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Sound Absorption Performance of Ink-tube Waste as Absorber

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Abstract: Plastic waste generation is increasing with the rapid development and increasing human population. Improper plastic waste management contributes to many devastating effects on humans and to the environment. The utilization of recycling plastic waste to local industry was implemented in ensuring less accumulated waste production. This study aimed to utilizing empty ink-tube plastic from unused pen as the core material for sound absorber. The effectiveness of the material to be used for the sound absorption panel is tested in different lengths of the ink-tube with various placement of the cotton layer on the samples. Measurement of sound absorption coefficient is done using impedance tube ranging from 350 Hz to 5000 Hz frequencies. The result shows that tubes with 3 cm and 5 cm length able to absorb more sound with the presence of cotton layered at the front and backside of the sample. The absorption coefficients reached 0.79 at 2000 Hz and 0.95 at 1250 Hz for 3 cm and 5 cm samples, respectively. Findings also show that introducing a cotton layer covering the front side of the sample able to enhance the absorption coefficients of the ink-tube absorber at a wider frequency sector.

Keywords: Sound Absorption, Ink-Tube Waste, Cotton Layer

1. Introduction

The World Health Organization (WHO) reported that issues regarding noise pollution are now gaining global attention. Noise has become a major world health problem affecting the everyday life of people in the world, especially in the urban area. If a person is exposed more to excessive noise, undesired physiological and psychological effects may happen caused by exposure to excessive noise. Any adverse effects of long-term exposure to high levels of unwanted sound on human health include loss of hearing, stress, exhaustion, insomnia, high blood pressure, or severe medical problems such as heart attacks. [1]. Further studies and investigation is needed in controlling noise pollution effectively.

The sustainable use of natural resources is explored through the production, reuse, or recycling of new materials using waste as a raw material, in part or in its entirety [1]. The materials for sound absorption is widely used since the past to reduce noise or to reduce echoes in enclosed spaces. The

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concern and awareness of noise pollution in daily activities from the public has increased the need for sound absorption materials as a noise barrier.

There are seven sources of solid waste. These sources are from residential, commercial, industrial, municipal waste, institutional, and construction and demolition [2]. From the stated sources, the sources showed that waste generates at places that consist of high occupancy of people. The solid waste generated by the consumer is food waste, metals, packaging, and others. The source of wastes from commercial and institutional have the same types of solid waste. The solid waste is glass, paper, wood, cardboard, plastics, food wastes, metals, e-waste, and hazard. From all the waste stated, plastic waste is chosen to be the material of the sound absorption in analyzing sound performance.

Plastic pollution happened globally, as this pollution is a major source of global marine pollution. Marine synthetic contamination was a disturbing concern due to its growing development, density, diligence, and the huge impact it has on all aspects of the ecosystem. Plastic pollution is a threat to marine life with long term impacts on ecosystems and organisms in the sea [3].

Major contributing to plastic wastes is commercially from soft drinks, water bottles, plastic bags, and many more examples which have been discharged inappropriate way [4]. This shows that plastic demand is getting larger along with the population; hence the formation of waste materials is increasing too. The increment of waste material has affected the animal, humans, and the environment. Plastic polymers are not considered toxic, but plastic materials contain some residual monomers [5]. Chemical compounds were used almost in every plastics manufacturing and act as additives, which in particular plasticizers are harmful to the environment and human health.

1.1 Problem Statement

Environmental risks faced by plastic waste in the environment continue to be a major concern today, closely related to the increased use of plastic. [5]. Efforts had been associated with the world regarding plastic waste collection, recycling, and reuse. In the paper studied by Comnita et al. [5], the paper highlighted the current requirement and tendencies in reducing the need for plastic, the enhancement of recycling and recovering waste, simultaneously with the replacement of plastic from fossil fuel with a continuous widening spectrum of biodegradable polymers.

Over 300 million metric tons of plastics are made annually in the world, and about 50% of this quantity is for disposal applications, a commodity that is discarded within a year of purchase. [6]. The effect caused by the plastic waste resulting in pollution clogs up rivers, oceans, lands, and affecting biodiversity.

A part of the environmental protection system is solid waste management (SWM). SWM has been turned into a more realistic and productive alternative for sustainable development focused on "reduce," "reuse," and "recycle." The utilization of plastic waste in the industry has been implemented in ensuring plastic waste production to reduce.

The previous study by Putra et al. [7] made an enhancement of acoustical performance of hollow tubes as a sound absorber. The study was utilizing the recycled lollipop sticks as acoustic absorbers. By taking the idea of the hollow tube as a sound absorber, ink-tube waste was proposed to identify the performance as sound absorption material. However, there are no study was made using ink-tube waste as sound absorption material. This study was done to investigate the sound absorption performance of ink-tube waste as material used for sound absorber.

Berardi and Iannace [8] made a study upon natural fiber material with various fiber material, which is kenaf, wood, hemp, coconut, cork, cane, cardboard, and sheep wool. From the study, natural fiber material showed a high sound absorption coefficient in this study, also proposing effect of cotton layer upon ink-tube with a different condition. The effect of the cotton layer will be analyzed to show the difference sound absorption coefficient between the sample with different conditions which including with and without the cotton layer.

1.2 Objective

This paper aim to determine the sound absorption performance of ink-tube, hollow structure using different lengths of an empty ink-tube, which is 3 cm and 5 cm with different placement of cotton layer.

2. Materials and Methods

This research experimented with two different lengths of an ink-tube hollow structure, which at 3 cm and 5 cm. Different cotton layer placements are used covering the front, back, and both the front and back of the ink tube sample to examine their effects on the sound absorption coefficients of the sample.

2.1 Materials

There were two preparations need to be done before experimental works. These preparations were important in justifying the objective of this study. The preparations consisted of fiber preparation and ink-tube preparation.

2.1.1 Fiber preparation

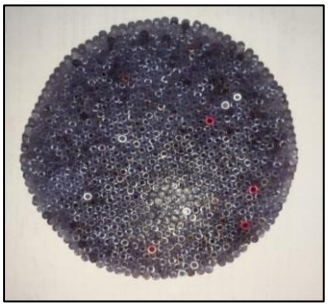
The type of fiber used in this study is cotton. Cotton pads were prepared during the sample preparation. The cotton pad was replacing glass wool and mineral fiber, which is commonly used as insulation and sound absorption material in the study. This study uses the brand new cotton pads to ensure the cotton pads are dried and clean from any impurities and moisture.

2.1.2 Tube preparation

This research intended to use a hollow tube from wastes material. For this purpose, an empty-ink pen is used as the raw material for the sound absorber. The ink-tube was removed from the main body of the pen. The outer diameter of the tubes is approximately ±3 mm. All ink-tube is cut into different length, 3 cm, and 5 cm respectively using cutter. The cutting process was carefully to ensure the consistency of the size.

In the second stage, the ink tube will undergo the cleaning process to remove the excess ink inside the tube using liquid thinner. The ink-tube was left to sink overnight with the solutions to ensure that all excessive ink diluted into the thinner, hence removed out of the tube. Then, acetone is used to ensure the tubes are well cleaned from the excessive ink.

Figure 1 shows the arrangement of ink-tube hollow as a structure with different diameters. The ink-tube was arranged into a cylindrical shape to estimate the quantity needed for the impedance tube testing. Samples are prepared in two sizes, 100 mm diameter for low frequency and 28 mm for high frequency.



(a)

(b)

Figure 1: Axial arrangement of sample for diameter, (a) 100 mm and (b) 28 mm

2.2 Sample preparation

The hollow structure of the ink-tube was arranged in axial arrangement [7]. There were four conditions during the testing. The first condition is where the ink-tube sample is tested without any cotton layer covers. In the second condition, the ink-tube sample is covered with a layer of thin cotton at the front, followed by the third and fourth sample where a thin layer of cotton is placed at the back side of the sample and at both sides (front and back) of the ink-tube samples.

2.3 Experimental work

Sound absorption coefficient measurements are conducted using an impedance tube in accordance to BS EN ISO 10534: Acoustic determination of sound absorption coefficient and impedance tube: Part 2: Transfer function method [9][10]. The impedance tube set used in this research, as shown in Figure 2. This set consisted of a set of the test tube (measuring chamber and sample holder), two units of microphones, the transducer, and an electronic sound generator. This setup ran on the SCS8100-Kundt software installed in the computer operating system [11].

There are two frequencies sector in which the sample was tested, which is low frequency and high frequency. For the low frequency, the diameter of the impedance tube was 100 mm, while for the high frequency, the diameter of the impedance tube was 28 mm. The tested frequency range for low frequency is between 200 Hz to 1500 Hz, and 2000 Hz to 6000 Hz for the high frequency. The results for sound absorption coefficient (α) values of 0 to 1 (where 0 is a total reflection and 1 is absolute sound absorption) for both tubes were between 315 Hz to 5000 Hz.

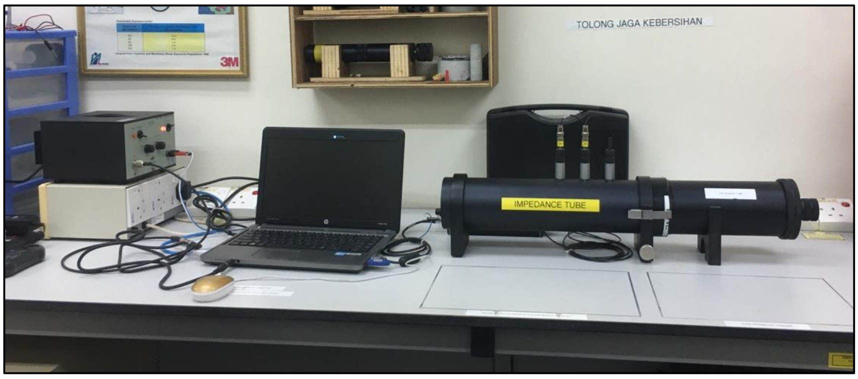


Figure 2: Experimental setup using impedance tube method

3. Results and Discussion

Overall, six samples are prepared in this testing consisted of 3 samples for each thickness (3 cm and 5 cm). Measurement results for sound absorption coefficient for 3 cm and 5 cm thickness ink-tube samples are shown in Figure 3, while in Figure 4, comparison between each condition of the sample at a different thickness of the sample is made to observe the effect of layer a thin cotton onto the hollow ink-tube absorber.

Findings showed in Figure 3a revealed that by layering a thin cotton to the front of the ink-tube sample able to improve the sound absorption coefficient values for the 3 cm sample at above 2500 Hz. Sample without cotton layer shows less absorbency compared to the other three conditions with the presence of cotton layer. Hence, the highest sound absorption coefficient for 3 cm thickness was obtained by sample with a cotton layer at front and back. In-tube sample with cotton layer at the front achieved maximum sound absorption coefficient of 0.951 at a frequency of 4000 Hz, while the other samples showed maximum absorbency at frequency range between 2000 Hz till 2500 Hz. Even though layering a cotton to ink-tube sample improved the absorption coefficients on most frequency, but not much improvement was observed obtained by sample with a cotton layer at backing, and at front and back especially at above than 2500 Hz frequency compared to the bared sample.

Meanwhile, as shown by Figure 3b, the sound absorption performance of 5 cm samples are improving at below 2000 Hz. The sound absorption coefficient value improved by 20 % after adding a backing cotton layer to the bared sample. A slight increase in the sound absorption coefficients are shown at the sample with a cotton layer at front and sample with front and back cotton layer at the same frequency sector. At 1250 Hz, the highest sound absorption coefficient is when the sample has a cotton layer at front and back with a coefficient of 0.953, followed by a sample with a cotton layer at the front only with a coefficient of 0.869.

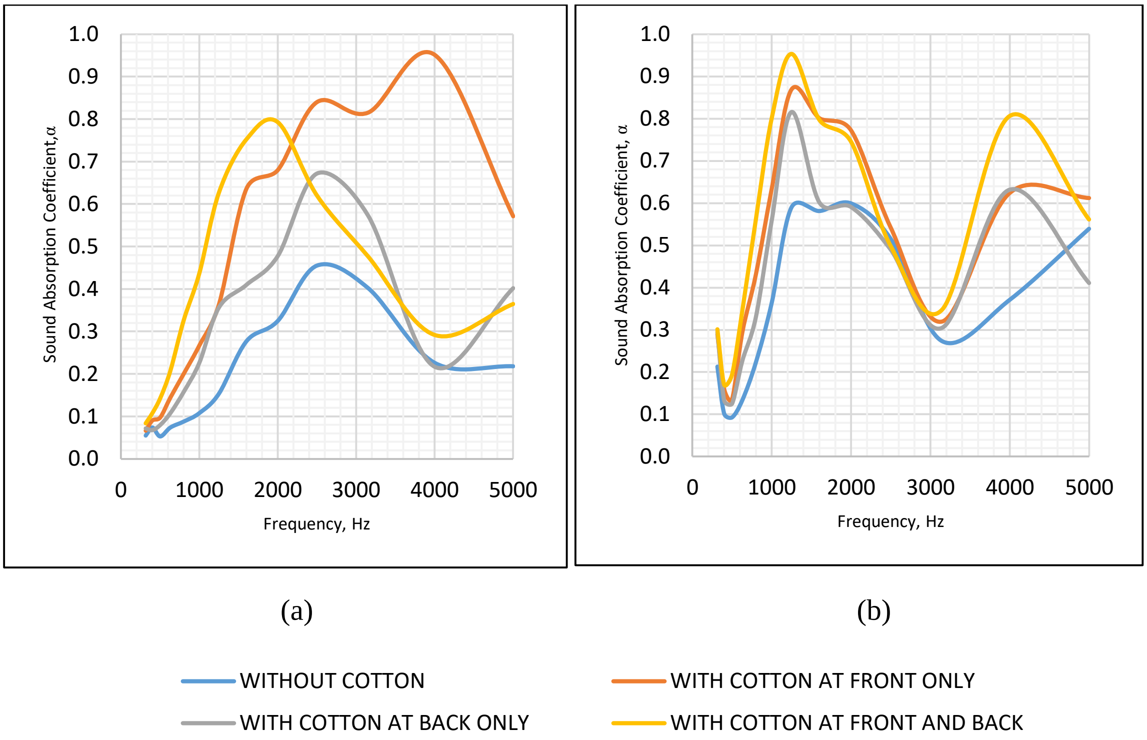


Figure 3: Sound Absorption Coefficient with different condition of cotton layer at thickness of sample, (a) 3 cm and (b) 5 cm

Furthermore, analysis on sound absorption performance for ink-tube samples are made by comparing the absorbency between different thickness in the same condition. The results are shown in Figure 4 a to d for bared samples and samples with different cotton layer placements. In Figure 4a (sample without cotton layer), the sample with longer sticks shows better absorbency at a lower frequency sector compared to the 3 cm sample.

In Figure 4b, a cotton layer was added to both 3 cm and 5 cm samples. Analysis shows that placement of cotton cover to the front of sample boost up the absorption coefficient values for 3 cm sample at above than 2000 Hz. The peak sound absorption coefficient achieved 0.951 at 4000 Hz. Hence, the front cover of cotton also able to improve the sound absorption performance for a 5 cm sample at a lower frequency region.

Results for samples with cotton layer backing are shown in Figure 3c. There is not much improvement in the sound absorption coefficient value obtained for this sample compared to the bared sample. Sample with 5 cm thickness shows better absorbency at lower frequency sector compared to the 3 cm.

Finally, analysis for sample with cotton cover at front and backing improved the ink-tube sample absorbency at lower and high-frequency sector for 5 cm sample. However, for the 3 cm ink-tube sample, cotton placement does not much improve the sound absorption coefficients at above than 2000 Hz frequency. The highest sound absorption coefficient of the 3 cm sample achieved 0.793 at 2000 Hz, while in the 5 cm sample, the sound absorption coefficient reaches 0.953 at 1250 Hz. From all analysis in figure 4, it is clearly shown that the 5 cm sample is very weak at 3000 Hz. The absorption coefficients value of all four conditions shows the sound absorption coefficients only able to reach ±0.3000 compared to the other frequency. Research by Putra et al. [7] and Samsudin et al. [9] have proven that thicker samples are good for low-frequency application while thinner panels are good for high frequency. This relation is following the theory of frequency-wavelength relationship in sound physics.

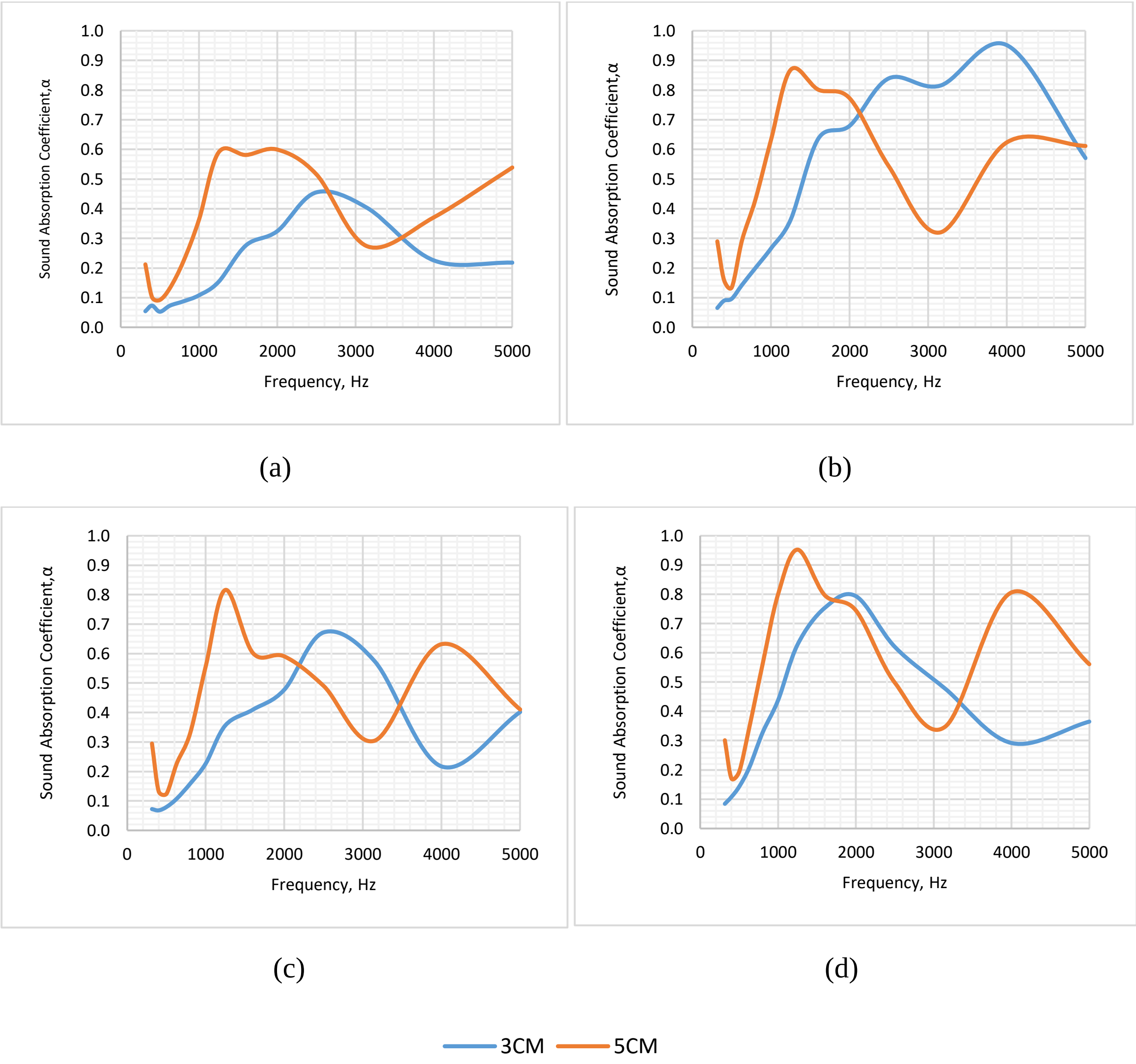


Figure 4: Sound Absorption Coefficient in different thickness with different cotton layer position, (a) no cotton layer, (b) cotton at front side, (c) cotton at back side, (d) cotton at both sides

4. Conclusion

In this study, 3 cm shows great sound absorption at high frequency, while the sample with a thickness of 5 cm had better sound absorption at low frequency; adding a layer of fibrous material to the hollow sample able to improve the sound absorption coefficient value to the ink-tube sample for both thicknesses. Adding a layer cotton cover to the 3 cm sample shows much improvement to the sound absorption coefficients of the hollow ink-tube sound absorber at a wider frequency sector compare to the 5 cm sample in other cotton layer placements.

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