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THE EFFECTS OF DENSITY ON MICROSTRUCTURE AND ACOUSTIC PROPERTIES OF OPT NATURAL FIBERS

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ABSTRACT

Palm oil is the world's most productive oilseed trim. Malaysia is one the largest producers and exporters of palm oil in the world. Almost 4.49 million hectares of land in Malaysia are under oil palm cultivation and producing 17.73 million tons of palm oil and 2.13 tons of palm kernel oil in a year. Therefore, oil palm wastes have created a major disposal problem in Malaysia. Producing materials from oil palm trunk (OPT) natural fibers can minimize and recycle the waste to our environment. This paper reports the effects of density on microstructure and acoustic properties of OPT natural fibers as sound absorbing material in four different targeted densities (120 kg/m^3, 140 kg/m^3, 160 kg/m^3 and 180 kg/m^3) with constant thickness of 10 mm. It is interesting to note that, the SAC values of these three targeted densities (120 kg/m^3, 140 kg/m^3, 160 kg/m^3) show a minimum SAC of 0.8 over a wide frequency range of 3000 - 6400 Hz. The maximum SAC (α) = 0.91 can be reached by a sample with a density of 120 kg/m^3. However, sample with a density of 180 kg/m^3 does not exhibit high absorption rate due to compact fiber within the sample. Morphological analysis was conducted using Scanning Electron Microscope (SEM). The structure of parenchyma and vascular bundle play an important role in determining the acoustic properties.

Keywords: Oil Palm Trunk (OPT), Natural Fiber, Sound Absorption Coefficient (SAC, α), Microstructure

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INTRODUCTION

Malaysia, one of the key players in the palm oil industry, is doing truly well regarding dealing with its backwoods assets. Undoubtedly, Malaysia's timberland territory today is 22,195,100 ha or 67.6% (more than 66%) of the land range. In 2000, the scope region was 21,591,000 ha. In the vicinity of 2010 and 2015, wood range has ascended by 14,000 ha every year (Boemeester et al, 2016). Ultimately, Malaysia's woodland territory is expanding, not diminishing (Hassan et al, 2005).

Various research has been shown to maximize the usage of palm oil waste materials. The advancement in research of materials utilization of characteristic fiber from oil palm trunk is dynamically being explored and delivered. Specific research has been studied and conducted in using oil palm tree parts as acoustic panel. One of the major reasons for this is due to the vast availability of oil palm biomass.

Satisfactory adaptability and quality are shown by the center, mid-part and fronds of OPT. Thammarong has investigated the sound absorption of the middle part of OPT with three different cut section, parallel-cut, grooved panel and with a 3 mm diameter hole. The experiment was conducted by utilizing a one-receiver impedance tube. While unmodified oil palm shows small sound absorption performance, cut directions yield different sound absorption where the cross-cut panel possesses better sound absorption than the parallel-cut panel (Thammarong et al. 2016).

Other parts of oil palm such as Mesocarp (Hanif et al. 2015) and Oil Palm Empty Fruit Brunch (OPEFB) (Or, 2016) also showed the suitability of the fiber to be used as acoustic panel. In the experiment conducted by Hanif, using thickness variable of 10 mm, 20 mm, 40 mm and 60 mm as well as with an air gap of 5 mm and 10 mm. He has concluded that the sample with thickness of 40 mm showed the optimum sound absorption rate. The air gap is able to increase the rate of absorption, especially at low frequency range (Hanif et al. 2015).

Further study on oil palm Mesocarp was conducted by changing the binder percentage which varies from 10%, 20%, 30% and 40%. The increase in binder percentage resulted in more compacted material and this can affect the stiffness of the material. However, it can be presumed that oil palm Mesocarp is capable to be utilized as an acoustic panel (Hanif et al. 2016). While oil palm empty fruit bunch was studied based on three different criteria, density, thickness and air gap. Better sound absorption is resulted, especially at low frequency from the increase in thickness and air gap (Muhammad et al, 2012).

An experiment done by Fatima proved that low density jute has a better sound absorption rate if compared to the high density jute. In addition, Sound Absorption Coefficient, SAC (α) of natural rubber latex has a better performance than fiber glass which shows that natural fiber can be used to substitute synthetic materials (Fatima et al, 2011).

Particleboards produced from Betung bamboo have a guarantee for facilitating improvement as development material, particularly for acoustical reason (Karlinasari et al, 2012). These natural fibers have better acoustic properties in comparison to composite material at high frequency range. This shows the importance and effort from the researcher into examining the acoustic qualities of natural materials.

Therefore, it is interesting to study the effects of density on microstructure and acoustic properties of the Oil Palm Trunk (OPT) natural fibers as an acoustic panel in order to get more insight about this material.

METHODOLOGY

A. Sample Preparation

The OPT fiberboards were prepared using the method of fabrication of Low-Density Fiberboard (LDP). The fabrication steps involved chipping process, refining process, glue blending process, mat forming process, pre-pressing process and hot pressing process (Figure 1).

In the glue blending process, the Urea Formaldehyde (UF) glue with grade E1 was added gradually as a binder to the refined fiber using wind pressure. After about four minutes, the mixture with perfect mix were removed from the machine. The OPT panel then formed in a 300 mm × 300 mm mold and manually pressed before it is pre-pressed. This is to ensure the pores within the fibers are removed.

B. Sample Characterization

The fabricated OPT panels as shown in Figure 2 were tested for Sound Absorption Coefficient, SAC (α) and Scanning Electron Microscope, SEM.

The SAC (α) of a material is a dimensionless number valued between zero (0.0) and one (1.0) over a range of frequencies. It represents a percentage of sound energy absorbed based on a unit area exposed to the sound. The value of 0.0 means all of the incidence sound energy that is reflected or transmitted, whereas the value of 1.0 means all of the incidence sound energy is absorbed (Ismail, 2012). The SAC (α) was measured using Impedance Tube Method (ITM). The equipment used was Bruel & Kjaer (B&K) Impedance Tube Type 4206 (Kalaivani et al., 2016).

The surface of OPT panels was gold coated at 25 mA plasma current and 2 Pa of chamber pressure to make them conducting samples. Cellular structure images were examined by using

SEM of JEOL-JSM6380LA operates at 15 kV at 30 µm magnifier under high vacuum (Anika, 2014).

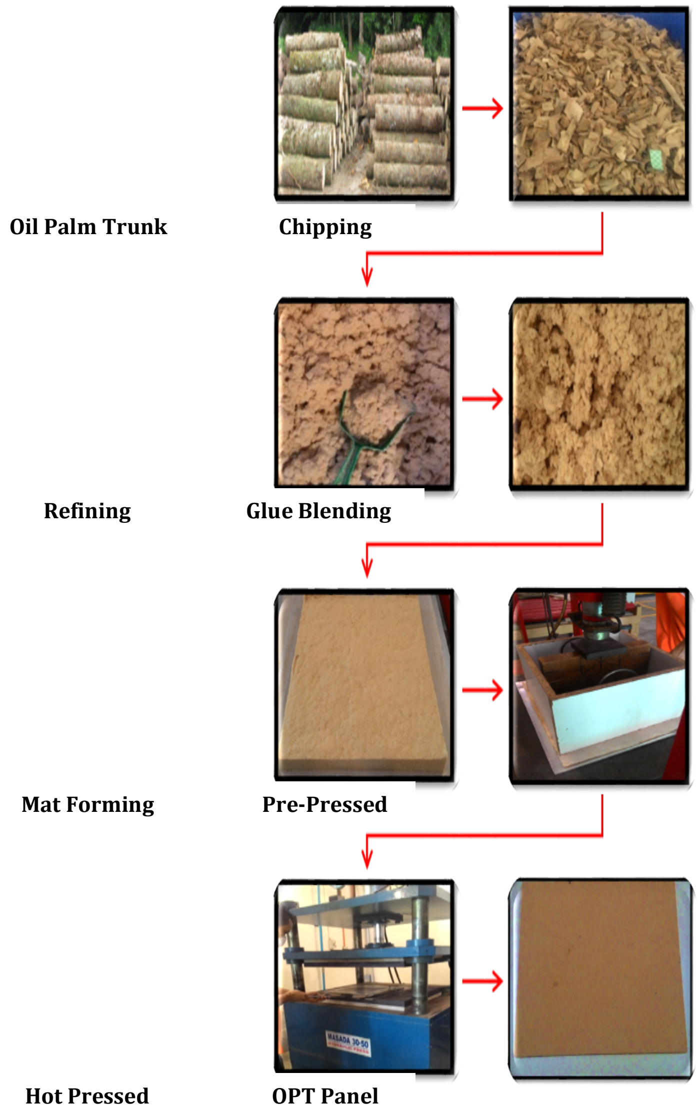

Fig.1. Oil Palm Trunk Sample Preparation

Fig.2. OPT Panel with Finishing

RESULTS AND DISCUSSION

A. Sound Absorption Coefficient, SAC (α)

The Sound Absorption Coefficient, SAC (α), is the proportion of the sound power transmitted through the material specimen into another medium to the sound power episode on one side of a material example. For instance, when a material has a SAC (α) of 0.8 at a recurrence of 1000 Hz. This implies 80% of the episode sound was consumed by the material where else 20% of the sound is reflected back to space or encompassing. Impedance Tube Method (ITM) was used to obtain the SAC (α) which is based on ASTM E1050-09 standard.

This method places a loudspeaker at one end of an impedance tube and a small sample of the material under test at the other end. The loudspeaker generates broadband, stationary random sound waves. The sound waves propagate within the tube strike the sample and is reflected resulting in a standing wave interference pattern (Hanif et al. 2015).

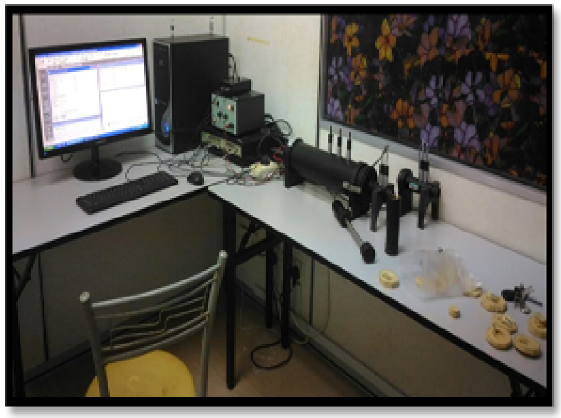

Fig.3. Sound Absorption Coefficient, SAC (α) testing using Impedance Tube Method (ITM)

To improve the accuracy of the results, the SAC for each sample has been tested two times to obtain an average result. Figure 4 shows the SAC values of four different targeted densities in thickness of 10 mm. SAC values are found to increase with increasing density from frequency range of 0 – 1500 Hz.

This is due to more sound energy can be absorbed across the increasing density of the sample via increase of flow resistivity and tortuosity. From 1500 Hz - 3500 Hz, the rate of SAC increase except for samples with a density of 180 kg/m^3 if compare to others. From 3500 Hz – 6400 Hz, SAC values are found to increase with decreasing density.

In general, all samples demonstrated SAC (α) = 0.5 at wide frequency range of 2000 Hz – 6400 Hz. It is noteworthy that, for frequency range of 3500 Hz to 6400 Hz, samples with targeted densities of 120 kg/m^3, 140 kg/m^3 and 160 kg/m^3 possessed the SAC values higher than 0.8. Moreover, sample with a density of 180 kg/m^3 possessed the SAC values below 0.7 from 0 – 6400 Hz.

The increment of density can improve the sound absorption performance in high frequency region for oil palm empty fruit bunch fibers (Or et al, 2016). Nevertheless, natural fibers of oil palm trunk show opposite results at high frequency range.

Sample with a density of 180 kg/m^3 shows significant decrease in the SAC at higher frequency ranges compared to samples with densities of 120 kg/m^3, 140 kg/m^3 and 160 kg/m^3. Theoretically, this can be explained that sample with higher density are more compact with higher amount of fiber. Therefore, less porosity were available within the panel. According to Cox and D’antonia, the porous material will be more effective to absorb the noise at mid-high frequencies (Cox and D’antonio, 2009).

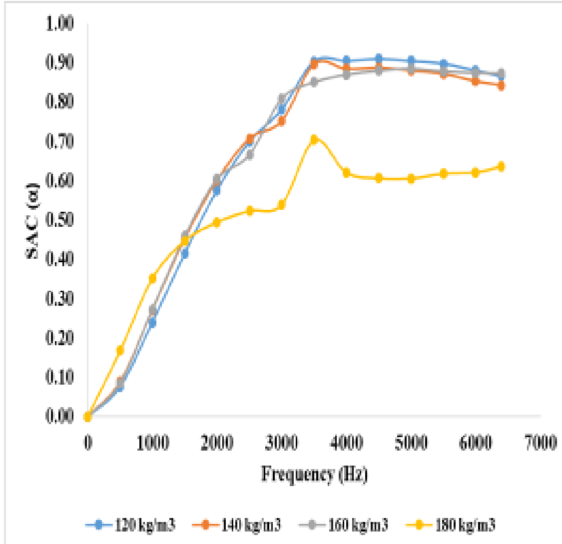

Fig.4. SAC (α) versus Frequency for Four Different Targeted Densities with Thickness of 10 mm

Based on the universal standard ISO 11654, the sound absorption performance can be categorized into five classes, from A to E as shown in Figure 5. The SAC (α) values in this research have been compared to a series of fixed reference curves. The range between the reference curves is wide, so absorption classes provide only a rough indicator of sound absorption (Srinivas et al. 2011).

From our results, almost all the samples can be classified as Class A and Class B at wide frequency range of 3500 Hz to 6400 Hz except for samples with a density of 180 kg/m^3. At mid-frequency of 2000 Hz to 3500 Hz, all samples having SAC (α) values within 0.4 – 0.8. Therefore, it can be classified as Class B to Class D.

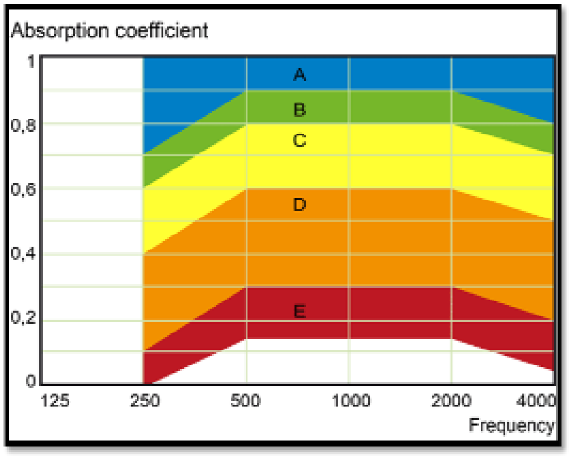

Fig.5. Absorption Classes (Srinivas et al. 2011)

B. Scanning Electron Microscope, SEM

The surface analysis of OPT natural fibers has been carried out using Scanning Electron Microscope (SEM) as shown in Figure 6. Parenchyma and vascular bundle are the major contents of the oil palm trunk. Parenchyma contribute more moisture to oil palm trunk as compared to that of vascular bundles. Whereas, vascular bundle is less hygroscopic compared to parenchyma, naturally spongy and have high capacity in water absorption to store in the tissue cell (Sitti Fatimah et al., 2012).

Based on SAC results, above 3500 Hz, it is found that sample with a density of 120 kg/m^3 possessed the highest SAC values if compare to others. From the images, parenchyma with open and porous characteristics can be observed in the sample with a density of 120 kg/m^3. Parenchyma with open and porous characteristics able to enhance sound propagation and it takes place between interconnected pores such that viscous and thermal interaction cause acoustic energy to be dissipated and converted to heat. Therefore, it can enhance the SAC values.

Theoretically, lower density will be resulting in higher porosity. Higher porosity can lead to more sound attenuation. Furthermore, porous characteristic caused a non-straightness of sound wave flow through the medium. The more complex the path, the more time a sound wave is in contact with the absorbent and hence more energy dissipation and increase the absorbing capability. Hence, the structure of parenchyma and vascular bundle play an important role in determining the acoustic properties.

ρ = 120 kg/m³

ρ = 140 kg/m³

ρ = 160 kg/m³

$\rho = 180\ kg/m^3$

Fig.6. SEM of Oil Palm Trunk Natural Fibers at different densities

CONCLUSIONS

Oil Palm Trunk (OPT) natural fiber is one of the competitors among the natural fiber as sound absorbing material. The density variable plays an important role in determining the properties of the panel produced. It is clearly demonstrated that physical factors have significant contribution on SAC of fibrous materials. As for sound absorption, overall, almost all samples showed that the higher the frequencies, the better the sound absorption coefficients. Samples with a density of 120 kg/m^3, 140 kg/m^3 and 160 kg/m^3 showed good acoustic performance at wide frequency range of 3000 – 6400 Hz. Overall, panel made from OPT fiber has good sound absorption properties at high frequency range. This experiment proves that this natural fiber can be a good alternative sound absorber among many other natural fibers.

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