Experimental investigation of fabric-based micro perforated panel absorber

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Abstract. The most popular sound absorbers are made of porous material. Although porous material provides decent sound absorption, their fibers may harm health and environment. Thus, micro perforated panels (MPP) are considered an alternative option to deal with the health and environment issues. However, manufacturing minute holes of the MPP in Indonesia is not easy. As an alternative to MPP, this research uses microstructure of available materials on the market. The inherent microstructure potentials of fabric as MPP material will be investigated. Two kinds of woven fabric, namely Alabama and Lisburn, also one kind of denim fabric are employed. Absorption coefficient of the fabrics is measured using impedance tube with various air cavities. Measurement results show that all of the three fabrics are potential to be used as sound absorbers, as the absorption coefficient of the fabrics are greater than 0.5 at various frequency bands. For further investigation, the geometrical properties of the fabrics are measured using Scanning Electron Microscope. From the measured microstructures, woven fabrics are predicted to be more feasible for further development as the microstructures are more predictable compared to the denim fabric. For woven fabric themselves, Alabama shows greater performance than Lisburn in terms of absorption coefficient. It is predicted that the fibrous holes for Alabama made the resistive part become more apparent rather than Lisburn that has clearer holes, thus increasing its potential as sound absorber.

1. Introduction

Porous absorber has been widely used for a long time, but nowadays the use of Micro Perforated Panel (MPP) absorber is being considered as an alternative because MPP absorber poses no environmental and health issues like most porous absorbers do [1]. The basic construction of MPP absorber consists of a thin flat panel that has sub-millimeter holes backed by a rigid wall with an air space between them, and none of these components produce fibrous waste that harms health and environment. Based from this fact, MPP absorber is considered to be a basis for the next generations of sound absorbing constructions [2], and many researches are being conducted regarding MPP absorbers technology. For instance, MPP absorbers have been used when a robust sound absorber was needed for severe environments such as on airplane [2] and for low frequency sound absorption in room acoustics such as glazing [9-10].

For some developing countries, mass production of these micro perforated panels with minute holes may be very costly to produce because of insufficient manufacturing technologies. As an attempt to eliminate the usage of high-end technologies, fabric - which is considered to be analogous to MPP structure - will be investigated. Hypothetically, the yarns serve as the panel and the gaps between the yarns serve as the minute holes. In order to prove this prediction, the sound absorption coefficients of several fabrics would be investigated using impedance tube with transfer matrix method. The measurement results determine whether the predetermined fabrics proved feasible to be used as low-cost micro perforated panel absorber.
In this study, results show that the three tested fabrics have the potential to be used as a resonator-based sound absorber. Despite their potential, it is still not clear yet whether the absorption phenomenon is mainly contributed by inertial effect of the fabric vibrations or by the viscous-thermal effect of the fabric holes backed by air cavity. In order to provide more insight to the mechanism, morphology investigation using scanning electron microscope (SEM) is conducted. The morphology structure contributes in explaining the difference of sound absorption coefficient amplitude and the presumptions of the fabric utilization as MPP absorber. There are some constraints for a panel to be considered MPP such as hole diameter should be less than 1mm (d<1mm), panel thickness should be less than 1mm (t<1mm), corresponding panel should be rigid and backed with air cavity, and the perforation ratio should be less than 19.6%. The selected fabrics are presumed to fulfil the prerequisites in this study, and validated later on throughout the experiment. Further parametric survey for mathematical modeling of these fabrics may reinforce the presumption of fabric as MPP absorber, but is yet to be done.

2. Methods and Materials

2.1. Fabric Materials

Ideally, the MPP absorber proposed by Maa assumed being rigid. Therefore, the strength of the knitting structure is strongly considered as the fabrics are stretched to fulfill the rigid MPP assumption. Other than fulfilling the assumption, the rigidity of the fabric is mandatory in the impedance tube mounting system. There are three types of fabric based on the integration structure of the yarns to determine the feasibility of the fabric utilization as MPP.

The first type of fabric is non-woven textile, presented in Figure 1(a). The figure shows that non-woven fabric has no clear structure in its build, as the composition may consist of recycled materials and other yarns that are tangled one to each other randomly. This structure results in bulkier build and seemingly harder to do parametric survey, and it is not preferably investigated as an alternative to MPP absorber.

Knitted fabric is the second type, and the morphological structure represented in Figure 1(b). It is visually clearer than non-woven fabric in terms of parameter determination from the recurring perforated morphology structure. This fact implies knitted fabric as a promising alternative as the fabric-based MPP absorber, but knitted fabrics consists of only one yarn stitched in such manner or integration from many coils of yarn, leaving the structure very stretchy.

The last type is woven fabric represented in Figure 1(c). The hole-yarn pattern resembles knitted fabric, but differs in the structure’s strength. The figure shows that yarns are adjacent to other yarns, thus increasing the static friction between the yarns. Therefore, the main focus on this study is related to woven fabric as the potential MPP substitute.

![Figure 1. Type of Fabrics (a) Non-Woven[3] (b) Knitted[4] (c) Woven[5]](image)

In a previous experiment conducted by Nico [6] a kind of denim fabric was investigated and modeled using membrane absorber approach, but the correlation between the measured absorption coefficient and model-predicted absorption coefficient show a significant gap. The membrane model approach suspected to be the reason, and this study will provide another basis of MPP absorber investigation by scanning the surface of the denim fabric.
2.2. Experimental Setup

The absorption coefficient of fabric based MPP was measured using impedance tube as per ISO 10534–2 [7]. The schematic diagram of impedance tube could be seen in Figure 2 in this system. First, the values of relative humidity and environment temperature were measured and involved in the measurement to add corrective values of the results. Also, two microphones were calibrated using 114dB white noise to ensure the accuracy of the measurement. The next step, each respective MPP was placed inside impedance tube with 15mm air cavity. White noise was generated as the input through speaker inside the impedance tube. This noise propagated through 3 cm and 10 cm diameter tubes using two calibrated microphones. These microphones obtained sound pressure level data in the impedance tube in order to get the normal incidence absorption coefficient of the MPP using built-in analyzer. From this dimension of tubes, the normal incidence absorption coefficient between 64 to 6300 Hz thus could be obtained. Measurements of the absorption coefficient were conducted three times each tube. The duration of each measurement lasted 120 seconds to ensure the steady state response of the system (60 seconds each configuration of microphone). Lastly, the absorption coefficients of three measurements were averaged, resulting in one set of measurement. The experiment was conducted on two other different samples of the same fabric, as the data presented on this study consists of three sets of measurements for each kind of fabric. The presented data is assumed to be accepted statistically as the variance of fabric properties could vary very randomly.

3. Measurement Results and Discussion

There were 3 different woven fabrics measured using impedance tube, namely Alabama, Lisburn, and Denim. The results showed all 3 woven fabrics showed a different absorption coefficient, which could be seen in Figure 3.

Figure 3 shows the absorption coefficient of each fabric at 64 to 6300Hz. The absorption coefficient fluctuations at low frequencies are likely to be caused by the vibrational modes of the mounted fabric in the impedance tube. But, the environmental moisture and temperature has little impact on the result as each measurement showed similar output values.

The difference in the absorption coefficient can be explained by its surface morphology that has been observed using SEM. The Alabama fabric has a small hole between its yarn and amorphous yarn pattern that can be seen in Figure 4(a). These small holes and amorphous yarn pattern are predicted to be the reason why Alabama fabric performed better (with absorption coefficient close to 1) compared to the Lisburn and Denim fabric.
For Lisburn, its hole can be seen clearly and the yarn pattern is well-shaped. Because of its bigger hole, the coefficient absorption is lower than Alabama (about 0.7) which can be seen in Figure 4(b). As for Denim, its surface morphology is different from Alabama and Lisburn. In Figure 4(c), the yarn has oblique pattern and its hole cannot be seen clearly. The coefficient absorption of Denim is analogous with Lisburn but has a different frequency resonance. The frequency resonance of each fabric is affected by its stiffness. Therefore, all 3 fabrics have a different absorption coefficient on a different frequency resonance using the same air cavity in the investigation.

Error analysis investigation is not explained in this study as the main aim for this study is to investigate the potential of the three fabrics as MPP-like absorber. It would be crucial to include error analysis in the model validation phase, as the measurement result could differ from the model output that could be used, namely Maa model [2] or Johnson-Allard model [8]. The input parameters for MPP-like structure models such as diameter of the holes, distances of the holes, and the panel’s thickness may vary broadly as the mounting process and random sampling of the fabric can result in different surface geometry thus resulting in different absorption performance.

4. Conclusion
In conclusion, based on ISO 10534-2, the conducted measurement result showed that the 3 fabrics provided a good result of absorption coefficient. The 3 fabrics absorption coefficient amplitudes showed values larger than 0.5 using 15mm cavity thus could be potentially implemented as sound absorbers. Despite being so, the surface morphology observation using SEM had unseen holes and oblique patterns on Denim fabric, therefore only Alabama and Lisburn fabric were considered to be further investigated as MPP absorbers. The three sets of measurements were assumed to provide sufficient insight regarding the potential of these fabrics, but for further analysis such as absorption modelling, more complicated analysis on the data variance and error should be elaborated.
Therefore, further studies could focus on parametrical survey of fabrics (i.e. perforation diameter and distance between perforations) and model validation on these MPP-like structured fabrics using Maa Model, Johnson-Allard Model or other MPP models.

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