



THE EFFECT OF THICKNESS AND DENSITY ON THE ACOUSTICS PROPERTIES OF *Ceiba pentandra* NATURAL FIBER

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ABSTRACT

This paper presents a study of the acoustic properties of the single layer kapok fiber @ *Ceiba pentandra*. The acoustic properties studied in this study are the sound absorption coefficient, α and the value of Transmission Loss, TL. Experimental measurement was conducted in Acoustics Lab, Mechanical and Materials Engineering Department, UKM by using an impedance tube in accordance to ISO 10534-2 and ASTM E1050-98 standards. Two sets of diameter used in this experiment are 28 mm for high frequency and 100 mm for low frequency experiments. This study examines the effect of thickness and density of kapok fiber on sound absorption coefficient and transmission loss value. The tested sample has 3 different thicknesses of 20 mm, 30 mm, and 40 mm for both diameters but having the same density of 40 kg/m³. For different densities, the sample divided into 3 densities of 40 kg/m³, 50 kg/m³ and 60 kg/m³ with all the samples having a thickness of 20 mm. The experimental results of sound absorption coefficients for different thickness samples show an optimum sound absorption coefficient of 0.91 at 4250 Hz for all three thicknesses. Different density tests provide the optimum noise absorption coefficient at 4250 Hz for all thicknesses of 0.89, 0.91 and 0.86 for density 40 kg/m³, 50 kg/m³ and 60 kg/m³ respectively. For transmission loss, optimum loss happens at 5600 Hz frequency with a value of 17.5 dB, 25.8 dB and 34.5 dB for the thickness of 20 mm, 30 mm and 40 mm respectively. The results show that natural fibers of the kapok trees can produce some quality, value for sound absorption and can be used as an alternative material for use as sound absorbers. Furthermore, kapok natural fibers are widely available, safer for the environment and do not endanger to human.

Keywords: sound absorption, transmission loss, natural fiber, kapok fiber.

INTRODUCTION

Rapid development in the automotive, construction and heavy industries has caused noise pollution problems. Noise or noise pollution can provide disruption and discomfort to a person who is exposed to it persistently. Noises can also contribute to a person's health problems such as high blood pressure and hypertension problems. Organ such as the heart will be affected by the effects of non-uniform beats and sleep disturbances, the affected immune system, reduced work performance and more are the effects of noise [1].

Current sound insulation is made of synthetic materials and composite materials. These insulation materials are widely used in engineering applications such as cooling towers, vehicles, heavy plants, opera halls and others. However, synthetic sound insulation can cause an individual to have difficulty breathing and skin problem. Synthetic materials will also cause environmental problems because synthetic materials take a long time to be disposed. Alternative sources of replacing synthetic materials have been studied and these natural fibers can be an alternative source that can replace synthetic materials to be used as sound absorbers [2, 3].

There are many studies conducted to study the natural fiber acoustic properties such as sound absorption coefficient and the value of broadcast loss. In order to find natural fibers that can provide high absorption coefficient and high frequency loss coefficient for high frequency range and low frequency range the researchers have used

various types of natural fibers. Some researcher uses pure porous date fibers to find that this material is suitable for sound absorber for high frequency and low frequency range [4]. Apart from using palm fiber naturally, researchers use vegetable fiber as an alternative way of being used as sound absorbers [5]. They studied the sound absorption coefficient for these sisal fibers and these fibers originate from the Mexican desert region and the scientific name for sisal plants (*Agave Sisalana*) was introduced in northeastern Brazil. These fibers have the potential to be used for medium frequency and high frequency ranges.

Karlinasari studied the acoustic properties of particleboard made of betel tree (*Dendrocalamus asper*) as a building material [6]. This study looks for noise absorption coefficient and the value of transmission loss. The results of the experiments found that dust boards had the potential to be used as a construction material especially used for acoustic purposes.

Ismail conducts experiments on pinnata natural fibers for the search for sound absorption coefficient, AAC [7]. Through experimental results it can be concluded that pinnanta fibers have the potential to make raw materials for sound absorbers at low cost, less heavy and can be disposed.

Ceiba pentandra (L.) Gaertn. belongs to the family Malvaceae, previously part of family Bombacaceae, and was named from the Latin pentandrus, meaning, with 5 bundles of stamens [8]. This species is locally called kapok, kekabu or kabu kabu and it is a small



to medium sized tree up to 30 m tall and 25 cm in diameter. Based on the structure and properties of kapok fiber, Zhang [9] provides a summary of recent research on kapok fiber including chemical and physical treatments, kapok fiber based composite materials, and the application of kapok fiber as an absorbent material for oils, metal ions, dyes, and sound with special attention to its use as an oil-absorbing material.

This study aims to determine the sound absorption coefficient and sound transmission loss of acoustic properties for kapok fiber as a sound absorbing material. More details studies of this type should be carried out to obtain the true potential of native fibers and many more unreachable natural fibers to obtain the best natural fiber acoustic properties.

METHODOLOGY

A. Sample preparation

In order to determine the sound absorption coefficient parameter and the value of the sound transmission loss, two sets of sample size with diameter of 28 mm and 100 mm were prepared. The first set was prepared with different thickness, but have the same density and the second set was prepared with different density but the same thickness. The raw material of kapok fiber is obtained from local supplier. Figure-1 shows early stage of the sample with respective diameter preparation. The thicknesses used in the experiment are 20 mm, 30 mm and 40 mm. The average density for all the samples for different thickness properties is $40 \text{ kg/m}^3 \pm 5 \text{ kg/m}^3$.

For different density tests, there sample densities used are 40 kg/m^3 , 50 kg/m^3 and 60 kg/m^3 with a thickness of 20 mm, respectively. The sample is prepared by using a specific mold and weight to obtain the specified thickness and density



Figure-1. Sample size with diameter of 100mm (above) and 28mm (below) from kapok fibre.

B. Experimental apparatus

The experiment was carried out using an impedance tube method according to ISO 10534-2 and ASTM E1050-98 standards. Figure-2 shows the impedance tube setup for sound absorption experiment.



Figure-2. Impedance tube setup for sound absorption experiment.



Figure-3. Impedance tube setup for transmission loss experiment.

The addition of tubes for microphone 3 and microphone 4 on the impedance tube was carried out to conduct transmission loss experiments as shown in Figure-3. The experimental data will be taken using the dBFA suite 4.8.1-Symphonie and SCS80FA 1.1.0.0 software.



RESULTS AND DISCUSSIONS

A. Kapok fiber sound absorption coefficient

Based on the experimental data obtained throughout the tests, all kapok fibers with different thickness show an increasing sound absorption value except in the range of 1000 Hz to 1500 Hz. The entire sample gave a high noise absorption coefficient at a frequency of 4025 Hz up to 4250 Hz. At the frequency of 500 Hz the granular fibers with a thickness of 40 mm have shown a high noise absorption coefficient compared to the 30 mm and 20 mm granular fibers with sound absorption coefficient of 0.77 and for the 30 mm and 20 mm kapok fibers respectively give the noise absorption coefficient of 0.61 and 0.38 respectively. The sound absorption coefficient at the low frequency range (below 1000 Hz) for all the three thickness has shown a high increment and this indicates that the low-fiber fiber has the potential to be used as a low-noise absorber especially at 900 Hz. Full result of the thickness effect was shown in Figure-4.

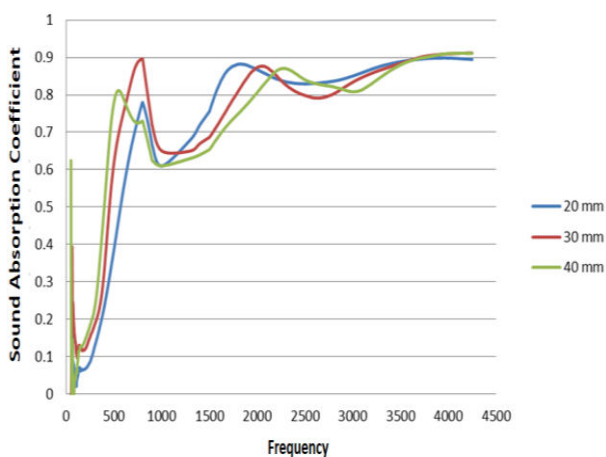


Figure-4. Result of sound absorption coefficient for three different thicknesses with density of 40 kg/m³.

For a mid-range frequency of 1500 Hz frequency up to 2500 Hz with a noise absorption coefficient of 0.8 to 0.9, the sample with a thickness of 20 mm will provide a higher noise absorption coefficient than the sample of 30 mm and 40 mm. For a sample of 30 mm it will give a high noise absorption coefficient at 2250 Hz and a 40 mm sample will give a high noise absorption coefficient at 2500 Hz. This result shows that the increased thickness will give a high frequency absorption coefficient at higher frequencies. Peaks for a high frequency range for each thickness of the sample will change to a higher frequency value by increasing the thickness of the sample.

Jailani [10] mentioned by increasing the thickness of material, it will enhance the sound absorption in lower frequencies. It specifies that the absorption rises as impinging wave has to go long way through the material and losses its energy. According to absorption phenomena inside a porous material, long dissipative process of viscosity and thermal conductions in the fluid inside the

material due to increased thickness expand the absorption value.

Seddeq [11] also discussed the influence of felt thickness which shows that thicker the material better sound absorption values. Moreover, the importance of thickness on low frequency sound absorption that is based on the physics - low frequency means higher wavelength and higher wavelength sound can be absorbed if the material is thicker

The decrease in sound absorption coefficient at 1000 Hz may be due to restriction of impedance tube for low frequency and high frequency. The use of two impedance tubes can cause errors when the low frequency and high frequency experimental data are combined into one data.

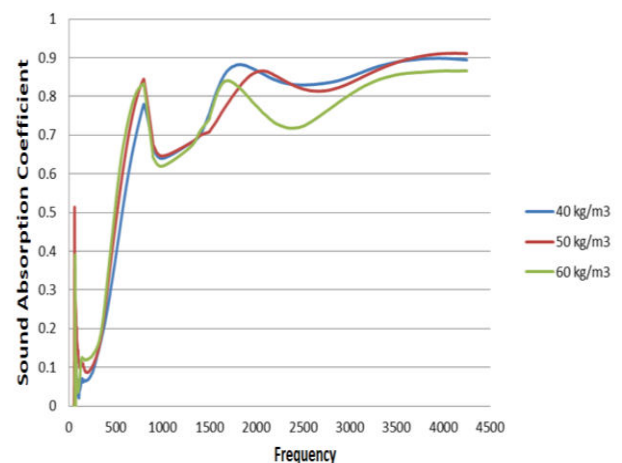


Figure-5. Result of sound absorption coefficient for three different densities with thickness of 20 mm.

For sound absorption coefficient with different density, the result can be seen as shown in Figure-5. In general, there are not significant different between the densities of 40 kg/m³ and 50 kg/m³ except at 60 kg/m³, especially after passing through mid-range frequency of 1800 Hz. At low frequency range (below 1000 Hz) the increase in sample density doesn't give much different with all of them give 0.8 sound absorption coefficient at 800 Hz. At this low frequency range, high density will result in slightly higher noise absorption coefficient.

The decrease in sound absorption coefficient at 1000 Hz once again may be due to restriction of impedance tube for low frequency and high frequency. The use of two impedance tubes can cause errors when the low frequency and high frequency experimental data are combined into one data as mentioned before.

At the frequency of 2150 Hz, the sound absorption coefficient for sample 50 kg/m³ is 0.86 and for sample 40 kg/m³ is 0.84. At a high frequency range the sample with a density of 60 kg/m³ shows a low absorption coefficient compared to samples of 40 kg/m³ and 50 kg/m³ although in the case of sample density of 60 kg/m³ it is higher. Density of 60 kg/m³ shows the most significant noise coefficient drop and starts to increase again throughout the increment of frequency.



This behaviour was discussed by Limin [12] with mentioning that when the density and airflow resistivity increased, the average sound absorption coefficient was firstly increased and then decreased. There was a best airflow resistivity and corresponding density for certain composite fibrous material. In a certain range of the thickness of the materials, the larger density means the denser structure thus most of the acoustic energy was reflected at the surface rather than transmission so that the absorption properties were decreased.

B. Kapok fiber transmission loss result

Generally, with the increment of thickness, sound transmission loss (STL) also increases. All of the samples also show a much higher value of STL in higher frequency range compare to lower frequency range as can be seen in Figure-6.

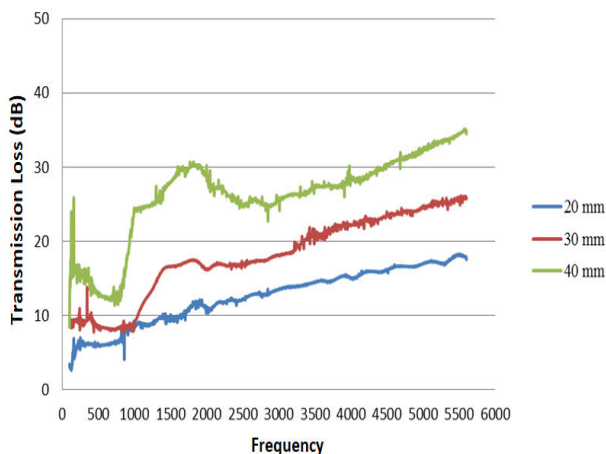


Figure-6. Result of transmission loss for three different thicknesses with density of 40 kg/m^3 .

Sample with 40 mm thickness recorded STL more than 30 dB ($> 4500 \text{ Hz}$) and small range around 2000 Hz. Sample with 30 mm thickness documented STL value of more than 20 dB for frequency higher than 3500 Hz. The value of the STL decreases with the with the increment of frequency in the range of 2000 Hz to 2500 Hz for 40 mm thickness before it starts to increase again later. Kapok fiber gives satisfactory results for the STL experiment, however it still have room for improvement because commercial products typically provide the value of 40 dB broadcasting losses and above for high frequency and low frequency range.

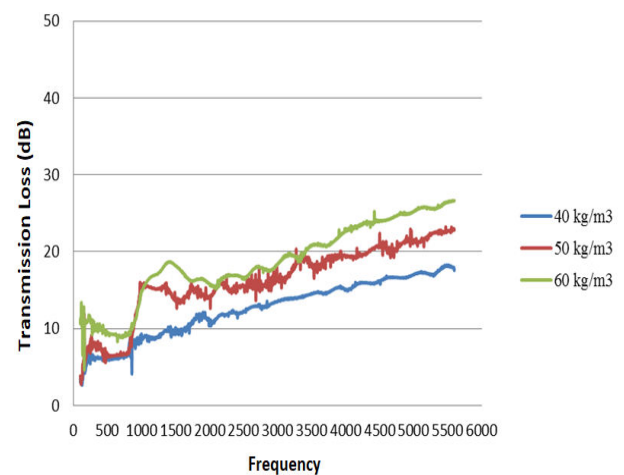


Figure-7. Result of transmission loss for three different densities with thickness of 20mm.

Figure-7 show a result of STL comparing with different densities with a constant thickness. From the graph, it is shown that increasing density in test samples will also increase the value of STL. Higher values of STL are also noted in higher frequency compared to lower frequency range. The highest STL value for sample 60 kg/m^3 is 26.6 dB at 5600 Hz frequency. For the frequency $< 1500 \text{ Hz}$, the highest broadcast loss value for all three samples is 18.0 dB. Samples with a density of 40 kg/m^3 provide the highest STL value of 17.5 dB at a frequency of 5600 Hz. The 50 kg/m^3 sample gave the highest broadcast loss value at 5600 Hz frequency of 22.9 dB.

CONCLUSIONS

The study uses kapok fiber with 3 different thicknesses of 20 mm, 30 mm and 40 mm with density of 40 kg/m^3 and each gave the value of "Noise Reduction Coefficients", NRC of 0.50, 0.59 and 0.61. NRC is defined as an arithmetic average, rounded to the nearest multiple of 0.05, of the absorption coefficients for a specific material and mounting condition determined at the octave band center frequencies of 250, 500, 1000 and 2000 Hz. The sound absorption part of the density parameter uses a density of 40 kg/m^3 , 50 kg/m^3 and 60 kg/m^3 giving NRC values of 0.50, 0.52 and 0.51 respectively. The density increases in the samples will also led to the rise in the the sound absorption coefficient.

The thickness used to find the value of STL is 20 mm, 30 mm and 40 mm with a density of 40 kg/m^3 and each thickness gives the STL value at 5600 Hz frequency of 17.5 dB, 25.8 dB and 34.5 dB. This result shows that the increase in sample thickness will increase the value of STL. Through this study, it can be concluded that the natural fibers of kapok have a potential to be used as an alternative sound absorbing fiber material. It is abundant, cheap, and safe for humans and more importantly it is environment friendly



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