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# Experimental Investigation on the use of Natural Waste Fibres as Acoustic Material of Noise Silencer

*A.Y. Ismail*[*,1], *M. J. Chen*[2] , *M. F. Azizi*[3] *and M. A. Sis*[4]

[1]ViBRO Research Group, Center for Advanced Research on Energy (CARe)
[1,2,3,4]Faculty of Engineering Technology, Universiti Teknikal Malaysia Melaka, Hang Tuah Jaya, Durian Tunggal, 76100 Melaka, Malaysia
[*]*ahmadyusuf.ismail@.utem.edu.my*

**Abstract** – *The use of synthetic materials as an acoustic material of absorptive silencer is still dominant in the industry. These materials not only have an impact on human health, but also contribute to environmental pollution. This study presents an experimental investigation on the use of natural fibres i.e. coconut and paddy straw fibres as a substitution for the synthetic materials. The samples were fabricated with several different densities of the fibres to identify the most effective composition to absorb sound. The experiments were conducted using the dynamic insertion loss technique as the most applied and simplest method to observe silencer performance. It is found that the natural fibres perform well as absorptive materials and prospective to be used in the future.* 

**Keywords:** Noise barrier, natural fibre, sound pressure level, green technology

## 1.0 INTRODUCTION

Noise is generally defined as unwanted or undesired sound. In practice, it is generated from turbulence fluid flow and also from vibration of mechanical structures [1]. Noise is one of the most pervasive occupational health problems in industry which can cause sleep disturbance and psychological condition for the workers [2, 3]. Moreover, Fernandez, *et.al.* reported that a person can have a serious harmful health effect such a permanent hearing loss if that person works with continuous high level of environment noise [4]. It is also found that around twelve percent of workers accidents are attributed from noise exposure and noise-induced hearing loss [5]. Therefore, the International Standard Organization (ISO) has established a regulation for the maximum permissible noise exposure to protect the hearing system from high level noise [6].

Many researches as well as products have been developed in order to reduce noise effect [8 – 12]. One of the methods to control noise is by employing a silencer as seen in Figure 1. It has received most attention from researchers [13]. Bilawchuk and Fyfe investigate several methods used to calculate transmission loss of silencers. It is found that the finite element method is suitable for the applications [14]. Choy, *et. al.* studies the use of composite plates in a compact silencer. The result shows that the plate is effective to produce sound transmission loss up to 10 dB [15]. While Denia, *et.al.* extend the inlet and outlet of a silencer with an empty extensions and study their effect on the sound transmission loss performance. It is found that

Journal of Advanced Research in Materials Science
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the extension can improve acoustic performance at low to mid frequencies [16]. Liu, *et.al*. creatively investigate the performance of plate as a dissipative part of a silencer. Using the concept of Hemholtz-Kirchoff, the plate vibration is used to absorb sound and giving transmission loss performance. The result shows that the softer end of the plate silencer plays as the major factor to increase transmission loss bandwith [17]. Mehdizadeh and Paraschivoiu also investigate the performance of silencer computationally. 3D finite element method has been used and shows very well agreement with experiment [18]. Lately, Yu and Cheng modify the internal configuration of silencer i.e. by including the side band partition, multi chamber partition etc. in order to increase the performance. It is found that some critical issues have been found as a supportive matter to improve the design [19]. Nevertheless, most of the research only deals with the reactive part or design configuration. There has been lack of information regarding the development of the absorptive materials of silencer. It should be noted that most of the absorptive materials used in the commercial silencer are made from synthetics which causes serious problem to the global warming potential [20] as well as to human health such as various lung damages [21].

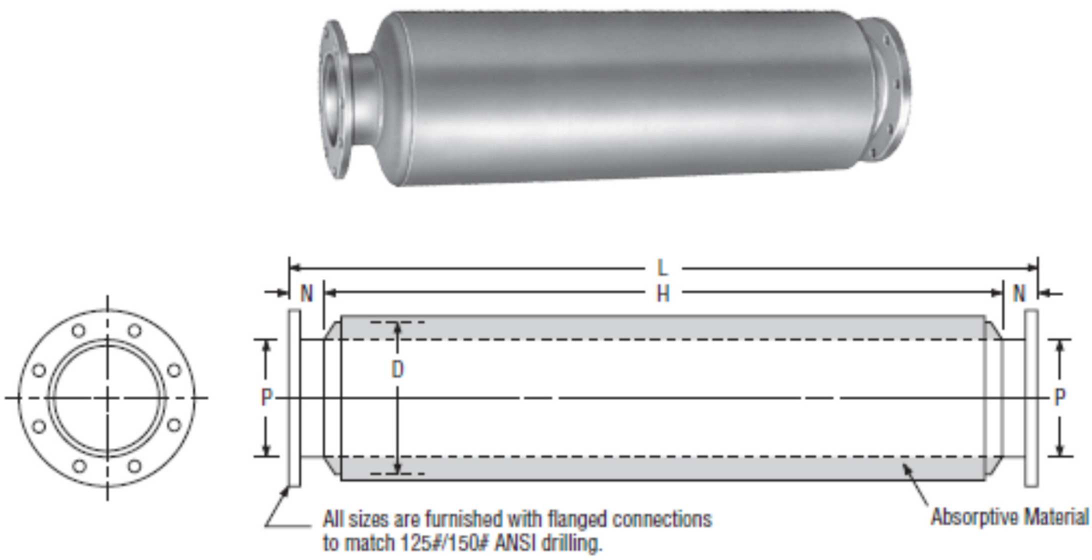


**Figure 1:** Commercial Absorptive Silencer [22].

Meanwhile, researches on natural fiber (NF) have been increasingly done by acoustical engineer and scientists because their good sound proofing performances. More than that, they are eco-friendly and still giving many benefits in engineering application [23]. At the moment, there are two natural fibers that are very easy to obtain and low cost so that researchers are still working on them. They are coconut and paddy straw fibers. Nor *et al*. found that single layer of coconut coir fiber has good absorption performance at mid and high frequencies and performs well at low frequencies if the layer is multiplied [24]. Additionally, combination of such coir absorber with perforated panel had apparently shifted the peak towards low frequencies [25]. Recently, Abdullah *et al*. have also found that dried paddy straw and sugarcane fibers are adequately feasible to be used as acoustic absorbers. Increasing the thickness gives better performance at low frequencies [26]. It is also found that both natural fibers perform well as noise curtain wall [27].

Journal of Advanced Research in Materials Science
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This paper, therefore, presents a preliminary investigation on the use of natural fibers as absorptive materials in a silencer. The investigation is made through experimental work in an anechoic chamber using insertion loss technique as the simplest and most applied method to evaluate silencer performances.

## 2.0 METHODOLOGY

### 2.1 Material Preparation and Silencer Design

Figure 2 shows paddy straw (PS) and coconut fibers (CF) that were used in this experiment. They are abundantly available in South East Asia. The preparation was generally divided into four processes which were drying process, cutting process, mixing process and finishing process until formed a fibers as depicted.

(a) (b)

**Figure 2:** Natural Fiber: (a) Coconut Fiber (b) Paddy Straw

While the fabrication and geometrical design of the silencer can be seen in Figure 3 and 4. The geometry of the silencer was following the previous researches with some modification. The diameter of the inner tube was 60 mm and the outer tube was 115 mm. The length of the inner tube was 40 cm while the outer tube was 20 cm. Both tubes were made from commercial PVC as used in previous research [28].

**Figure 3:** fabrication of silencer

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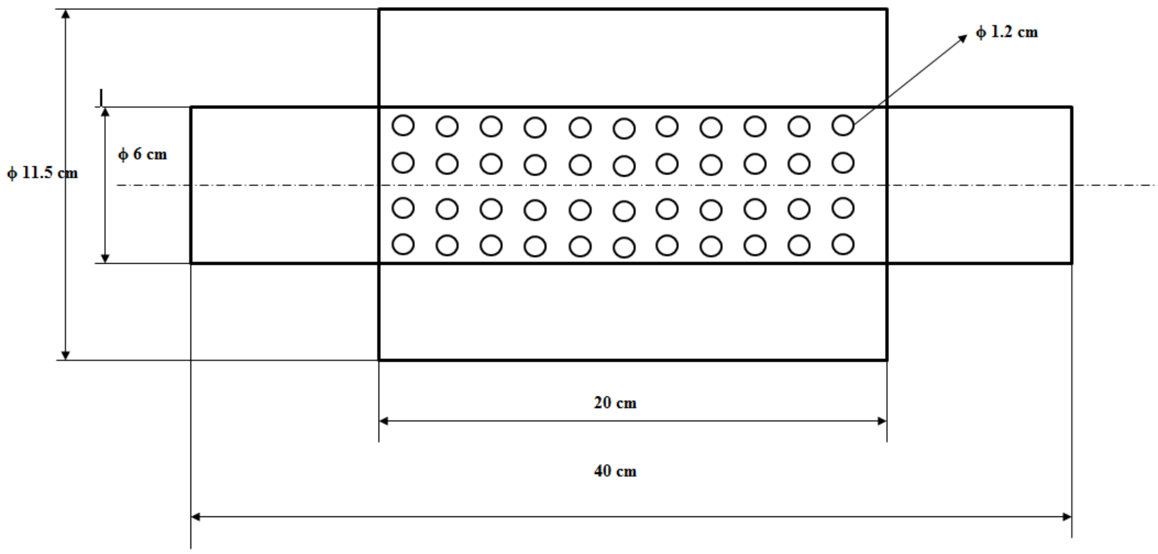


**Figure 4:** Silencer geometry

In order to investigate clearly the effect of natural fiber, several densities of natural fibers had been varied as shown in Table 1. The density of the fiber was determined from the ratio of fiber mass to the volume of absorptive area in the silencers. Since the volume of the absorptive area was constant, the only controlled parameter was the fiber mass. Paddy straw fiber was apparently much lighter than the coconut fiber. Consequently, with constant volume, the amount of paddy straw fiber filled inside the tube can be much more than the coconut fiber. Therefore, to obtain similar percentage of density, the mass of fibers shows a bit differences between the two fibers as seen in the table.

**Table 1:** Natural fibre varied densities

| Sample | Natural Fibers | Mass Density (gr) |
|---|---|---|
| **1** | PS | 190 |
| **2** | PS | 210 |
| **3** | PS | 230 |
| **4** | PS | 250 |
| **5** | CF | 60 |
| **6** | CF | 80 |
| **7** | CF | 100 |

Journal of Advanced Research in Materials Science
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### 2.2 Experiments

As mentioned in the previous section, the experiment was performed using applied insertion loss method in an anechoic room. This method was known as the most applied *in-situ* measurement of industrial silencer. Basically, it was the subtraction between sound pressure level before and after implementation of the silencer. The sound pressure level (SPL) is given by

$$SPL = 10 \log (p/p_{ref})^2 \qquad (1)$$

where $p$ is the measured acoustic pressure obtained from the measurement and $p_{ref}$ is reference sound pressure given by 2 x $10^{-5}$ Pascal. Where the Insertion Loss (IL) is defined by

$$IL = SPL_1 - SPL_2 \qquad (2)$$

$SPL_1$ is the sound pressure level before silencer application while $SPL_2$ is the sound pressure level after silencer application. The acoustic microphone used were the ½" Prepolarized free field microphones (PCB 378B02) with ½" ICP preamplifier (426E01) and TEDS. Data acquisition system used was VibPlot m+p SO Analyzer. Figure 5 shows the experimental setup of the measurement.

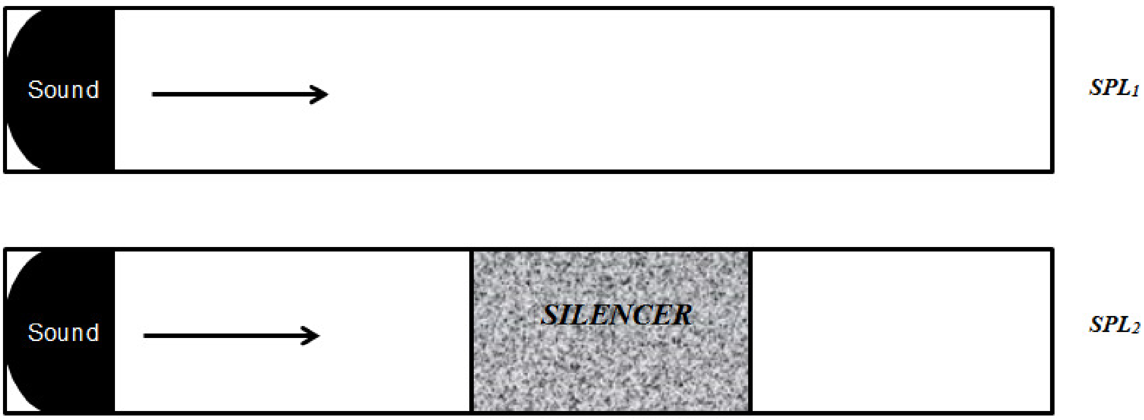


**Figure 5:** Measurement setup

## 3.0 RESULTS AND DISCUSSION

### 3.1 Sound Pressure Level

Figure 6 shows the sound pressure level (SPL) of silencer with PS fibres. It can be generally seen that the density of the fibres only give slight differences to the SPL. This is well agreed with the previous works of the authors that different density of PS fibres give only 1 – 2 dB reduction of SPL in a noise curtain [27]. At low frequency from 31.5 to 500 Hz, the SPL is seen to be constant without any considerable differences. At medium frequency around 500 to 1500 Hz, the differences occur where higher fibre density reduces SPL performances. This means that the absorption becomes more effective within this frequency range. As the fibre

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density increases (represented by the mass increment) the SPL decreases considerably. The best porosity is well created within this frequency range from the silencer with 100 gr PS fibres. However, above 2000 Hz the SPL performance is seen to be constant again without any differences.

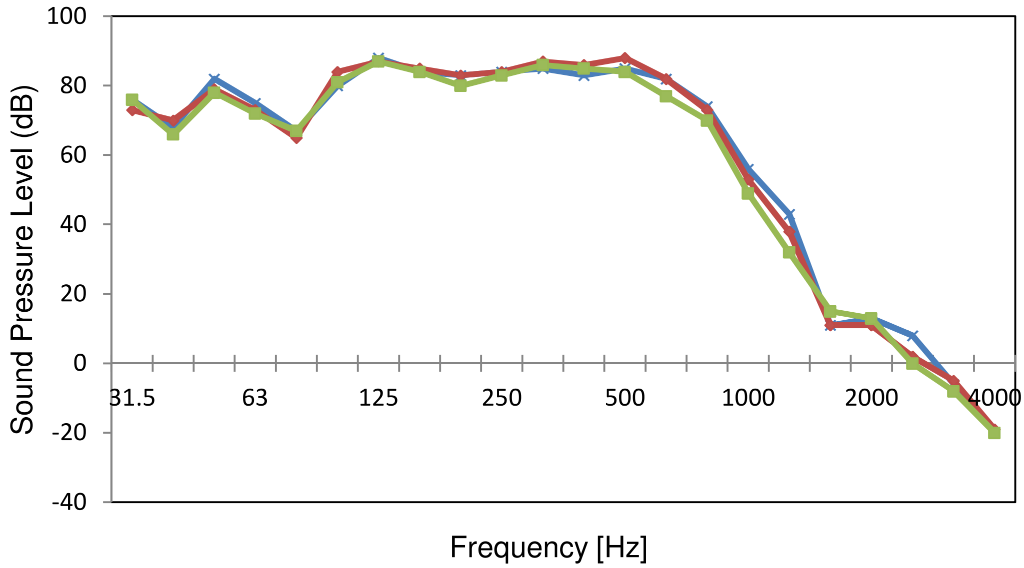


**Figure 6:** SPL performance of PS Silencer
(—60 gr, —80 gr, —100 gr).

While Figure 7 shows the SPL of silencer with CF fibres. Similar with PS, CF gives only slight reduction of the SPL. Silencer with the lowest CF density i.e. 190 gr even shows higher SPL than PS fibres around 125 to 500 Hz. This means that this density is not suitable to create porosity inside the layer and only less absorption obtained. Or in other words, the fibre mass inside the silencer is not enough to create porosity as compared to the silencer volume capability. The highest CF density (with 250 gr fibre mass), meanwhile, gives the best reduction particularly at mid-high frequency around 800 – 2000 Hz. This is good result since the sound intelligibility level takes places within this frequency range. At above 2000 Hz, the CF does not show any good performance at all. The result of this CF performance also agreed well with authors previous work [27] where the performance of CF almost the same with PS fibres with some certain densities.

Journal of Advanced Research in Materials Science
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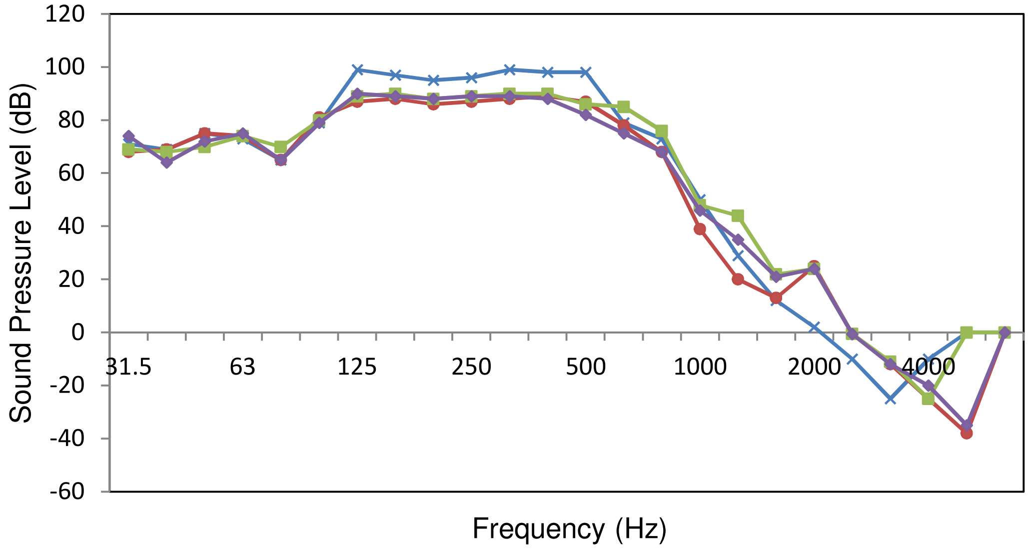


**Figure 7:** SPL performance of CF Silencer
(—190 gr, —210 gr, —230 gr, —250 gr).

### 3.2 Insertion Loss

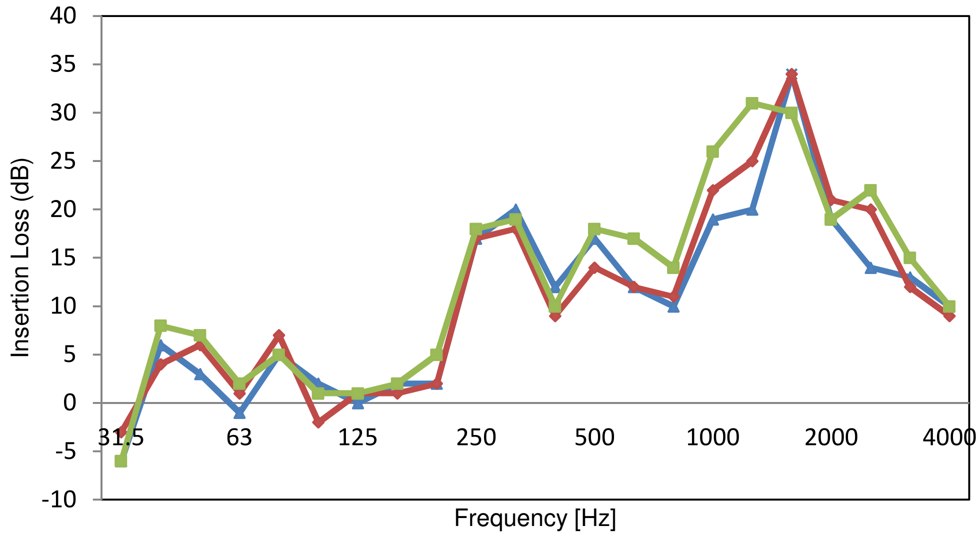


**Figure 8:** IL performance of PS Silencer
(—60 gr, —80 gr, —100 gr).

To clarify the level of reduction, Figure 8 and 9 shows the IL for both fibres. Generally, both fibres have the same pattern where the best reduction is obtained at around 1000 – 2000 Hz. As mentioned before, this is a good result for indoor sound quality application. PS fibres gives almost up to 35 dB at around 1800 Hz while CF gives 40 dB at 1200 Hz. It is also noted that both fibres have poor performance at low frequency around 30 – 500 Hz as well as high frequency above 2000 Hz. The natural fibres arrangements might only be effective for narrow frequency band absorption. Several improvements can be made for this research including adding some binding additive as well as using hot press machine to refine the natural fibres fabrication. It is also purposely to get more even fibre matrix and creating more effective porosity to the fibres.

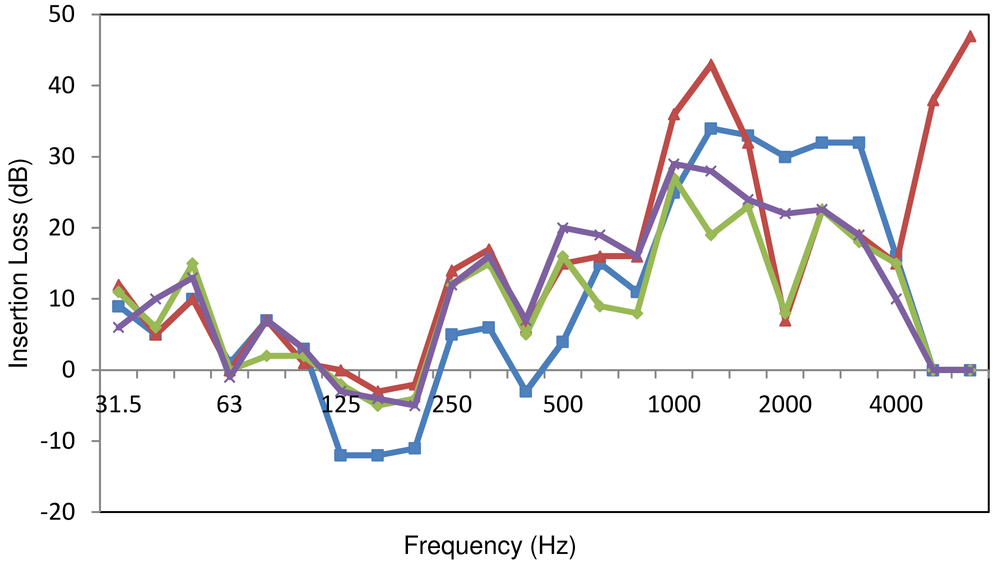


**Figure 9:** IL performance of CF Silencer
(—190 gr, —210 gr, —230 gr, —250 gr).

## 4.0 CONCLUSSION

The effect of natural fibre as substitutive acoustic materials in a silencer has been investigated experimentally. It is found that paddy straw and coconut fibre have shown a feasibility to be a modern eco-friendly acoustic material with several improvement ideas to widen the effective frequency band with performance. In the future research, the performance of natural fibre silencer will be more explored using sound transmission loss (STL) transfer matrix method using impedance tube to gain more detail and deeper information.

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