# THE THICKNESS EFFECTS ON ACOUSTIC PROPERTIES OF OIL PALM TRUNK NATURAL FIBER IN DENSITY OF 170 Kg/m³

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***ABSTRACT:*** *The awareness about the harmful effect on fiberglass as sound absorbing material on human health and environment has increased. Thus, the demand for natural fiber to replace fiberglass panel is expanding due to low cost in fabrication and more environmentally friendly. This research has studied the thickness effects on microstructure and acoustic properties of low-density fiberboard (170 kg/m$^3$) based natural fiber of Oil Palm Trunk (OPT). The morphologies and acoustic properties of all samples were examined using Scanning Electron Microscope (SEM) and Impedance Tube Method (ITM), respectively. The SAC values for all samples showed a minimum value of 0.8 at frequency range of 2500 Hz – 6400 Hz except for sample with thickness of 10 mm. However, the SAC values of sample with thickness of 10 mm almost reach unity (~0.99) at frequency range of 6000 Hz – 6400 Hz. SAC values are found to increase with increasing in thickness at frequency range of 0 – 3500 Hz except for sample with thickness of 12 mm. As the frequency increased from 5500 to 6400 Hz, the SAC values increased with decreasing in thickness with exception of sample 12 mm. Tortuosity, where it reflects the percolation paths may play a crucial role in determining the SAC at frequency range of 0 – 3500 Hz. The SAC values in frequency range of 0 – 2500 Hz have been fitted in linear equation. The results show that the experimental SAC values for all samples fitted well in linear equation, where the linear correlation, $R^2$ for all samples is above 0.98*

**Keywords:** Oil Palm Trunk (OPT); Natural Fiber; Sound Absorption Coefficient (SAC, α); Scanning Electron Microscope (SEM).

## 1. INTRODUCTION

Noise or sound pollution becomes a serious issue nowadays. However, humans tend to ignore it even though noise pollution has become a threat to them [1]. According to the data obtained from the National Institute of Occupational Safety and Health (NIOSH), an average human being is only able to withstand a limit of 85 decibels and that is only up to 8 hours per day. If a person is exposed to a high volume of sound for a certain period of time, it could risk the personal safety and health [2]. One of the most common method used to reduce noise or sound pollution is by installing sound absorbing material to absorb the unwanted noise. Customarily these sound absorbers are used in cinema theatre, recording studio, office meeting rooms, factory and etc.

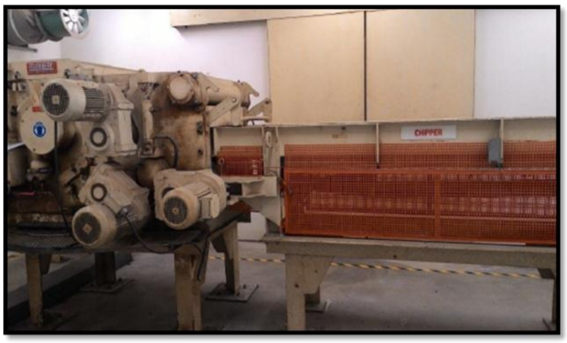
The common choices of sound insulations used in the market are fiberglass, cotton, mineral fiber, polyester and foam insulation. Fiberglass is synthetically made by a mixture of fiberglass, mineral wool and some chemicals. What makes this fiberglass so dreadful to human health is the shedding of fibers from the fiberglass [3]. Many would not know that the fiberglass can cause a lung infection, irritation to skin and eyes and the worst case would be cancer [4]. This piece of information was found out by the US government when a research was conducted. Fiberglass does not stop at affecting human health, it also affects animals. A study on fiberglass affecting animals discovered a growth of a lung tumor, which was caused by the very same fiberglass used as a sound absorbing material. The shedding of the fiberglass can alter DNA structure [3]. However, the physical properties of alternative choices such as foam insulation are not as good as fiberglass. Thus, scientists and researchers have moved on to find less harmful and environmentally friendly solutions to replace fiberglass. For example, natural fiber of oil palm trunk (OPT), kenaf core, paddy straw, arenga pinnata have been contemplated for acoustic properties [5] [6]. Natural fibers have numerous beneficial properties such as ecological, biodegradable and renewable as they can be used without depleting and can solve environmental problems [7, 8]. Advantages of natural fibers, in general, relates to durability factor, fiber strength, fabrication cost and the renewable features of natural fiber compare to synthetic materials.

Besides that, since natural fiber are eco-friendly, it has less pollution during the production process and will limit the health hazard to be reduced to minimal**.** Kenaf core, paddy straw and arenga piñnata are few natural fibers that have proven their acoustic properties as sound absorbing material. Arenga pinnata and kenaf particleboard have high potential to be used as a sound absorbing material. It has been proven from their SAC values, where Arenga pinnata has SAC value of 0.75 – 0.90 at a frequency range of 2000 Hz – 5000 Hz [9]. As for kenaf core particleboard, a board with a lower density of 350 kg/m$^3$ at frequency 2000 Hz showed a better noise absorption coefficient (NAC) than the high-density board of 450 kg/m$^3$ and 550 kg/m$^3$ [6]. In Malaysia, oil palm trunk (OPT) is left as a waste material. As a raw material, it cost lower to fabricate a fiberboard than a fiberglass [10]. Tortuosity is the complexity pathway inside a porous material. Theoretically, the more complex or tortuous the path, the longer the time taken for the wave in contact with the fiber. Hence, this leads to better sound absorption for each of the reflection with the fiber [11, 12]. This research mainly focused on the effect of different thickness on morphologies and acoustic properties of OPT fiberboards with the density of 170 kg/m$^3$ .

## 2. METHODOLOGY

Low-Density Fiberboards (LDF) in thickness of 10 mm, 12 mm, 14 mm and 16 mm were fabricated from the natural fiber of Oil Palm Trunk (OPT). Fabrication processes included chipping, refining, gluing, mat-forming, hot pressing and cold pressing as shown in Figure 1 [10]. The low-density fiberboards fabrication has been done at Malaysian Palm Oil Board (MPOB).

The most common measurements of sound or noise pollution are Noise Absorption Coefficient (NAC), Acoustic Absorption Coefficient (AAC) and Sound Absorption Coefficient (SAC) [13] [6]. Generally, the frequency is categorized into 3 different stages which are low frequency (0 Hz to 500 Hz), medium frequency (600 Hz to 1000 Hz) and high frequency (1000 Hz and above). In this research, SAC has been used to analyze the reliability of the OPT fiberboard as sound absorbing material. SAC (α) of a material is a dimensionless number valued between zero (0.0) to (1.0). If the value of SAC 1.0 is obtained, it means the sound energy is 100% absorbed. On the other hand, if the value of SAC 0.0 is obtained, it shows that the sound is 100% reflected. The SAC was measured using the Impedance Tube Method (ITM) (Bruel & Kjaer (B&K) Impedance Tube Type 4206) [7] and the results are plotted as shown in Figures 2 to 5.



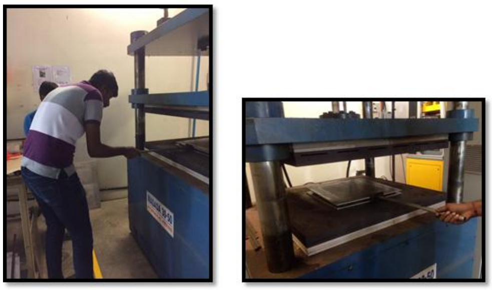
(a) OPT was chipped into small pieces using the Maier Chipper.

(b) The OPT chips have undergone a refining process in order to produce a better quality of fiberboard.

(c ) The ration of the UF glue was measured perfectly and blended in a mechanical blender together with the refined fibers.

(d) A square box, which acted as a mold, was used to shape the fibers.

(e ) A metal plate flattener was used to compress the fibers to achieve the desired thickness.



(f) This process was to heat up the fiberboard and to make it solid.

(g) The final product was then cooled to the room temperature.

**Fig 1: Low-Density Fiberboards Fabrication: Process (a) Chipping Process (b) Refining, Process (c) Gluing, Process (d) Mat Forming, Process (e) Pre-pressing Process (f) Hot Pressing, Process (g) Cooldown Process**

## 3. RESULTS AND DISCUSSION

Figure 2 shows the effects of different thickness on SAC values of LDF in the frequency of 0 to 6400 Hz. On average, the SAC values for all samples increased with increasing of frequency. From 0 to 3000 Hz, where the SAC values increased rapidly. At frequency 3000 Hz and above, the SAC values are found to fluctuate in between 0.8 to 1.0, except for sample with a thickness of 10 mm. For a sample with a thickness of 10 mm, SAC values increased gradually from the frequency range of 0 – 6400 Hz (Figure 3). It is interesting to note that, the SAC values for all samples exceed 0.8 and above a frequency range of 2500 – 6400 Hz except for sample with a thickness of 10 mm. These range of SAC values can be classified as class A or B according to Absorption classes [14]. From Figure 2, it can be seen that the highest SAC values obtained for the thickness of 10 mm, 12 mm, 14 mm, and 16 mm are 0.99, 0.99, 0.99 and 0.97 at a frequency of 6000 Hz, 4000 Hz, 4000 Hz and 3500 Hz, respectively.

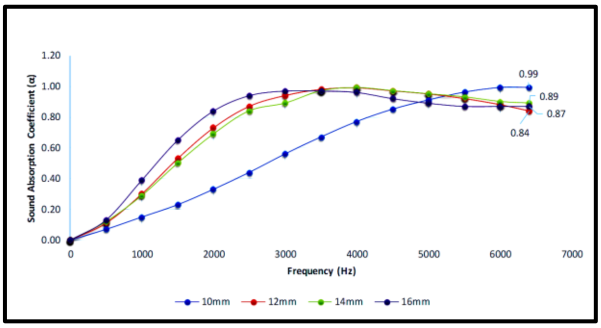



**Fig 2: Sound Absorption Coefficient (α) versus Frequency (Hz) for thickness 10 mm, 12 mm, 14 mm and 16 mm at a frequency range of 0 Hz to 6400 Hz**

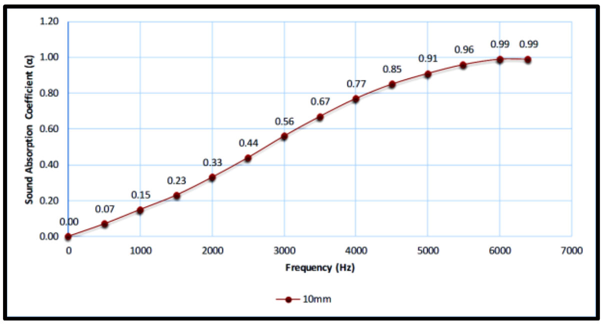
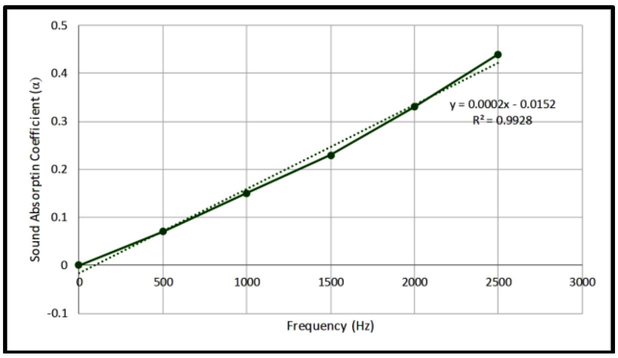
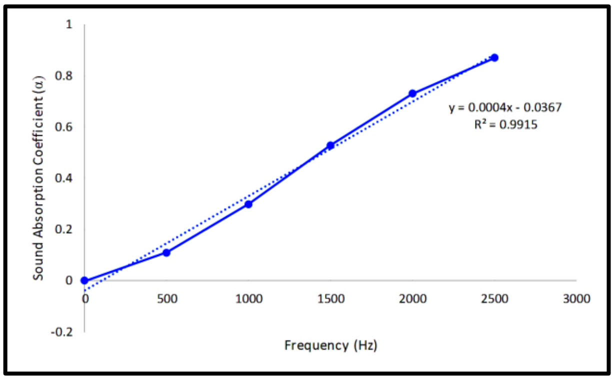



**Fig 3: SAC (α) versus Frequency (Hz) with an ideal thickness of 10 mm at a frequency range of 0 Hz to 6400 Hz**

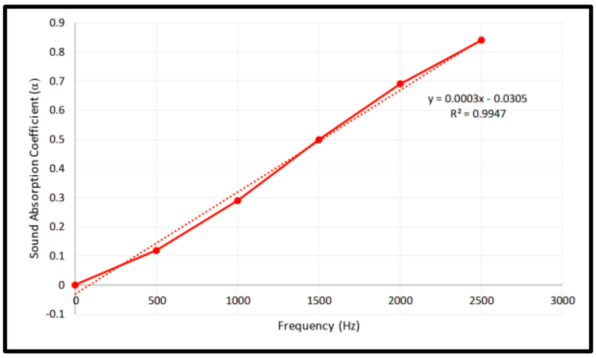
From frequency range of 0 – 3500 Hz, SAC values are found to increase with an increase in thickness except for sample with a thickness of 12 mm. It is to note that the SAC values for samples with a thickness of 12 mm and 14 mm have only subtle differences. It can be explained by tortuosity, where the increase in thickness for porous material, the number of fibers will increase too. Thus, it will create a more complex path [15]. Indirectly, it prevents a direct flow of the wave through the porous medium. The more complex the path, the more time a wave is in contact with the absorbent and hence, the more energy dissipation and more sound absorbing capability. Whereas, when frequency increased from 5500 to 6400 Hz, the SAC values are nearly increased with decreasing in thickness.



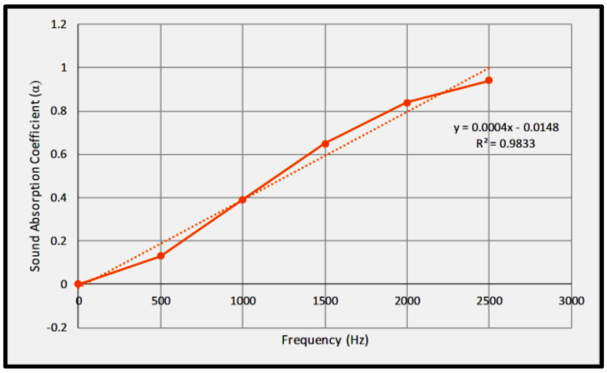

(a)




(b)




(c)




(d)

**Fig 4: SAC (α) against Frequency (Hz) in different thickness at frequency from 0 Hz to 2500 Hz (a) 10 mm (b) 12 mm (c ) 14 mm and (d) 16 mm (Solid lines are fitting with linear equation)**

Figures 4 (a) – (d) show the linear fit of SAC values of LDF in different thickness from the frequency range of 0 – 2500 Hz. The results show that all the samples fitted well with a linear equation. The square of linear correlation coefficient $R^2$ was found to be 0.98 and above for all samples, where it allows the prediction or inverse prediction of the SAC value.

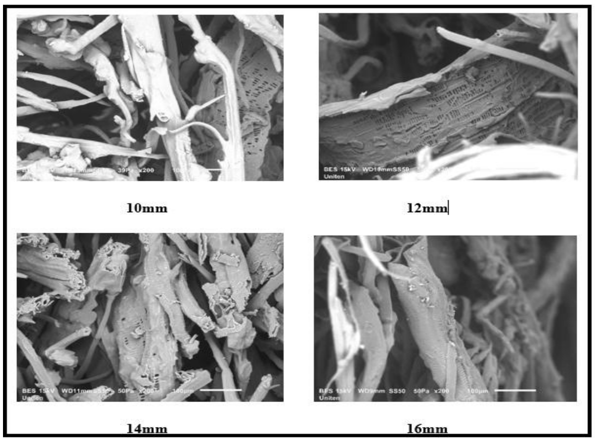



**Fig 5: SEM of LDF in thickness of 10 mm, 12 mm, 14 mm and 16 mm (Magnification × 200)**

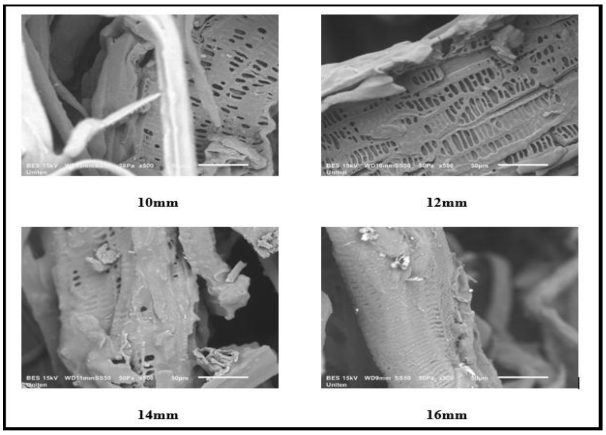



**Fig 6: SEM of LDF in thickness of 10 mm, 12 mm, 14 mm and 16 mm (Magnification × 500)**

A cross-section of OPT fiber being used for SEM test. The electrons in the beam interact with the sample, producing various signals that can be used to obtain information about the surface morphology and content [16]. Figures 5 and 6 show the morphologies of the OPT fiberboard in different magnification. The main contents of OPT natural fibers are parenchyma and vascular bundles. From Figures 5 and 6, the amount of parenchyma and vascular bundles increase with an increase in thickness. The quality of LDF is influenced by the amount of parenchyma content [17]. The increase in parenchyma content may enhance the SAC values of samples with a thickness of 12 mm, 14 mm and 16 mm at a frequency range of 2500 – 4000 Hz. The increase in parenchyma may enhance the capability of the sound absorption in the sample due to more air flow content in the sample. Nevertheless, for frequency above 4000 Hz, the parenchyma content may not play an important role in determining the SAC values.

## 4. CONCLUSION

To summarize, SAC measurements have been carried out for LDF based natural fiber of OPT with a thickness of 10 mm, 12 mm, 14 mm and 16 mm in the density of 170 kg/m$^3$. It is noticeable that all samples can reach the SAC values of 0.8 at the frequency range of 2500 – 6400 Hz except for sample with a thickness of 10 mm. Sample with a thickness of 10 mm shows a gradual increase of the SAC values from 0 - 6400 Hz. Moreover, at frequency 4200 Hz and above, the SAC values of the sample with a thickness of 10 mm exceed 0.8 and reach almost unity (~0.99) at a frequency of 6000 – 6400 Hz. SAC values are found to increase with increasing in thickness at frequency range of 0 – 3500 Hz. Whereas, when frequency increased from 5500 to 6400 Hz, the SAC values are found to increase with decreasing in thickness. Tortuosity, where it reflects the percolation paths may play a crucial role in determining the SAC at a frequency range of 0 – 3500 Hz.

## ACKNOWLEDGEMENT

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