Sound Absorption Coefficient of Coir Fibre with Poly-Lactic Acid (PLA)

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ABSTRACT

This project involves the study of the sound absorption coefficient of a composite material made from coir fibre reinforced with poly lactic acid (PLA). Sound absorption coefficient, α is the value of sound that the material can absorb. This study was conducted to investigate the sound absorption properties of coir fibre composite based on the different values of coir fibre ratio. It also determined whether the coir fibre composite is suitable or not to be used as noise level reducer in the spaces like room or hall. The sound absorption coefficient's values of the test specimens for low and high-frequency bands were determined experimentally using the impedance tube method or known as two-microphone transfer function method with the range of frequency around 500-4500Hz by referring to the ISO 10534-2 standard procedure. The result of the sound absorption coefficient was processed using Audacity software and LDS Dactron Photon signal analyser while the results were presented in graph form using MATLAB. The characteristics of the sound absorption coefficient for each coir fibre ratio were discussed based on the range of frequency used. For the specimen with higher fibre ratio, it had a higher value of alpha, α compared to the lower fibre ratio. In

ISSN 1823- 5514, eISSN 2550-164X

Received for review: 2017-05-09
Accepted for publication: 2017-10-10
Published: 2018-04-15

conclusion, the specimen with the highest amount of fibre ratio has better sound absorption coefficient which the value is 0.98 compared to the specimen with lowest fibre content which is 0.3. Thus, higher fibre content is more suitable to be used as a noise level reducer.

Keywords: *Sound absorption coefficient; Coir fibre; Poly lactic acid; Impedance tube.*

Introduction

Noise pollution is one of the pollutions that exists in the surrounding comes from the unwanted sound that interrupts people. Because of the noise disturbance, the choice of material to solve the problem should be chosen correctly. There are several groups of material available that can be used to tackle the noise and vibration control problems. They are absorbing material, barrier material, vibration damping material and silencers. The most common type that being used to control the noise in the closed spaces like room and hall is the absorbing material. The properties of most sound absorbing materials are usually porous as they allow adequate sound energy to transmit them to be dissipated. Presently, most of the sound absorption materials use in architectural and industrial noise are mineral and fibre glass. But using this material as absorption material also encounter several limitations too. For example, the uses of asbestos are quite dangerous because it can lead to skin irritation and health problem. Other than that, the cost to import the material from the abroad is very high [1].

Natural fibre is the alternate material to replace the synthetic fibre. Since the natural fibre is a bio-gradable material, it always being chosen to be used in many applications as people are very much concern about the environment nowadays. Besides, most of the natural fibres usually have a high amount of porosity that can influence the acoustic properties of the materials. There is various studies regarding the sound absorption coefficient characteristic using different types of natural fibres and the results are quite encouraging. Koizumi [2] stated that the used of bamboo fibre as the sound absorbing material giving the acoustic properties that are almost similar to the glass wool. Next, Abdul Hakim and others [3] also study the acoustic properties of natural fibres consist of banana stem fibre and sugarcane baggase fibre. The results of the sound absorption value from the hybrid composites are around 0.6 to 0.75 at a frequency of 2000-2500Hz. Besides, the result of the sound absorption study of industrial tea leaf fibre waste done by Sergin and Haluk [4] also showed a good outcome which is the tea leaf fibre waste able to absorb around 0.9-0.98 between the frequency of 2400-4000Hz. Other than that, Rozli [5] also conducted the experiment for comparing the acoustic properties between coir fibre and oil palm fibre and stated that oil palm fibre obtained 0.78 to 0.97 from frequency range 1000Hz to 5000Hz while the coir fibre gained 0.77 from frequency of 2000Hz to 5000Hz.

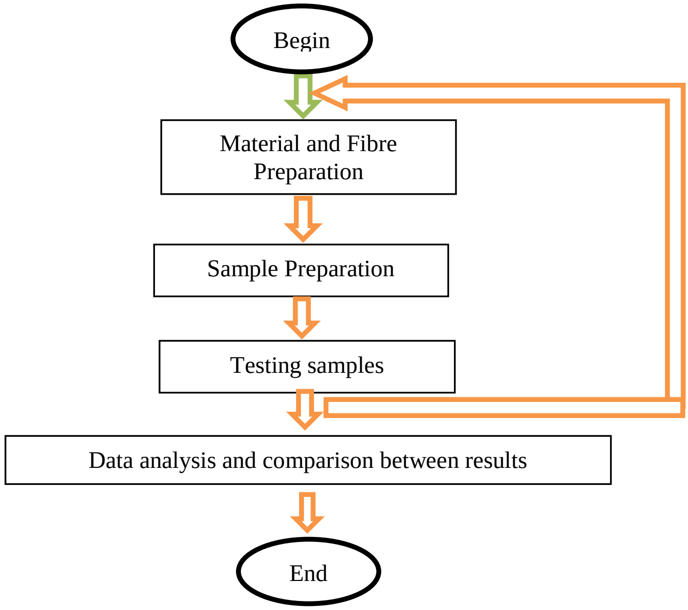

Fig. 1 Flow Chart of the project

For this project, the coir fibre is selected and the fibre can be obtained from the coconut husk. There are many beneficial factors that make the coir fibre a versatile material. Coir fibre is one type of industrial waste that is available abundantly. It is renewable source, non-abrasive and the price is quite reasonable. Besides it is not harmful to health and does not has safety issues when process and handle it [6, 7]. Each of the coir fibre contain the cavity that located at the center of the fibre cell functioning as the acoustic and thermal insulator. Then the coir fibre will be reinforced with the poly-lactic acid (PLA). PLA is a semi crystalline, thermoplastic and hydrophobic polyester. It is also a bio-gradable material that can be recycle and replace the synthetic polymers [8]. The coir fibre reinforced with PLA will become environmental friendly composite material since both of the fibre and matrix is bio-gradable.

Methodology

Fig. 1 shows the project flow chart throughout the research.The project begins with material and coir fibre preparation which means dividing the fibre content into three fibre ratios category. 10 %, 15% and 20% coir fibres were prepared in order to have the significant result. As the sample binder composite, Poly-Lactic Acid (PLA) was used for each samples. Next, the mold preparations of 33 mm precisely were equipped. As for the specimen preparation, both fibre and the binder; PLA were mixed together and three samples have been properly fabricated. After all the preparations acquired completed, a test should be carried out. Specifically, the impedance test was needed to be accomplished in this project in order to determine the sound absorption coefficients. If the testing was not satisfied and followed the expected results, it should be tested again until satisfied results acquired. Lastly, the results will be gathered and analysed.

Materials and fiber preparation

For the material preparation, the materials used for the project were divided into two part. The first part was the preparation of the fibre material which is the coir fibre. The coir fibre was extracted from the husk of the coconut fruit. Husk or known as mesocarp is the thin or dry layer that covers some seeds and fruits. The coir fibre was cut into smaller sizes for easing the handling process when mixing with the PLA. After the fibre was cut into smaller size, the density test was done to determine the standard density of the coir fibre. The average density of the coir fibre was about 1.232g/cm^3.

For the second part was the preparation of the matrix. The type of matrix used for the the composite is the PLA LANDY PL-1000 that came from the Miyoshi Oil & Fat Co., Ltd. The PLA was in emulsion form. The study on how to use the emulsion type PLA was also done before mixing it with the coir fibre.

(a) (b)

Fig. 2: (a) PLA (b) coir fibre

Sample preparation

The samples of the coir fibre composite were prepared after all the material to be used were obtained. First was the preparation of mold used for molding the mixture of the coir fibre and PLA. Aluminum plate was chosen to be used as the molding material with the thickness of 10mm. The cross section of the circular molding dimension was 33mm diameter. The mold was cut into the circular shape for easing to fit the sample into the impedance tube for measuring both low and high frequency sounds.

Next, the volume for 33mm diameter circular shape mold was calculated. Then, the weight of the coir fibre to be used based on the density were calculated based on the selected ratio which were 10%, 15% and 20% from the volume fraction of the circular mold. After the weighing process done, the coir fibre was mixed together with the PLA and being soaked for 15 minutes. After 15 minutes, the coir fibre composite was squeezed to let the excess PLA out before being placed on the mold. Next, the composite was compacted on the circular mold. Followed by drying the composite at 50°C for 24 hours by using the drying oven.

Fig. 3: The coir fibre was soaked in the PLA

Fig 4: The specimens of coir fibre composite

Sound absorption test

The test was set up using two microphones-transfer function method. The circular shape specimen of 33mm diameter was placed inside the impedance tube machine for testing. The impedance tube will measure for both low and high frequency sound. The test was run on the impedance tube based to ASTM E1050-98. The two microphones used for the test had to be calibrate using sound calibrator from the speaker for 114dB [3]. The calibration was done to rate the acoustic absorption of the gauge frequency value set for 0 to 1. Others required sources were connected with each others before the experiment was started. Once the sample was placed inside the tube, the piston was moved gently outward until the sample was reached the aligned of the tube edge and the outer surface of the material does not exceed the tube's edge. The frequency for the tube was set up from 500Hz to 4500Hz. The sound waves obtained were translated into the digital signal using Audacity software that functions in conjunction of signal analyzer LDS Dactron Photon that act as the server that connect the impedance tube and the computer. The output of the results were saved in graph form using MATLAB software.

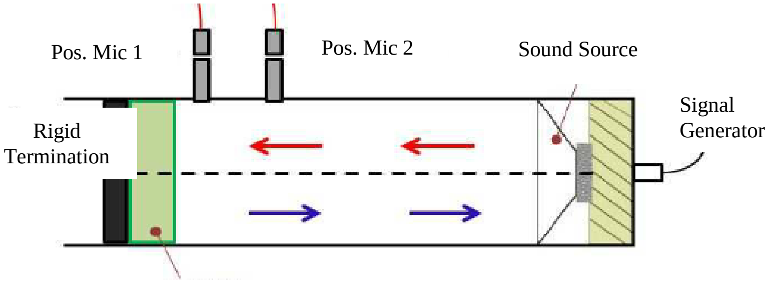

Fig. 5: Schematic diagram of impedance tube [9]

Results and Discussion

Sound Absorption Coefficient

From Fig. 7 it was shown that the 20% of coir fibre sample had the highest sound absorption coefficient compared to the 15% and 10% of coir fibre samples. The value of the highest peak was 0.98 at the frequency of 4500Hz approximately. On the other hand, the least fibre content which was 10% gave the lowest value of sound absorption coefficient compared to the others. The lowest value was at the frequency of 1500Hz with 0.05 coefficient value. All three samples were decreased gradually from 500Hz until 1500Hz within the range of 0.3 coefficient to 0.05.Then, from 1500Hz onwards the coefficient rose steadily for sample b and c, whereas the a sample increased slightly before it dropped again at frequency of 3000Hz. However from that frequency ahead, the a sample coefficient growth rise about 0.3 of sound absorption. At the frequency of 3900Hz, the sound absorption coefficient graph for b and c samples were having the same alpha, α which is 0.94. Both of sample b and c give better sound absorption coefficient at the high frequency region compared to low frequency region.

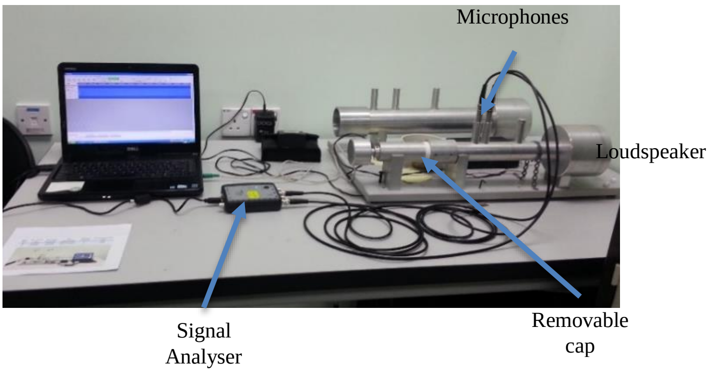

Fig. 6: The setup of impedance tube

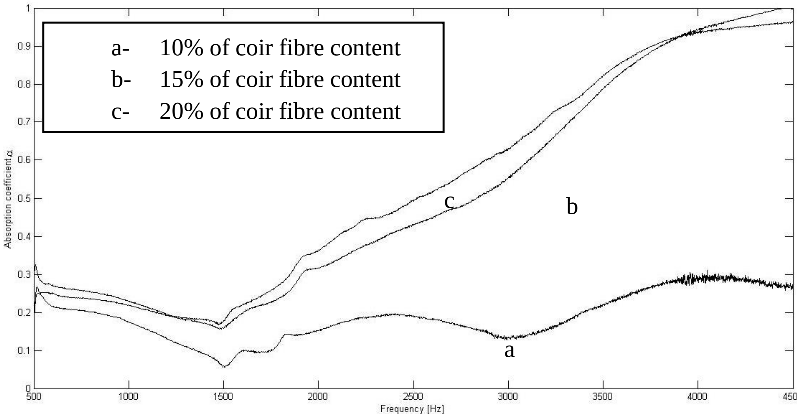

Fig. 7: Sound absorption coefficient versus frequency for three fibre ratio

The sample c had the highest sound absorption coefficient compared to sample a and sample b. It is because the sample was sightly thicker than the other two samples. For sample a, it was more thinner compared with others. By increasing the thickness of the sample, it actually can enhance the sound absorption for the low frequency region. The sample with increased number of thickness can caused the incident sound waves to lose more energy as they take longer path through the sample. When the sample is thicker, the interrupted sound waves have to experience extended dissipative procedure of viscosity and thermal conduction in the air inside the composite sample [10]. Due to the thicker sample used, hence porosity presence might be higher too. The size, type and amount of pores of porosity is a significant influences to the sound absorption properties of porous materials. The sound wave will enter the porous material and dissipated it by friction. Therefore, the amount of of pores on the surface should be enough to allow the sound pass through and get dampened [11].

There are several ways to improve the performance of the sound absorbing material. Reducing the diameter of the fibre can influence the sound coefficient because it can increase the fibre content in the sample, hence increase surface area of the sample as well. Therefore, the sound energy is loss more due to the viscous friction of air molecule with the greater surface area. This is because it will increase the sound absorption coefficient value for the lower frequency region [10]. The sound absorption also can be improved by increasing the bulk density of the material as it had extra matrix material [12]. In addition, increasing the air space behind the specimen can help to enhance the performance of the sound absorption properties of the sample [3].

In Fig. 8, the effect of air gap to the sound absorption coefficient can be seen from the graph. When adding the air gap behind the sample, the sound absorption for the low frequency region also increased. By implementing the air gap concept, higher sound coefficient can be absorbed including the low region frequency as well. Good sound absorption coefficient depends on the longer air gap length applied.

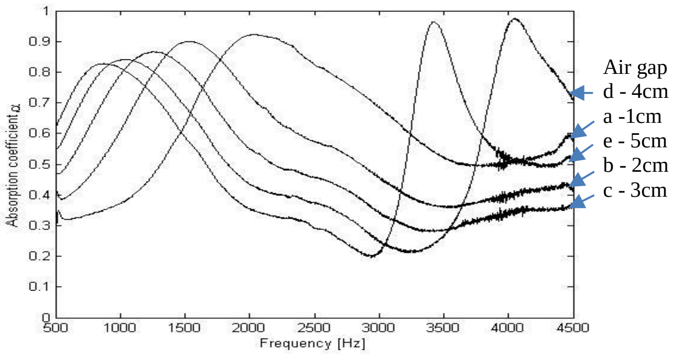

Fig. 8: Sound absorption coefficient versus frequency for 20% fibre ratio with air gap implementation

Conclusion

As a conclusion, the maximum sound absorption coefficient for the 10% fibre content sample is 0.3. For 15% fibre content, the highest sound can be absorbed is 0.96 while for the 20% coir fibre ratio gave the maximum value of 1 sound absorption coefficient. In this research, the best sound absorber would be the 20% coir fibre ratio due to its highest absorption property. The coir fibre can be used as the sound absorber material to replace the synthetic material such as glass wool which is widely have been used nowadays. Besides, the PLA which is environmental friendly material is also appropriate to be used as the binder for the composite of the three different fibre ratios which are 10%, 15% and 20%. The application of coir fibre composite could be used as a sound absorber in the room or hall. All of the samples are being characterized using the impedance tube in the Dynamic lab. For future, more research should be done intensely in order to pursue a better understanding of composite properties for coir fibre reinforced with PLA.

Acknowledgement

The authors would like to thank the Research Management Institute (RMI) of Universiti Teknologi MARA (UiTM) and Ministry of Education, Malaysia for financial support and facilitating this project support to this study through Research LESTARI GRANT awards 600-RMI/DANA 5/3 (43/2015).\\

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