The Application of Coconut Fiber as Dissipative Silencer

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Abstract. *Heat ventilation air conditioning system (HVAC) is one of the ducting systems that broadly applied in the building. There are HVAC silencers in the market, however the sound absorptive material commonly used is mineral wool. In this research study, a sound absorptive material made of coconut fiber was tested to identify its performance as a potential replacement of green material for ducting silencer. The experiment was carried out in a testing apparatus that follows the BS EN ISO 11691:2009 standard. Different configurations of sound absorptive material and contents of coconut fiber were investigated in the study. The trend of insertion loss at 1/3 octave frequency was identified where at frequency below 3000Hz, the insertion loss of dissipative silencer is observed high at certain frequency with a very narrow range. At 3000Hz, the insertion loss of 4dB to 6dB is constant until 4000Hz and drops until 5000Hz before it increases again steadily up to 13dB at 10000Hz. A similar trend was observed for different configuration of sound absorptive material. Despite the configuration different, the outcome shows that the insertion loss is increasing with higher content of coconut fiber.*

1. Introduction
Heat ventilation air conditioning system (HVAC) is a ducting system that commonly found inside the building. HVAC system serves the purpose of making the people inside the building feel comfortable by moving the air for cooling or heating which is depends on the weather of the area. However, the HVAC system at the same time will produce noise that makes people feel uncomfortable. The sources of noise are from fan, passage of air through straight ducts and impact of air flowing through components such as elbows, branches and mixing boxes [1].

This is where a dissipative silencer required to be installed in HVAC duct systems in order to reduce noise transmitted through the ducting system. The principal advantages of this device are: (1) provides good absorption at medium and high frequencies, and (2) useful for narrow and broadband noise [2]. Theoretically, silencer works by transforming partial of incident acoustic energy into heat by causing motion in silencer's sound absorbing material when the sound passing through the silencer [3]. This device typically contains fibrous or porous materials and it is commonly made from mineral wool.

On the other hand, coconut fiber is a renewable resource and it is a CO_2 neutral material. The coconut fiber is abundant in Malaysia and the price also is very cheap. In contrast to mineral wool and other polymer materials, coconut fiber is biodegradable, low in density, good mechanical properties and light weight [4,5]. The fiber's structure is determined by the dimension and arrangement of various unit cells. Lumen is a central hollow cavity that located at transverse section of the unit cell and it serves as an acoustic and thermal insulator because its presence decreases the bulk density of the fiber.

Of all natural fibers, coconut fiber has a good ability to absorb noise in which the absorption coefficient was found to be 0.42 at frequency 500 Hz [6]. The thickness and the spacing of this absorptive material are critically important as these can affect the performance of the silencer. Hence, this work is carried out to investigate the potential of using coconut fiber as a raw material for sound absorptive material in the ducting system. The performance of fabricated dissipative silencer made of coconut fiber with different configurations and fiber content are determined in the study. The outcome of the study can help in further utilize the use of natural fiber material and at the same time reduce the cost of purchasing the dissipative silencer that made of other materials which are more expensive than the natural fiber of coconut.

2. Experimental Set Up

2.1. Design of Experiment
The apparatus setup and testing was conducted based on the BS EN ISO11691:2009. The testing apparatus are made of Perspex which consists of two test duct and one silencer duct where the sound absorptive material is arranged inside the silencer duct. The cross section of the testing apparatus is 150 mm x 150 mm. The length of test duct and silencer is 875 mm and 200 mm respectively. The molds are made of mild steel with dimension of 155 mm x 205 mm x 15 mm.

In the making of the sound absorptive materials, a certain amount of coconut fiber is put inside the mold. The coconut fiber is compressed so that it takes the shape of the mold with the same dimension. The fiber is removed from the mold. The mass that used are 30grams and 60grams but the sound absorptive materials that produced are the same dimension. The sound absorptive material is tested in the impedance tube to determine its ability to absorb noise at various frequencies.

2.2. Experimental Procedure
There are various type of configuration of dissipative silencer such as lined duct, splitter silencer and bar silencer. Each of these configurations has its own advantages and disadvantages. The dissipative silencer has the ability to filter out the acoustic energy over a wide range of frequencies [7]. In this study, the sound absorptive materials are arranged in the silencer duct with different configuration (5 pieces, 4 pieces, 3 pieces, 2 pieces and 4 sides). Noise is generated inside the test tube. The TES sound analyzer is used to collect the data of noise at frequency of 1/3 octave. The data collected in the TES sound analyzer is transfer to the computer. The data taken is interpreted into visual form for better analysis.

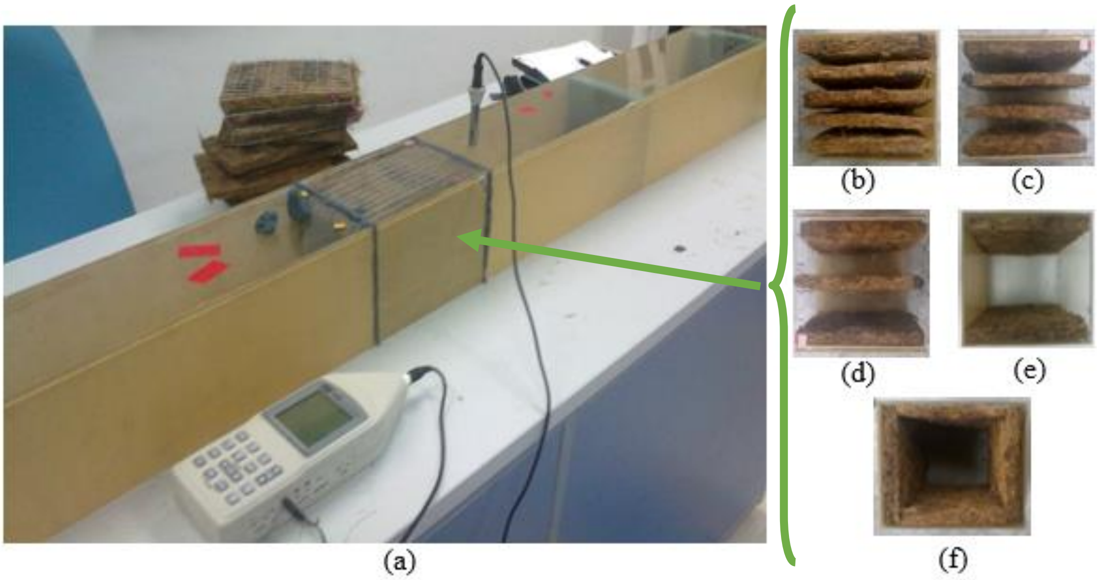

Figure 1. (a) Experimental setup; (b) 5 pieces configuration; (c) 4 pieces configuration; (d) 3 pieces configuration; (e) 2 pieces configuration; (f) 4 sides configuration

3. Results and Discussion

Basically, there are two comparison that are made. The first comparison is the insertion loss of silencer of sound absorptive material with same content of coconut fiber at different configurations. The second comparison is the insertion loss of silencer with same configuration with different content of fiber.

Figure 2 shows the result of noise inside duct before installed the silencer. The result comparison of silencer with same content of coconut fiber at different configurations, and same configuration but different fiber content can be seen in Figure 3 to Figure 7, and Figure 8 to Figure 11 respectively.

From the experiment, the trends insertion of sound absorptive material silencer with 60g fiber but with different configuration are identical. From Figure 3, we can see the insertion loss at below 3000Hz has very narrow range where the insertion loss is high at certain frequency only. Figure 4 shows that at 3000Hz, the insertion loss is constant until 4000Hz and decrease until 5000Hz. After 5000Hz, the insertion loss increase steadily until 10000Hz.

The trends of the insertion of silencer of sound absorptive material with fiber content of 30g with the configuration of 5 pieces, 4 pieces, 3 pieces, 2 pieces and 4 sides silencer is same with fiber content of 60g where the insertion loss at below 3000Hz has very narrow range where the insertion loss is high at certain frequency only. At 3000Hz, the insertion loss is constant until 4000Hz. After that, the insertion loss decrease until 5000Hz. After 5000Hz, the insertion loss increase steadily until 10000Hz.

The differences of all these configuration of 5 pieces, 4 pieces, 3 pieces and 2 pieces silencer shows that the more sound absorptive material in the silencer, the higher the insertion loss. While the trend of the silencer with configuration of 4 sides is same as other except for the insertion loss after 8000Hz where the insertion loss of the 4 sides configuration become stable and constant (Figure 11).

From the observation that made on both experiments above, we can conclude that the more sound absorptive material in the silencer, the higher the insertion loss.

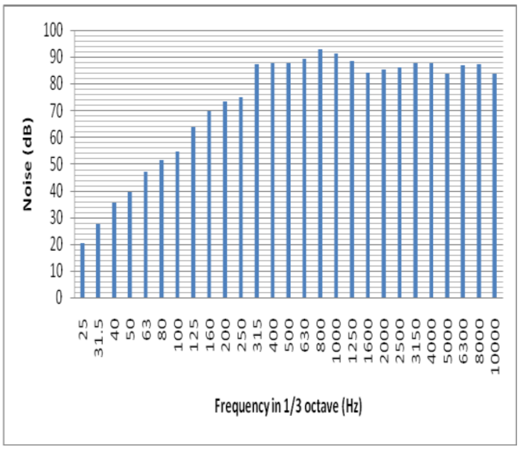

Figure 2. Graph of noise before insertion of silencer versus frequency (Hz) in 1/3 octave

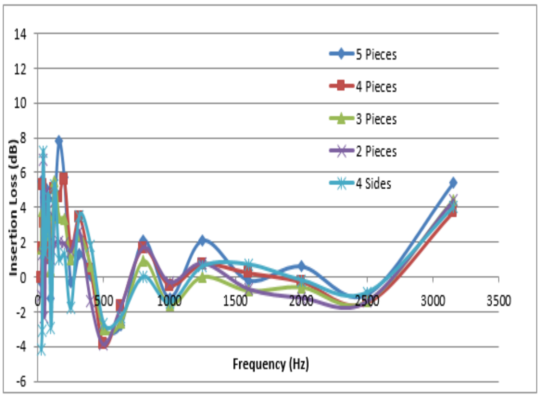

Figure 3. Comparison of Insertion Loss for all 60g Sound Absorptive Material at frequency below 3150Hz

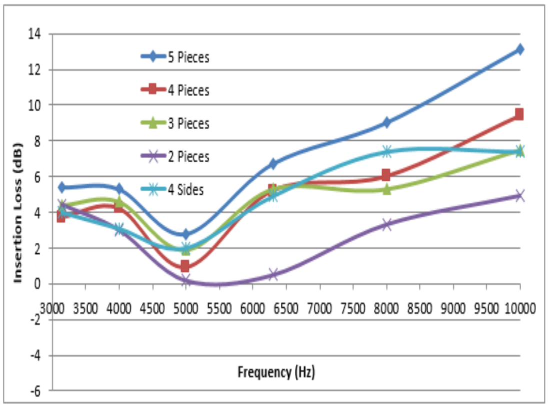

Figure 4. Comparison of Insertion Loss for all 60g Sound Absorptive Material at frequency above 3150Hz

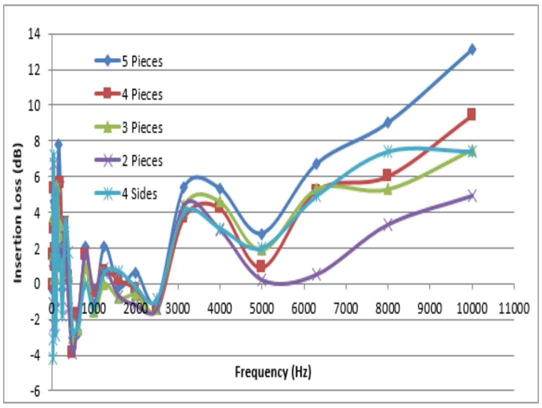

Figure 5. Comparison of Insertion Loss for all 60g Sound Absorptive Material in 5 Pieces Configuration

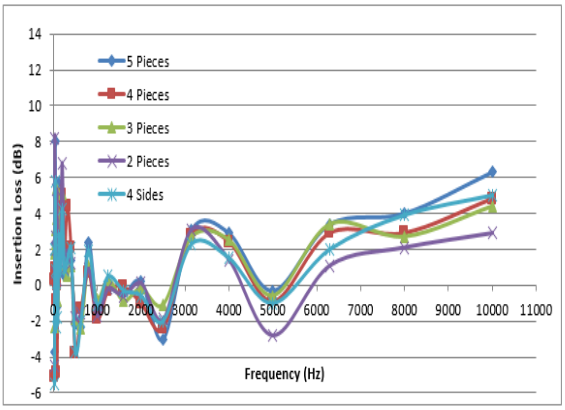

Figure 6. Comparison of Insertion Loss for all 30g Sound Absorptive Material

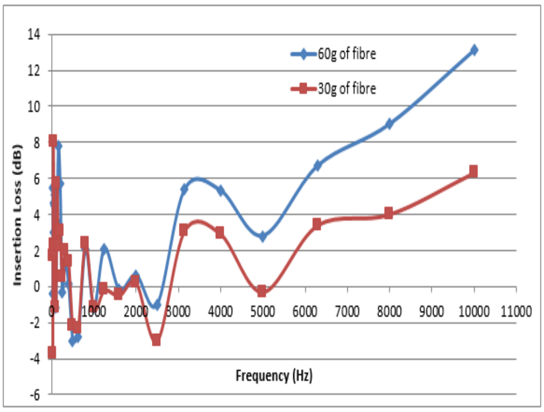

Figure 7. Comparison of Insertion Loss for 30g and 60g Sound Absorptive Material in 5 Pieces Configuration

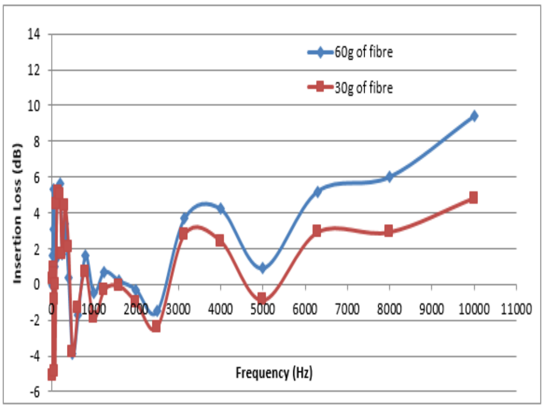

Figure 8. Comparison of Insertion Loss for 30g and 60g Sound Absorptive Material in 4 Pieces Configuration

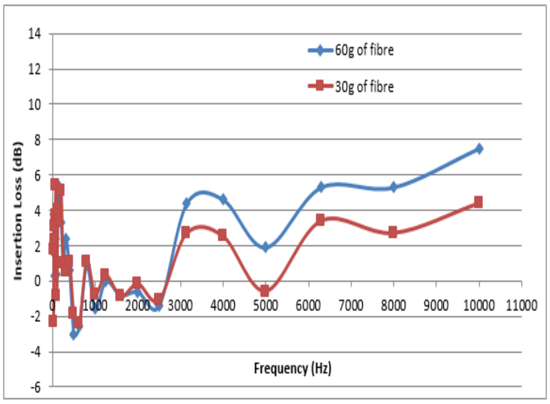

Figure 9. Comparison of Insertion Loss for 30g and 60g Sound Absorptive Material in 3 Pieces Configuration

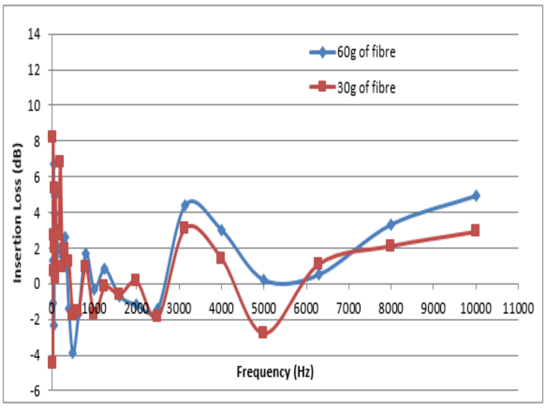

Figure 10. Comparison of Insertion Loss for 30g and 60g Sound Absorptive Material in 2 Pieces Configuration

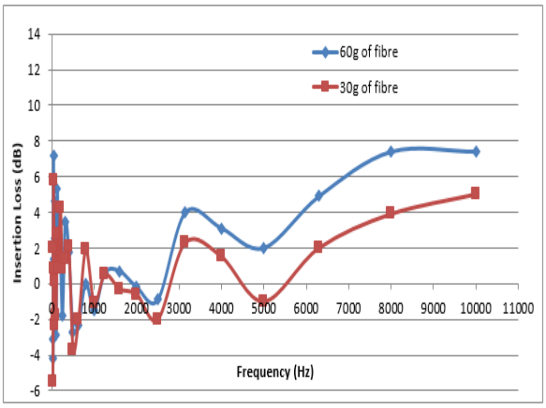

Figure 11. Comparison of Insertion Loss for 30g and 60g Sound Absorptive Material in 4 sides Configuration

4. Conclusions

In this paper, there are two types of sound absorptive materials which are 60g fiber and 30g fiber with the same dimension. The data collected are the noise at 1/3 octave frequencies before and after silencer is installed. The silencer has five different configuration testing. The analysis that made are the comparison of silencer with same mass of fiber but different configuration and same configuration but different mass of fiber. In this study, the insertion loss increase to 13dB at 10000Hz as the pieces of sound absorptive materials in the silencer increase. Similarly, the insertion loss was found increase as the mass that coconut fiber used in the sound absorptive materials increase. In addition, the insertion loss of silencer with same configuration with different content of fiber has been tested. It is found that the insertion loss of sound absorptive material with higher content of fiber has higher insertion loss at each frequency.

5. Acknowledgements

The authors would like to acknowledge Noise and Vibration Analysis Research Group (NOVIA) of Universiti Tun Hussein Onn Malaysia for providing laboratory facilities and Ministry of Higher Education Malaysia for the financial support under Fundamental Research Grant Scheme vote 1546.

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