Sound Absorption Characteristics of Sandwich Panel Made from Double Leaf Micro-perforated Panel And Natural Fiber

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Abstract. One of sound-absorbent developed nowadays, micro-perforated panel (MPP), effectively reduce reflected acoustic energy after approach the panel based on a Helmholtz-type resonance absorber. Some MPPs modifications have been applied to increase its performance, like the application of double-leaf MPP. Furthermore, the implementation of sound absorption materials made of natural fibers recently has invited more attention to some researcher because it is biodegradable, environmentally friendly, and economical. In this paper, a sandwich panel made of double MPP and natural fiber as sound absorptive material is investigated. The MPPs are made of a transparent acrylic board 1.5 mm thickness, 0.8 mm hole’s diameter with five mm hole distance in front panel, and five mm in the backing panel. Two different types of natural fibers panel; pineapple leaf fiber and oil palm fiber from empty fruit bunches are used in this sandwich. a low-cost impedance tube with double channel microphone is used to measure the sound absorption coefficients. It is found that the sandwich model changes the sound absorption characteristics of MPP by shifting the maximum absorption coefficient into the lower frequency and raising the absorption coefficient of the double MPP following its natural fiber panel absorption coefficient. The total impedance of sandwich gives the effect of decreasing the frequency peak of the absorption, and higher resistance of the fiber panel will increase the absorption coefficient and broaden the frequency peak.

1. Introduction

Concerning noise, its attenuation is becoming a significant issue nowadays. It is considered as one of the pollutants that not only from the annoyance point of view but also health problems and quality of life. The first way to control the noise is by attenuating it from the source by considering all possible noise generations during the designing process of a product. Unfortunately, so far, this design process has not entirely successfully eliminated the noise from its source. In this situation, the possible solution is to reduce the noise on its transmission path and the receiver side.

Sound-absorbent materials are then generally used to minimize the noise on its transmission path by reducing reflected sound hitting a hard or rigid interior wall or surface. The material absorbs some acoustical energy, and remain less part then is reflected. Various of sound absorptive materials are now available and developed. Recently, there have been two methods that commonly used and developed as the sound absorber panel, i.e. porous material and micro-perforated panel (MPP) [1,2]. Porous absorptive material is mostly categorized based on its microscopic structures; fibrous, cellular, and granular. Rock wool, glass wool, polyester, and polyurethane are fibrous materials that generally found in this application. Nevertheless, Their process of manufacture and application contributes to some unfavorable impacts to human and environmental health [3].
Therefore, researchers then give more attention to developing the use of natural fibrous material as sound-absorbent, because they are biodegradable, naturally renewable, and environmentally friendly. Several kinds of natural fibers have been investigated and developed as sound absorptive material, like palm oil male flower [4], kenaf, cork, hemp, cotton, wood, cane, cardboard, and sheep wool [5], the combination of rice husk grain and coconut coir [6], extracted pineapple-leaf fibres and empty fruit bunches of oil palm fiber [7]. Some researchers also developed natural fiber-reinforced composites to enhance the lack of the natural fiber’s mechanical and moisture properties [8, 9].

Furthermore, micro-perforated panels (MPPs) are investigated being able to absorb the sound energy effectively by composing of a big number of small Helmholtz resonators. While the sound waves enter an MPP, the sound energy is converted into the heat by the friction among the perforation surfaces and the moving air molecules. The idea of MPP was introduced first as an alternative for porous sound absorbers that remains the health and environmental problems [10]. However, MPPs are still working in specific frequency, and low absorption outside the resonance frequency range [11].

Various methods have been developed by many researchers to improve the frequency band, and sound absorption coefficient of MPP, such as inserting a mechanical impedance plate behind the panel [12], partitioning different depth cavities [13], combining with a structure consist of a membrane cell and mass blocks composite [14], and multi-layering elastic MPP plates [15]. Moreover, other researchers also proposed improvement by making the MPP from composite materials, such as wooden panels [16], kenaf and polylactic acid [17], and hybrid MPP combination with perforated date palm panel and porous layer [18].

Besides, pineapple leaf and empty fruit bunches of oil palm are two of the natural fiber source that abundantly available in many tropical countries. Pineapple leaf fiber, for example, has been used in some traditional applications like textile and home accessories. Because it’s some good mechanical properties, the fiber from oil palm also has a good chance to be developed commercially [14].

In this paper, the sound absorption characteristic of a sandwich panel made of a natural fiber material inserted between a pair of MPP panel is investigated experimentally. MPPs are made from a thin transparent acrylic panel with different sizes and density of the micro-hole. Two different types of natural fibers panel; pineapple leaf fiber and empty fruit bunches fibers of oil palm are used in this sandwich.

2. Measurement Method
2.1 Material

The fibers from pineapple leaf and empty fruit bunches of oil palm, firstly, are cleaned by spraying with mineral water and then drying naturally at room temperature. The sample panels are made in a 54 mm diameter cylindrical shape following the impedance tube diameter. The fiber panel is composed using a dies using a short PVC pipe. The thin layer of fiber is added into the dies, and a paper glue is dabbed by brush between the layers. The specimen is then compressed to obtain 20 mm of thickness. The glue then let dry naturally at room temperature. The density of the samples is shown in Table 1. Figure 1 shows the natural fiber panels and MPP. Pineapple leaf panel has more density than the palm empty fruit bunches one.

| The sample material       | Density (gr/cm³) |
|---------------------------|------------------|
| Palm empty fruit bunches  | 0.2328           |
| Pineapple leaf            | 0.3279           |

Then, two MPPs are made of a transparent acrylic panel with 1.5 mm thickness, 0.8 mm hole’s diameter and three mm distance between the holes in backing panel (MPP A), and 0.8 mm hole’s
diameter and five mm distance between the holes in front panel (MPP B). It means that the perforation ratio is about 0.056% for backing panel and 0.02% for the front panel. The sandwich panel is then made from two MPPs, and a natural fiber panel is inserted between the MPPs panel.

Figure 1. Fiber panel samples; pineapple leaf fiber panel (left), and empty fruit bunches fiber (middle) and acrylic MPP (right).

2.2. Experimental setup
A low-cost impedance tube with double microphones with a 54 mm inner diameter made of aluminum pipe is used to conduct the measurements within a frequency range of 200 Hz to 3000 Hz like illustrated in Fig. 2. The testing set up is designed based on ASTM E 1050. The load speaker generates chirp sound within a frequency range of 100 Hz to 10 kHz as a sound source. The sound pressure is measured by two BSWA microphones MPA 215 type with each sensitivity factor 43.7 Pa/mV and 51.2 Pa/mV. These two microphones are then connected to the NI 9234 data acquisition. Firstly, the impedance tube calibration is conducted using Rockwool 45 with a density of 45 kg/m\(^3\) and 40 mm thickness. The coefficient of sound absorption is then obtained by the transfer function of two microphone channels. The sample panel composition set-up is depicted in Fig. 3.

Figure 2. Double microphones channel impedance tube set up.

There are three compositions of panels reported in this paper, as illustrated in Fig. 3. The first is fiber panel only (Fig. 3a), double leaf MPPs where MPP A is set to make five mm air gap in front of the rigid plunger and the MPP B is allocated 20 mm in front of MPP A and directly faces the sound source (Fig. 3b), the sandwich panel by inserting fiber panel between the MPPs. The change of the sound absorption coefficients between the various set-up they will be observed.
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3. Result and Discussion

The sound absorption coefficient of both fiber panels is depicted in Fig. 4. The sound absorption characteristic of pineapple leaf fiber, in general, is seen higher than empty fruit bunches of oil palm, especially at up to 3000 Hz observed frequency range. The maximum absorption coefficient approach 100% at frequency of 2200 Hz. On the other hand, empty fruit bunches panel only has up to 93% sound absorption but shows a tendency to increase or keep constant at higher frequency. Moreover, both panels shows very low absorption coefficient at less than 500 Hz, and some noisy signal appears in this impedance tube measurement.

It is found that material density contributes more effect on the absorption properties. Higher fiber density and thickness of the panel increase its absorption coefficient. More fibers available make more
energy of sound pressure trapped within the panels and raise the absorption coefficient. The fiber size of both natural sources observed under the microscope are depicted in Fig. 5. It is shown that the empty fruit bunches oil palm fiber has larger diameters, more empty volume, and low density. On the other hand, pineapple leaf fiber is shown has uniform fiber size and higher density. The fiber diameter and density will affect the ability of the fiber panels to absorb the acoustic wave energy that hits its surface. Moreover, More dense fiber in panel increases the resistance of airflow by the viscosity friction through the air molecule's vibration. Therefore, when a sound wave enters the fibers, the wave amplitude is reduced by friction like the waves trying to move through pass the tortuous passages. Therefore, the acoustical energy then is converted into heat [1].

Figure 5. The fiber size of empty fruit bunches oil palm (left) and pineapple leaf (right)

Then, the sound absorption coefficients of MPP and palm empty fruit bunches fiber panel are depicted in Fig. 6. Double leaf MPPs in this model have a deficient ability to absorb the sound energy, only up to on the characteristics of MPPs themselves, air cavity between the leaves, and air gap backing the MPP [19]. However, in this paper, the MPPs are setting in constant. On the other hand, the palm fiber panel may absorb more than 93% at 2500 Hz and more. The sandwich panel reduces the frequency peak into 1000 Hz, with sharp peaks and a maximum 93% sound absorption.

Figure 6. The sound absorption characteristic of MPP and empty fruit bunches fiber sandwich panel.

Likewise, the sound absorption coefficients of MPP and its sandwich panel with pineapple leaf fiber are shown in Fig. 7. The pineapple leaf fiber panel has an almost 100% sound absorption coefficient at 2200 Hz. The sandwich panel reduces the frequency peak into 800 Hz, with very sharp peaks and a maximum 100% sound absorption.
Firstly, a multiple-leaf MPP idea was proposed by Maa [10] using a double-leaf MPP and a rigid-back wall behind the air-cavity. This model produces two resonators to get a wider range of frequency absorption. Nevertheless, when MPP has a back wall, sound absorption occurs only by the Helmholtz resonance, and the absorption is restricted in the region of its resonance frequency [19]. In some conditions, the sound absorption is not only limited in a sharp frequency range but also produces a lower absorption coefficient.

Previously, in general, it was known that the fiber panels, including natural fibers, have good sound absorption coefficients at a higher frequency. Furthermore, a wider gap of air cavity MPP has a lower frequency peak of the sound absorption. In Fig. 6 and 7 can be observed that the sandwich panel of both using two types of natural fiber increases the absorption capacity at a lower frequency. It means that the frequency peak of the absorption coefficient is shifted into a lower frequency. Therefore, when the acoustic resistance of the double-leaf MPP is not good at low frequency, inserting the fiber panel will be significant to increase the absorption performance.

When the fiber panel that kind of a porous layer is inserted in the air cavity between the MPPs, the absorption may be deteriorated by the large acoustic resistance due to the porous absorbent. The effect is not only to increase the acoustic resistance, but also to the impedance. The total impedance of front MPP, fiber panel, backing MPP, and air cavity give the effect of decreasing the frequency peak of the absorption. When the resistance of the fiber panel is higher at a wider frequency band, it may be expected that a fiber panel can broaden the frequency range of absorption of the sandwich panel by the additional damping by the porous absorber.

4. Conclusion
The measurement and analysis of the sound absorption coefficient of sandwich panels made from the double-leaf micro-perforated panel and pineapple leaf and empty fruit bunches of oil palm fiber have been done. From the result and discussion, it is found that the sandwich model of double-leaf MPP inserted by natural fiber changes the sound absorption characteristics of MPP by shifting the maximum absorption coefficient into the lower frequency and increasing the absorption coefficient of double-leaf MPP into the maximum absorption in accordance to the maximum absorption coefficient of its natural fiber panel. The total impedance of sandwich gives the effect of decreasing the frequency peak of the absorption, and higher resistance of the fiber panel will increase the absorption coefficient and broaden the frequency peak.
5. References

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