2012). The Decree reinforces a United Nations (UN) warning regarding environmental degradation caused by the irresponsible disposal of garbage.

In order for the life cycle of the PET to be more sustainable, it is necessary that the disposal is not made in an uncontrolled manner (OLIVEIRA, 2013). One of the possible ways to mitigate this problem is the industrial use of PET in the form of wool (TRISOFT, 2017) besides the initial purpose, that is, the use as simple packaging (MATEUS and MOREIRA, 2007). In addition, in the recycling chain of PET, the human factor is inserted, which corroborates for a positive social impact, since it contributes to the valorization of people who deal with recyclable waste as formal work (DAGNINO and JOHANSEN, 2017).

One of the applications of PET wool is based on its physical properties of vibrational absorption (TRISOFT, 2017). Over the years, other characteristics have been discovered, such as: thermal and acoustic insulation (MARQUES, 2018).

With this perspective, the main objective of this work is to develop a methodology for the characterization of vibrational insulators and make possible the technical comparison for a possible safe substitution of materials already used by new ones with great potential of use. The methodology was developed to validate and expand the use of PET wool over glass wool, which is already widely used. In addition, it should be noted that the methodology developed allows the expansion of the application of PET wool and other potential technologies, which contributes to the preservation of the environment and technological advances.

2. LITERATURE REVIEW

Vibrations are physical oscillations of a system that has a mass on an equilibrium position. Such vibrations begin at the instant that an external force excites an element of inertia which is displaced from its equilibrium position. When leaving its equilibrium position the system oscillates and if there is no non-conservative element to dissipate energy, the system will oscillate forever (KELLY, 2012).

A vibrational system consists basically of an inertial element that is capable of storing kinetic energy, elastic elements that can store potential energy and some element known as non-conservative that is able to dissipate energy from the system. The generic equation to represent any vibrational system can be written as:

$$Mx'' + Cx' + Kx = F$$

Where M is the matrix of masses or inertias, C is the damping matrix, K is the stiffness matrix of the system, F is the vector of forces imposed on the system, x is the vector of positions, and x 'and x' are the first and second derivatives of x, respectively (RAO, 1995).

If the vibrations are caused by a periodic external force, they are called harmonics, otherwise they are transient. There is also the difference between free vibrations which are the free response of a system after suffer an excitement and be left free. Forced vibrations is when the system is imposed on an excitation source for a longer time (KELLY, 2012).

The vibrational question is of paramount importance within the context of the sciences in general, especially within Mechanical Engineering (SINGIRESU, 1995). The question of vibrations is vitally important in mechanical and aeronautical projects, mechanical maintenance, machine performance and engines, etc. In addition to the concern for the health of people who are being subjected to vibration, it is also necessary to consider equipment that can suffer damage. To prevent impacts of vibrations may be used vibrational insulation (MEIROVITCH, 2001).

The NR 09 defines: "Employers should adopt preventive measures and control exposure to mechanical vibrations that can affect the safety and health of workers, eliminating the risk or, where arguably there is no technology available, reducing it to the lowest possible levels . "(FUNDACENTRO, 2013).

Mechanical vibrations are also considered by NR 12 and NR 15, besides being regulated by FUNDACENTRO, in Occupational Hygiene Regulations 09 and 10. These standards establish the levels of vibrations, indicating acceptable limits and insalubrity.

2.1 Vibrational absorption

Kelly (2012) defines "Vibration isolators are used to protect structures from excessive forces developed in the operation of rotating machinery." These forces are partially absorbed by the insulation, which reduces the amplitude of the forces, being important especially when dealing with harmonic forces (Meirovitch, 2001). Two materials, rock wool and glass wool, have been widely used as insulators for structures, but PET wool is a new material that can replace these materials.

2.2 Glass wool and PET wool

Glass wool is a material widely used as thermal and acoustic insulation, not only in civil constructions but also in industries, aviation, among other sectors. It is made from a high-speed process where a mixture of sand, recycled glass and binder is heated to a temperature of 1400 ° C, undergoes a centrifugal acceleration and is forced to pass through small holes. Thus, the obtained glass in the heating of the components is converted into fibbers, and the wool is obtained by joining several filaments with the help of a resin (KNAUF INSULATION, 2017).

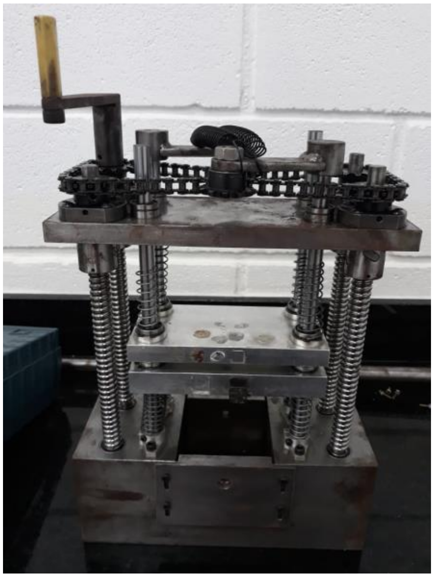
PET wool is obtained by a process of recycling products made of polyester which are milled to become small grains. As in glass wool, there is also a heating of the raw material, but lower, reaching a temperature around 160 ºC. The material is then extruded, pressed to pass through small holes, obtaining the yarn form, which is grouped, forming a "mat".

Both wool are considered sustainable, but the process of manufacturing glass wool uses more chemicals and spends more energy to heat the raw material, and PET wool is a better choice in this regard, since it has in its composition a most recycled and recyclable materials. In addition, tailings from their manufacturing process can be reintroduced at the beginning of the production chain, which greatly reduces the production of waste from the process. Another disadvantage of glass wool compared to that of PET and the fact that its handling is dangerous, since if handled without proper protection the fiberglass can irritate the skin or even the lungs of the operator.

3. METHODOLOGY

The method is based on the use of a platform consisting of four bars that support two metal plates, the lower one with a mass of 750 g and the upper one with 600 g, which are free to translate in the supports. To support the plates were used eight springs, four below and four above them. The lower springs have a spring constant of 1313,84 N / m which is the same for the upper springs. The excitation of the system was made by a shaker, which came in contact with the lower plate.

Two accelerometers captured the signals from the system, one of the company PCB Piezotronics model 353B04 with a sensitivity of 9.75 mV / g and another of the KISTLER model 8632C10 with a sensitivity of 488.8 mV / g, each one on a plate, and using the adapter module MX-410B data were transferred and analyzed on a computer with *Catman Easy* software. They were processed and analyzed. The system was modeled as shown below:



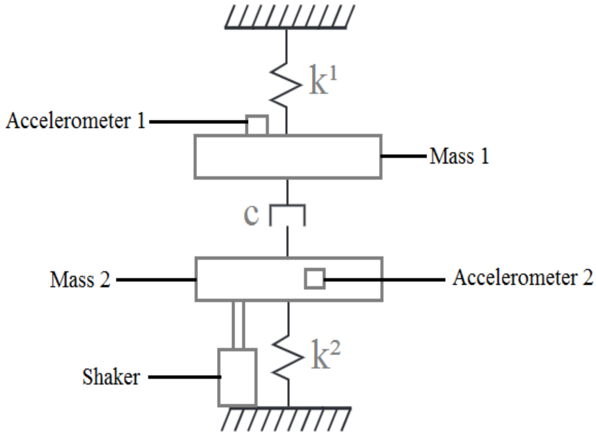


Figure 1: Set for vibrational analysis. Figure 2: Schematic for vibrational analysis.

The tests were started with a sample of 45mm thick black PET wool positioned between the masses and the shaker was driven at a frequency of 5Hz. The working frequency of the shaker was varied, always waiting for the system to achieve steady state, up to a value of 1 kHz. The system was then shut down and the accommodation time was collected. The wool was replaced by glass wool of the same thickness and the process was repeated.

The data were collected with the aid of Catman Easy software and the analysis aimed to compare the damping ratio, the natural frequencies and the transmissibility indexes between PET and glass wool. The damping ratio is an important parameter for the vibrational analysis, since it determines the type of regime that the system operates. Regimes can be underdamped, critically damped or overdamped and parameter can be written as:

$$\xi = \frac{C}{Cc} (1)$$

Where C is the damping of the system and Cc is the critical damping of the system, which in turn is calculated by:

$$C_C = 2m\omega_n (2)$$

One of the ways to find the damping ratio is to observe the overshoot (Mp) that the system obtains after ceasing external excitation and use the equation below:

$$Mp = 100\%. e^{-\xi\pi} (3)$$

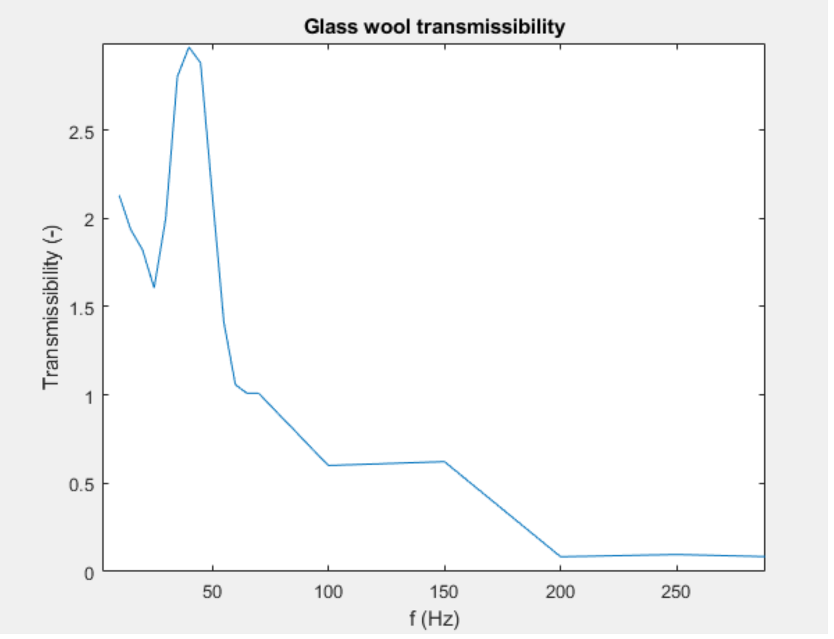
In the case of the specific system, using the following equation it is obtainained the damping coefficient of wool and the relative transmissibility of wool where Xs and Xi are the upper and lower maximum amplitudes, respectively:

$$C = \xi \ 2m \ \omega_n (5)$$

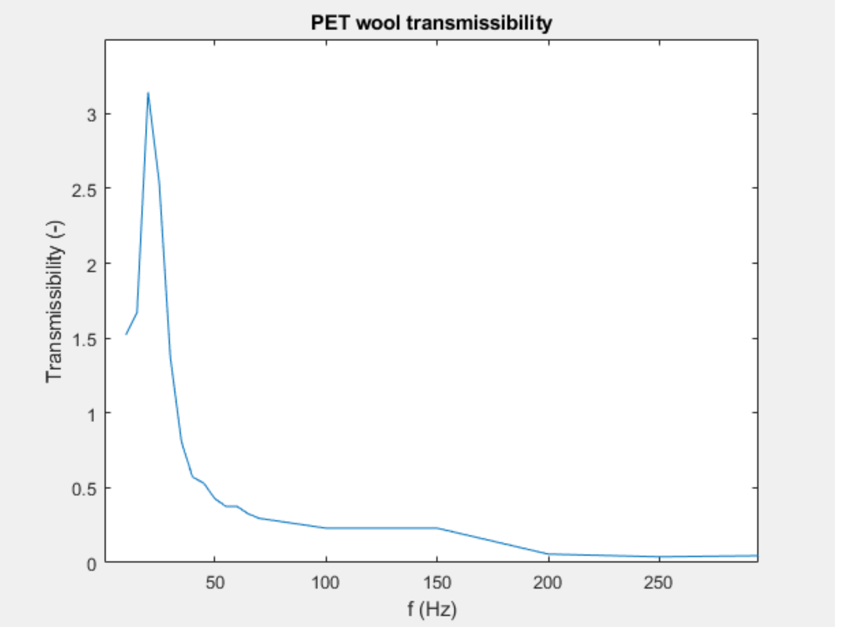
$$TR = \frac{X_s}{X_i} (6)$$

4. RESULTS

By observing the amplitudes of the input (shaker excited) and output (top plate) waves of the system and using formula (6), it was possible to find the relative transmissibility of the materials for each analysed frequency. Relative transmissibility is important for vibrational analysis because it relates the amplitude of the input signal of the system to the output amplitude, in other words it shows how much the material is effectively damping. After calculating the relative transmissibilities, a graph was plotted for each material in order to better observe the behaviour of these data.



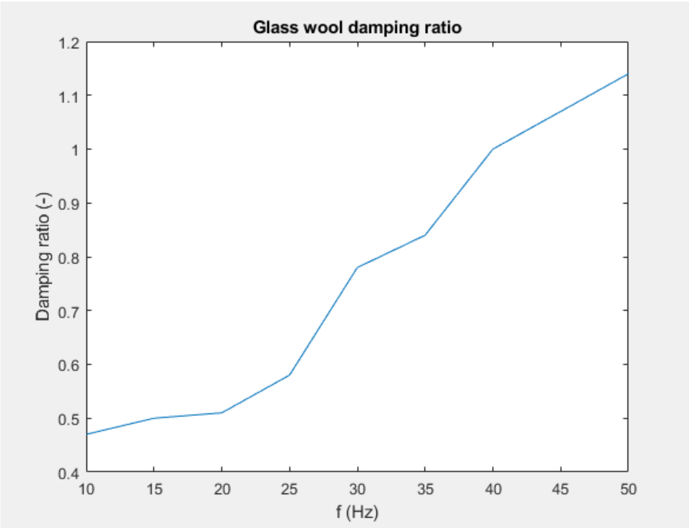
Graphic 1 : Glass wool transmissibility x frequency.



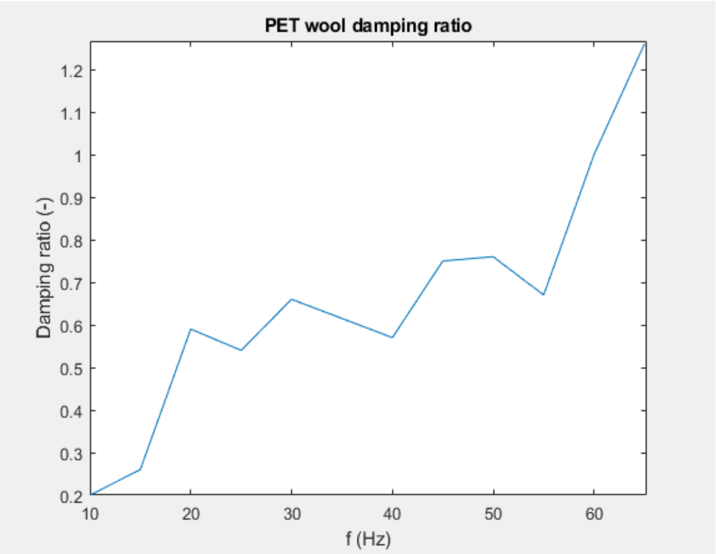
Graphic 2: PET wool transmissibility x frequency.

With the transmissibility graphs of the two wool it is possible to notice that both have a characteristic of increasing the amplitude of the output signal for low frequencies. However, PET wool showed a behaviour of greater reduction of the amplitude of the output signal, because it was able to match the input amplitude with the output amplitude in 35 Hz while the glass wool obtained this behaviour from 65 Hz. It is also possible to notice that the two materials obtained transmissibility close to zero from 200 Hz and the behaviour did not change to higher frequencies. Therefore, for the wool thickness chosen, from an excitation frequency of 200 Hz both wool are capable of absorbing almost all the excitations performed by the shaker on the lower (input) plate, causing minimal vibrational effect on the upper plate (output).

System accommodation data were also collected for each excitation frequency. Observing the overshoots of the systems after cessation of excitation and using equation (3), the values of the damping ratios for each excitation frequency were obtained and plotted by the respective excitation frequency.



Graphic 3: Glass wool and PET wool damping ratio x frequency.



Graphic 4: PET wool damping ratio x frequency.

From the graphics, it can be seen that both materials have low values of damping ratio for small frequencies and that this value increases as it is increased the frequency, which the system is excited before the accommodation. Therefore, the systems operate at a underdamped rate at frequencies between 1 Hz and 30 Hz, tend to pass through a small critically damped operating range and from 50 Hz for glass wool and 65 Hz for PET wool, systems operate with overdamped characteristic, that is, with the damping happening as fast and abrupt as possible.

5. CONCLUSIONS

The methodology developed was effective for data analysis and characterization of different damping materials. As well as a better understanding of several characteristics in a vibrational system.

Data analysis demonstrates that both wool begins to be efficient after near 200 Hz of excitation frequency. Besides that, it was possible to note that from the point of view of the damping ratio, the two wool had close behaviours and for 60 Hz or higher both operate in an overdamped system. PET wool presented a more abrupt drop in its relative transmissibility in relation with the frequency than glass wool. The fact of both having a similar response from the vibrational point of view, demonstrates that in addition to spending less energy on its manufacture and more safety in handling, PET wool can be used as a viable alternative for vibration damping.

Some of the ideas for further refinement of the methodology include using a larger frequency range, thus having more accuracy of the characteristics of the damping material, to use accelerometers of the same company with similar sensitivities so that the error in the data collection is smaller. Other possibilities are to automate the frequency variation system, thus obtaining more uniform data and more precise adjustments, use a unit impulse to achieve the accommodation time rather than just turning off the frequency generator, make the tests with the same material using different thicknesses to observe the influence of the geometry on the damping.

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