SOUND ABSORPTION CHARACTERISTICS OF PALM OIL MALE FLOWER SPIKES FIBER REINFORCED COMPOSITE


Faculty of Mechanical and Manufacturing Engineering, Universiti Tun Hussein Onn Malaysia, 86400 Parit Raja, Batu Pahat, Johor, Malaysia
Email: srizal@uthm.edu.my
Phone: +6074538421; Fax: +6094536080

ABSTRACT

A study has been carried out to investigate the viability of palm oil male flower spikes (POMFS) fiber reinforced polyurethane composite to be implemented as sound absorption panel. The composite panels were fabricated with increment of POMFS fiber weight percentage of 5 wt%, 10 wt%, 15 wt%, 20 wt% and 25 wt%. The samples were also fabricated in three different thicknesses which are 8 mm, 25 mm and 35 mm. The acoustics characteristics were investigated by using two microphones method for low and high frequency. The physical characteristics of the composite such as density and porosity were also been tested. The samples were also tested for mechanical characteristics with compressive test. The results demonstrate some potential characteristics of palm oil male flower spikes fiber reinforced polyurethane to be implemented as sound absorption panel.

Keywords: Sound Absorption; Palm Oil Male Flower Spikes; Polyurethane.

INTRODUCTION

Noise can causes human a lot of problems and disease, such as annoyance and aggression, hypertension high stress levels, hearing loss, sleep disturbances and others (Singh and Devar, 2004). There were a lot of methods has been implemented to reduce the effect of noise pollution. This study was focus to use an absorption panel method rather than any other methods.

Recently, natural fiber was implemented as alternative way to replaced synthetic fiber material to produced absorption panel. Because higher cost of manufacture, such as glass and carbon, synthetic fiber-reinforced is limited using in industry (Harish and Michael, 2009). Organic fibers as basis material for absorber materials have several benefit; renewable, nonabrasive, cheaper, abundance and less potential health risks and safety concern during handling and processing (Zulkifli et al., 2010). Several researchers also explored the potential of natural fiber to be implemented in sound absorption panel. The composite boards prepared with rice straw were found to be suitable as a sound absorbing insulation material in wooden constructions (Yang et al., 2002). It was found that sound absorption coefficients of the rice straw panel were higher than the other wood-based materials. The use of industrial tea-leaf-fiber (TLF) waste material for sound absorption purposes was also investigated (Ersoy and Kucuk, 2007). Here, it was found that a 1 cm thick tea-leaf-fiber waste material with backing provides sound absorption which is almost equivalent to that provided by six layers of woven textile cloth. The sound absorbing characteristics for Arenga Pinnata also had been investigated (Ismail et al., 2010). Here, the results showed that sound absorption...
coefficients of *Arenga Pinnata* were good from 2000 Hz to 5000 Hz within the range of 0.75 – 0.90 and the optimum sound absorption coefficient was obtained from the thickness of 40 mm. The promising potential of coconut coir reinforced with recycle rubber also has been highlighted (Mahzan et al., 2010). These findings show that natural fibers have high potential to be applied as raw material of sound absorbing materials.

Nowadays, Malaysia is one of major oil palm producing country. Huge areas in Malaysia were planted with oil palm tree. The economic life of the palm oil lasts only 25 to 30 years which are the suitable time and long lasting to earn a lot of profit. Among the part of oil palm, there was a part that usually being wasted and abandoned at the plantation. Beside fronds and empty fruit bunch, there was mature (unproductive) male flower of palm oil tree as show in Figure 1(a) and Figure 1(b). The male flowers are grouped in spikes and female flowers form other spikes. The male flowers only were used to fertilize the female flowers. After that, female flower as shown in Figure 1(c) turned into a cluster of fruit and male flower dried and bio-degraded.

Currently, there were still a lot of outstanding issues can be observed on using palm oil flower spikes to be implemented as raw material for sound absorbing panel. In addition, the acoustic data for POMFS fiber also had not yet been published. Hence, this research is carried out to investigate the potential use of palm oil male flower spikes (POMFS) in replacing synthetic and mineral based fibers for sound control applications.

![Spikes of male flowers](a)
![Male flower](b)
![Female flower](c)

Figure 1. (a) Oil palm male flower spikes (FAO, 2013); (b) male flower (The Star Online, 2013); (c) female flower (The Star Online, 2013).

**METHODOLOGY**

**Fibre Preparation**

Mature Palm Oil Male Flower Spikes in Figure 2(a) was harvested at area of Senggarang, Batu Pahat, Johor, Malaysia. The collected POMFS were cleaned and naturally dried for 12 hours. Then, the threads of fibers were extracted by hand pull out process since there was no available machine can be used. After that, the extracted fibers were washed in the running water to clean the fibers from the dirt and any particle. POMFS fibers were treated 10% of NaOH solution for 24 hour and then washed under the running water. Then the fibers were oven dried at 80-90 °C for 24 hours to remove moisture as shown in Figure 2(b). The POMFS fibers were cut into short length between 5 mm to 10 mm using the Granulator Machine as shown in Figure 2(c).
Figure 2. (a) Oil palm male flower spikes: POMFS; (b) treated and oven dried POMSF; fiber (c) short POMFS fiber.

**Mould Preparation**

Cylinder tube shape aluminum mould was fabricated to prepare the test sample as shown in Figure 3. The mould was fabricated in tube cross section with dimension of 100 mm inner-hole diameter and the height of 55 mm in order to form the testing sample. The mould was fabricated with Allen-key screw lock at top and bottom cover for easy process to pull off the sample.

Figure 3. Mould for sample preparation.

Figure 4. (a) Sample Preparation and Sample of (b) 5 wt% POMFS; (c) 10 wt% POMFS; (d) 15 wt% POMFS; (e) 20 wt% POMFS; (f) 25 wt% POMFS.
Sample Preparation

Sample was fabricated in 100 kg/m$^3$ density with dimension of 100 mm diameter and 35 mm height. Release agent (wax) was applied to the surface of mould for six times to facilitate the removal of the finished part. POMFS fibers were evenly mixed with polyurethane (PU) as a binder to produce the composite. Processed POMFS fibers and Polyurethane (Isocynate and Polyol) were weighted according to the testing percentage. Overall target of material weight is 29.138 g. The composite panels were fabricated with increment of POMFS fiber weight percentage of 5 wt%, 10 wt%, 15 wt%, 20 wt% and 25 wt%. The weight ratio of mixing Polyol and Isocyanate is 100:110. Fibers and Polyurethane were mixed evenly then poured into the 30 °C oven pre-heated mould. Mould was directly closed by tightening the screws. Then, the mould was cooled down at room temperature in 4 hours. Finally, the samples were prepared in two diameters which are 100 mm for low frequency and 28 mm for low frequency. The samples were also cut in three different thicknesses which are 8 mm, 25 mm and 35 mm. The dried release agent (wax) must be removed from the sample surface. Figure 4 shows the sample fabricated in this study.

Acoustic Testing

The acoustic properties of palm oil male flower spikes fiber reinforced polyurethane studied in this work were sound absorption coefficient ($\alpha$) and calculated noise reduction coefficient (NRC). Impedance Tube method was used to measure the sound absorption coefficient in accordance with ASTM E1050-98. The sound absorption measurement was done by varied the thickness of 8 mm, 25 mm, and 35 mm. The measurement process was done from frequency 87.5 Hz – 6206.25 Hz. The equipment used is located in Noise and Vibration Laboratory, Faculty of Mechanical and Manufacturing Engineering, Universiti Tun Hussein Onn Malaysia as shown in Figure 5.

![Figure 5](image)

Figure 5. Sound absorption coefficient measurement set up (Impedance Tube).

Sound absorption coefficient is obtained from the test using impedance tube which have two complete measurement set-ups at low frequency ranged from 1 to 1600 Hz and high frequency ranged from 1601 to 6000 Hz. Low frequency using large tube for the 100 mm diameter and maximum thickness of 200 mm. Otherwise, high frequency using tube for the 28 mm diameter and maximum thickness of 200 mm. Further analysis had been done by calculating the Noise Reduction Coefficient (NRC).
Mechanical and Physical Test

The compression test was done according ASTM D695 to determined behavior of materials under compressive loads. The specimen is compressed and deformation at various loads is recorded. Compressive Young Modulus was measured at the slope of the graph stress-strain graph. The sample with diameter of 100 mm and 25 mm of thickness had been used for the test. The load that we used is 10 kN and the stroke per unit time is 0.01 mm/sec. Then, porosity test was conducted to measure the percentage of voids in the material. Density value also been measured. All properties had been discussed to observe the composite acoustics performances.

RESULTS AND DISCUSSION

Sound Absorption Coefficient (α) analysis

Sample of 8 mm thickness results shows that the highest sound absorption coefficient was come from sample 25 % of POMFS fiber which is 0.800763 at 4103 Hz as shown in Figure 6. For the sample with 15 wt%, 20 wt% and 25 wt% of POMFS fiber at 8 mm thickness, it shows good sound absorption coefficient which above 0.5 at frequency range from 3000 Hz until 6000 Hz. Besides, sound absorption coefficient (α) result for sample with 25 mm thickness shows that the highest sound absorption coefficient is come from sample using 15 wt% POMFS fiber which is 0.858123 at 2053 Hz as shown in Figure 7. Furthermore, sample with 35 mm thickness results also shows that the highest sound absorption coefficient recorded by sample using 15 wt% POMFS fiber which is 0.761751 at 1603 Hz as shown in Figure 8. Sample with 5 wt% and 10 wt% POMFS fiber shows low sound absorption characteristics for various samples. Sample with 20 wt% POMFS fiber only shows good absorption characteristics while using 8 mm thickness. Thus, sample with 15 wt% and 25 wt% of POMFS fiber shows good and promising potential of sound absorption characteristics.

![Graph of Sound Absorption Coefficient vs Frequency](image)

Figure 6. Sound Absorption Coefficient, α versus Frequency, Hz for 8 mm thickness of the samples.
Figure 7. Sound Absorption Coefficient, $\alpha$ versus Frequency, Hz for 25 mm thickness of the samples.

Figure 8. Sound Absorption Coefficient, $\alpha$ versus Frequency, Hz for 35 mm thickness of the samples.
Noise Reduction Coefficient (NRC)

Based on the Table 1, the highest Noise Reduction Coefficient (NRC) is dominated by 15 wt% of POMFS fiber samples, and the lowest noise reduction coefficient is by 5 wt% of POMFS fiber samples. For the 8 mm thickness of samples, the highest noise reduction coefficient is shown by 25 wt% of POMFS fiber samples which is 0.1303. Otherwise, for the 25 mm thickness of samples, the highest value of noise reduction coefficient is 15 wt% of POMFS fiber samples which is 0.2447. 15 wt% of POMFS fiber also gets the highest value on 35 mm thickness of samples, which is 0.2055. The NRC for both sample of 5 wt% and 25 wt% POMFS fiber shows low sound absorbing characteristics. Thus, sample with 15 wt% and 25 wt% of POMFS fiber had a good potential of sound absorption characteristics.

Compressive Test

Table 1 shows the highest Young Modulus for compression is for 5 wt% of POMFS fiber at 0.0455 MPa and the lowest is 15 wt% of POMFS fiber at 0.0133 MPa. This is related to sound absorption for two compositions of samples shows that 5 wt% is the lowest value of sound absorption and 15 wt% is the highest sound absorption. This result is comparable with previous study that reported compression of fibrous mats decreases the sound absorption properties (Castagnede et al., 2000).

Density Test

Table 1 shows that density values was decreased when the weight percentages of POMFS fiber is increased. The highest density is 0.3662 g/cm³ shown by sample with 5 wt% of POMFS fiber and the lowest density is 0.0753 g/cm³ shown by sample with 25 wt% of POMFS fiber. The samples 15 wt% and 20 wt% of POMFS fiber also give lower densities which are 0.1212 g/cm³ and 0.1617 g/cm³ respectively. It was anticipated that the increment of POMFS fiber is increasing the pores inside the sample and decreased the density. The sample of 15 wt% and 25 wt% POMFS fiber has good sound absorption properties to be implemented as sound absorption panel with low density.

Porosity Test

Table 1 observed that the porosity is increased directly to the increment percentage of POMFS fiber in the samples. The highest porosity is 25 wt% of POMFS fiber at 29.71 % of porosity. The lowest of porosity is 5 wt% of POMFS fiber at 13.78 % of porosity. The sample 15 wt% of POMFS fiber is second highest at 21.05 % followed by 20 wt% of POMFS fiber at 18.12 % and sample 10 wt% of POMFS fiber at 15.74 %. It was found that porosity characteristics were inversely to the density characteristics. This condition was expected since the sample of 15 wt% and 25 wt% POMFS fiber shows good sound absorption coefficient and NRC. It was comparable with previous study that has reported in designing a nonwoven web that have a high sound absorption coefficient, porosity should increase along the propagation of the sound wave. (Shoshani and Yakubov, 2003).
Table 1. Testing Results of POMFS fiber reinforced PU composite.

<table>
<thead>
<tr>
<th>POMFS wt%</th>
<th>PU wt%</th>
<th>NRC</th>
<th>Sound Absorption Coefficient</th>
<th>Density, (g/cm³)</th>
<th>Porosity, (%)</th>
<th>Modulus Young, E (Mpa)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
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<tr>
<td>8 mm</td>
<td>25 mm</td>
<td>35 mm</td>
<td>8 mm</td>
<td>25 mm</td>
<td>35 mm</td>
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<td>5%</td>
<td>95%</td>
<td>0.0556</td>
<td>0.0619</td>
<td>0.0638</td>
<td>0.3545</td>
<td>0.3609</td>
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<tr>
<td>10%</td>
<td>90%</td>
<td>0.0825</td>
<td>0.0802</td>
<td>0.0546</td>
<td>0.3762</td>
<td>0.3493</td>
</tr>
<tr>
<td>15%</td>
<td>85%</td>
<td>0.1029</td>
<td>0.2447</td>
<td>0.2055</td>
<td>0.7961</td>
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</tr>
<tr>
<td>20%</td>
<td>80%</td>
<td>0.0929</td>
<td>0.1004</td>
<td>0.1611</td>
<td>0.7873</td>
<td>0.4605</td>
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<tr>
<td>25%</td>
<td>75%</td>
<td>0.1303</td>
<td>0.2124</td>
<td>0.1195</td>
<td>0.8008</td>
<td>0.6330</td>
</tr>
</tbody>
</table>

CONCLUSION

The composition of 15 wt% of natural POMFS fiber with sample thickness of 25 mm shows the optimum sound absorption coefficient and NRC compare to overall sample. Besides, sample of 35 mm of thickness and 15 wt% of POMFS fiber composition also show some potential as sound absorption panel. From the results of sample thickness of 8 mm, composite with 25 wt% POMFS fiber also shows good absorption characteristics. Porosity results shows increment pattern as the NRC and sound absorption coefficient was increased. Density and compressive strength results shows decreased pattern as the POMFS fiber composition and sound absorption coefficient was increased. The sound absorption coefficients were good from the medium to high frequency that is from 1600 Hz to 6000 Hz within the range of 0.76 - 0.86. Panel with 15 wt% POMFS with 25 mm thickness and 25 wt% of POMFS fiber with 8 mm thickness were proposed to be implemented for sound absorbing applications in certain frequency. These results indicated that Palm Oil Male Flower Spikes (POMFS) fiber allows further investigation opportunity and also shows promising potential to be used as raw material of sound absorbing material.

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REFERENCES


