An investigation into practical values of sound transmission loss across natural luffa fibers

Hangátviteli veszteség gyakorlati értékeinek vizsgálata luffa szálakat tartalmazó közegben

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Érkezett: 2019. 02. 29. ▪ Received: 29. 02. 2019. ▪ <https://doi.org/10.14382/epitoanyag-jsbcm.2020.17>

Abstract

Natural fibers could be used as sound insulation due to their advantageous acoustic properties. The main object of this study is to investigate the sound transmission loss (STL) of natural Luffa fibers (LF) due to their availability and sustainability where they would be a good choice instead of synthetic materials that have some health issues. The study has been done experimentally. The work has included a collection of LF from local gardens in Iraq, manufacturing of the specimens and measuring the STL using an impedance tube for selected samples: 20 mm of 970 kg/m³, 30 mm of 880 kg/m³ as well as 30 mm of 600 kg/m³. The effect of both thickness and density of the samples on the values of STL were studied. The results show that the increase of the thickness by adding 10 mm layer improved the STL value by 15-20 %. Also, the increasing of the density enhanced the sound insulation, where the STL value at 880 kg/m³ has improved by 30-40 % comparing to 600 kg/m³ for the same thickness (30 mm).

Keywords: sound transmission loss, acoustic insulation, natural fiber, luffa, sustainability

Kulcsszavak: hangátviteli veszteség, hangszigetelés, természetes szálak, luffa, fenntarthatóság

1. Introduction

Noise has many negative effects on humans including: nervous stress, sleep loss and hearing loss. In addition, acoustic waves may damage sensitive mechanical and electrical systems because of the corresponding vibration and fatigue. For these reasons, sound insulation materials are used to reduce the noise as well as to keep a certain range of calm.

There are two important terms describe the acoustic performance of a material which are the sound absorption and sound transmission loss. The sound absorption is the ability of a material to reduce sound reflections, reverberation, and echo within an enclosed space. While, the sound transmission loss (STL) is the ability of a material, panel, or wall to act as a barrier preventing airborne sound transmission from one space to another [1]. In this study, the sound transmission loss has taken into account where it provides an indication of the sound intensity stopped by a barrier for certain frequency. Insulation materials have the ability to reflect or absorb the sounds nearly at all frequencies [2-3].

Conventional acoustic insulators are evaluated depending on their fibrous construction and sizes of pores for their structure. Thus, most sound insulators are synthetic materials manufactured from combinations of minerals and plastics. Insulators made of synthetic materials, like glass wool, expanded polystyrene and polyurethane foams have many health side effects related to eyes and lungs. Hence, researchers have looked into natural materials and agricultural waste to find alternatives. These types of materials have many benefits as they are cheaper, nonabrasive and renewable. Also, organic substances impose less health and safety issues during processing [4, 5 and 6].

Luffa is a plant grows up in tropical and subtropical regions. It is available locally in Iraq and neighborhood countries, and the fruit is very fibrous so it is used as a scrubbing sponge, as shown in Fig. 1. In addition, Luffa usually grows up rapidly and profusely, where it requires 150 to 200 warm days to mature. The fibrous characteristic of Luffa is an encouraging factor of applying it as sound insulation and it would be a contribution to green technology.

Fig. 1 Luffa as a natural material: a) Local plant; b) Sponge shape of Luffa
1. ábra Luffa természetben megtalálható formái: a) termés; b) szivacsnak feldolgozva

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2. Literature review

There is currently much interest in developing sustainable insulators, either from natural, biomass or even recycled materials. Natural materials, such as plant fibers could be used to satisfy comfortable environment free of undesired sounds. Many investigations have developed a wide range of natural porous materials, where these materials have shown a bunch of advantages such as availability and no side effects [6].

A study, conducted under the EU HOLIWOOD project a decade ago [7], has tested the performance of several possible absorbers made from natural materials like: cotton, flax and cellulose. Results were compared with those for conventional fiberglass, mineral wool and polymers where the natural materials show encouraged conclusions. The most effective natural absorber was the flax, while cotton fibers have very similar acoustic properties to fiberglass. Cellulose fibers are not attractive where they may be attacked by fungi and dampness.

Nor et al. [8] analyzed the effects of compressing porous layers of Coir fibers on its sound performance, which can be used for automotive applications. Moreover, Nor, et al. [9] investigated the effects of various factors of Coir fiber on acoustic absorption. The results indicated that layer thickness and fiber diameter have important effects on the absorptive behavior of Coir fibers.

Yang et al. [10] studied the acoustic performance of assembled fiber consisting of: cashmere, goose down and kapok. These natural materials had internal structures that influenced the sound absorption as measured against mass, air gap and sound frequency. These fibers showed a good performance at low to medium frequencies, where with low density and tiny diameter, these fibers have good absorption but their performance deteriorated at higher frequencies.

Deveikytė et al. [11] investigated the effectiveness of different configurations of straw and reeds with respect to frequency bands. In order to compare their effectiveness, the specimens of the same density had different thicknesses (5-20 cm). The noise reduction values were between (10-25 dB) within frequency bands range from (100-3150) Hz. The result indicated that thicker specimens have better sound insulation. However, straw and reeds are good at low frequencies, and they could therefore be used to make composite panels of both fibrous and porous panels [12].

Khair et al. [13] used Bamboo as natural material for sound absorption. The result revealed that it is a good sound absorber at high frequency above 3 kHz with a sample of 2 cm long. Improvement of absorption at lower frequency can be achieved by increasing the air gap at the back of the sample.

3. Experimental work

The experimental work included the collecting of LF from a local garden then using spinning machine to rip the fruit and product the raw material yarns. In order to manufacture the composite fibers, the raw material was grinded and peeled it to tiny strings and then mixed with the Urea-formaldehyde resin as a cohesive material. The additional mass due to the resin was 20% of the original mass for each sample. After mixing the fibers with the resin in a mold, the sample has been inserted in the compressing machine, where thermal treatment involving. The

machine was running simultaneously to compact the composite under high temperature. The sample was covered by two plates upper and lower for an approximately 5-7 minutes under pressure of 170 kg/cm². Fig. 2 shows the processes of the manufacturing.

Fig. 2 Processes of manufacturing the composite sample
2. ábra A kompozit anyag előállításának folyamata

Three typical samples have manufactured and tested according to ISO10534-2 in order to determine the effect of both density and thickness on the practical values of STL. The samples were: 20 mm of 970 kg/m³, 30 mm of 880 kg/m³ and 30 mm of 600 kg/m³, as shown in Fig. 3.

Fig. 3 Samples used in the study
3. ábra A kutatás során használt minták

Measurements of bulk density for the panels have evaluated by taking random set of individual fibers of Luffa and measuring the dimensions and physical properties using electronic microscopy of 50X magnification. Some captured photos of the selected fibers are shown in Fig. 4.

The selected panels have cut into circular shapes (100 mm and 28 mm for each panel) to fit the diameters of the impedance tubes, as shown in Fig. 5.

Measurements were conducted at Noise and Vibration Laboratory, UTHM University, Malaysia. The readings of STL values have obtained using an impedance tube instrument, as shown in Fig. 6. The device allowed the normal incidence acoustic field to flow through the fiber to reach a resonator. Each test was repeated three times to confirm the measurements data where the time that required acquiring the absorber's spectrum by the instrument took approximately 10 s with a resolution of 3.13 Hz. Furthermore, calibration process has been utilized for GRAS-42 AB microphone at calibrations sensitivity of 114 dB at 1 kHz.

Fig. 4 Photos captured for some selected individual fibers
4. ábra Egyes kiválasztott szálakról készült felvételek

Fig. 5 Samples cut to circular shapes (100, 28 mm)
5. ábra Henger alakúra vágott minták (100 ill. 28 mm átmérő)

Fig. 6 Impedance tube instrument and setup system
6. ábra Impedancia meghatározására használt kísérleti összeállítás

4. Results and discussions

4.1 Effect of thickness

Fig. 7 illustrates the STL values of LF panels treated with Urea Formaldehyde for 20 mm (970 kg/m^3) and 30 mm (880 kg/m^3) at a range of frequencies from 50 Hz to 5000 Hz. The results show that the STL values of LF panels at 30 mm thickness shifted to up comparing to the 20 mm panel, thus indicated more reliability as a sound barrier. The 20 mm panel reached a maximum value of 24 dB at low frequencies (less than 1500 Hz) and 26 dB at high frequencies. The 30 mm panel (880 kg/m^3) reached a maximum value of 28 dB at low frequencies, and 30 dB at high frequencies. So in general, the increasing of the thickness improved the STL value by 15-20 %. A lack of measurement accuracy at frequencies between 1500 Hz and 2000 Hz was apparently marked, due to the combining of the data collected from both tubes in lower and higher frequencies that created unexpected sharp decline in STL curve. However, Luffa fibers (LF) may have less transmission loss in low to medium frequency ranges because the latex applied has not affected on the panel's inelasticity. The well mixing of fibers with sufficient amounts of air gaps may improve this problem to some extent [14].

Fig. 7 Comparison of STL values for the effect of thickness
7. ábra Minta vastagság hatása az STL-értékekre

4.2 Effect of density

The STL values from experimental test for the densities (600 and 880 kg/m^3) of the same thickness panels (30 mm) are shown in Fig. 8. Maximum STL values at low frequencies were 19 dB and 28 dB for densities of 600 and 880 kg/m^3 , respectively. Maximum STL values at high frequencies were 22 dB and 30 dB for densities of 600 and 880 kg/m^3 , respectively. Thus, the STL values have been increased by increasing the value of the density, and in general, the increasing in STL value was 30-40% for current samples. In frequency ranges less than 500 Hz, the difference in STL values between the panels is unrecognized and that is attributed to the high acoustic resistance which leads to diminish sound transmission. Whereas at high frequencies, the improvement was recognized due to lose the ability of dissipation the high sound power.

Fig. 8 Comparison of STL values for the effect of density
8. ábra Minta sűrűségének hatása az STL-értékekre

4.3 Sound transmission class

Plots of sound transmission loss are complex and are usually reduced to single number represent the sound transmission class (STC). To determine STC, the values of STL across a barrier could be compared at various frequencies, between 125 to 4000 Hz, to a standard contour. Then a standard curve could be plotted according to ASTM E413 over STL values where the value at 500 Hz is assigned as the STC [15]. The higher STC

value the better sound barrier. Figs. 9, 10 and 11) show the STC values of the selected panels, where the results show that value of STC has increased from 13 dB to 15 dB due to the increasing of the thickness from 20 mm to 30 mm. Evidently, STC value for the higher density of 30 mm panel is increased comparing with the less density one, where it was 11 dB for 600 kg/m³ panel and became 15 dB for 880 kg/m³ panel.

Fig. 9 STC for (20 mm, 970 kg/m³) panel
9. ábra STC értékek a 20 mm vastag, 970 kg/m³ sűrűségű minta esetén

Fig. 10 STC for (30 mm, 880 kg/m³) panel
10. ábra STC értékek a 30 mm vastag, 880 kg/m³ sűrűségű minta esetén

Fig. 11 STC for (30 mm, 600 kg/m³) panel
11. ábra STC értékek a 30 mm vastag, 600 kg/m³ sűrűségű minta esetén

5. Conclusions

The environmental concerns due to the utilization of petroleum resources, called to employ new eco-friendly materials for many applications. Among various natural materials, Luffa fibers (LF) have introduced as a matrix for sound insulation panels, where they have less environmental impacts, more economic advantage and no health side effect. The study has done experimentally by manufacturing Luffa composite panels and testing the sound transmission loss (STL) for selected samples. The effect of both density and thickness of the samples on the values of STL were studied. The results show that by increasing the thickness from 20 to 30 mm, the STL was improved by 15-20%. Also, the increasing of the density increases the STL value, where the STL value for 880 kg/m³ panel improving by 30-40% comparing to 600 kg/m³ panel for the same thickness (30 mm).

Acknowledgments

Author is grateful to all support given by: Malaysian Palm Oil Board (MPOB), Noise and Vibration Laboratory, Faculty of Mechanical and Manufacturing Engineering, UTHM University, Malaysia.

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Ref.:

Jawad, Lamyaa Abd Alrahman – Salih, Tawfeeq Wasmi M.: An investigation into practical values of sound transmission loss across natural luffa fibers
Építőanyag – Journal of Silicate Based and Composite Materials, Vol. 72, No. 3 (2020), 106–109. p.
<https://doi.org/10.14382/epitoanyag-jsbcm.2020.17>