Sound absorption performance of nonwoven fabrics

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Abstract. Nowadays, the demand of sustainable and eco-friendly absorber is increasing. Non-woven fabrics made of textile waste can be a good candidate to address such a demand. From measurement results, absorption capability of this kind of material is evident. However, most of non-woven fabrics are manufactured on the basis of density only rather than targeted acoustic parameter to meet particular absorption performance. This work is focused on investigation of non-woven fabrics sound absorption performance characteristics. For this, surface morphology of non-woven fabrics with different density is evaluated by which detail geometrical properties of fiber can be observed. Experimental works on similar material system with variation in density and thickness are also conducted to obtain sound absorption coefficients. It is found that fiber size affects the absorption performance for the same thickness by which flow resistivity can be determined. For thickness of 10-50 mm, fibre size of 15-23 µm can produce sound absorption greater than 0.7 while the thickness and flow resistivity are inter-play to determine overall absorption characteristics.

Keywords: non-woven fabrics; sound absorption; absorption coefficients; fiber size; flow resistivity

1. Introduction

Fibrous porous materials are common material structures for sound absorbers. Typically, materials of this kind are made of mineral fibres like rockwool and glasswool. With the progressing time, it has been known that the mineral fibres are harmful to human particularly related with respiratory problems and skin irritation [1, 2]. Hence, the mineral fibres are gradually replaced by the natural and synthetic or mixed of natural and syntetic fibres[3-8].

Nowadays, the global consumption of textile tends to increase. This condition leads to million tonnes of textile waste are generated [9]. Recycling approach to the waste can be useful to reduce the enviromental burden. In the context of acoustic material, this can be used to create products through a specific process where the recycled fibres of textile become raw materials for porous sound absorber. Moreover, sustanaible absorbers are thus be available where the used absorber can be reused for the same applications.
The recycled fiber textile mainly consist of PET, cotton, acrylic, PP, wool, nylon and other fibres [10]. This is subsequently used to form non-woven fabric absorbers. The density of the non-woven fabrics in gms is the main parameters in textile product from which the total of length of non-woven fabric can be determined. In practice, the density in gms or gramacy has been a “label” to absorption performance indicator.

The density of the fibrous porous material is related to flow resistivity and fibre diameter by which the sound absorption characteristics can be determined. Moreover, it differs from mineral fiber based, fiber size of non-woven fabrics can vary instead of in homogenous condition [10]. Hence, it is instructive to have a look dependency of those parameters in determining sound absorption characteristics of non-woven fabrics. In this paper, such an effort is realized by by experimental approach to obtain absorption coefficients. Moreover, morphology of non-woven fabric structure are also studied in order to establish their relationship to associated performance.

The remainder of this paper is organized as follows: section 2, material and method is presented where description of sample, measurement method are provided. In the next section, results are discussed. Lastly, some important results are summarized in conclusions.

2. Material and Method

2.1. Sample of non-woven
The samples of non-woven fabric were made of recycled fiber with the low melt fiber that it is consolidated by heat. Recycled fiber is obtained from waste fabric with the tearing machine. The specification of non-woven fabrics for each sample can be seen from Table 1 while samples can be seen from Figure 1.

| Sample | Thickness, d (mm) | Density, 𝜌(g/m²) |
|--------|------------------|-----------------|
| S1     | 5                | 350             |
| S2     | 10               | 600             |
| S3     | 10               | 900             |
| S4     | 10               | 1000            |
| S5     | 25               | 400             |
| S6     | 25               | 1500            |
| S7     | 20               | 1600            |
| S8     | 50               | 1200            |

Table 1. Specification of non-woven fabric
2.2. Measurement Method of sound absorption coefficients

The measurement of absorption coefficient of MPP was conducted using impedance tube as per [11]. The schematic diagram of the test can be seen from Figure 2. In principle, a white noise signal was generated in sound source and travelling plane waves through a 10 cm diameter tube were picked up using two microphones. Meanwhile, a 3 cm diameter tube was used to obtain data for 1 kHz to 6.3 kHz. From this, a transfer impedance can be determined and the sound absorption coefficient for frequency ranging from 64 Hz - 1.6 kHz can be obtained accordingly.

2.3. Morphology Characteristics

Figure 3 shows the morphology characteristic of fibers in the structure of woven fabric using digital microscope. It can be seen that fiber diameter for each sample is not homogenous. Such a condition can also be drawn from statistical results on fiber dimension as listed in Table 2. It is found that SD and min-max values extend on a wide value range. Apart from this, perforation of sample with higher weight tend to smaller. This is a results of number of fibers used where greater density is made of more fiber than lower one.
Considering the geometrical properties of fibers, flow resistivity prediction of non-woven fabrics are calculated based on formulation proposed by Garai-Pompoli [12] and the results are listed in Table 2.

Table 2. Fiber diameter of non-woven fabric (µm) and associated predicted flow resistivity

| Sample | S1     | S2     | S3     | S4     | S5     | S6     | S7     | S8     |
|-------|--------|--------|--------|--------|--------|--------|--------|--------|
| Diameter | 19.44 ± 0.33 | 15.81 ± 0.44 | 22.43 ± 1.59 | 23.79 ± 0.64 | 19.21 ± 0.53 | 20.91 ± 0.13 | 22.11 ± 0.21 | 15.09 ± 0.25 |
| Min     | 8.25   | 8.94   | 9.22   | 15.23  | 11.66  | 8.49   | 10.00  | 9.06   |
| Max     | 39.7   | 35.38  | 50.00  | 146.33 | 254.24 | 196.01 | 38.63  |
| Flow resistivity (Pa s/m²) | 29,168 | 35,518 | 31,181 | 32,136 | 3,761  | 20,305 | 27,199 | 10,770 |

3. Results and Discussions

3.1. Overall Absorption Characteristics
It can be seen that the increasing thickness of non-woven fabric results in increasing half-absorption bandwidth as reported in Table 3. In the mid-to-high frequency, sample S3 and S8 exhibit the highest peak of sound absorption 1 while the lowest one belongs to S5 which is around 0.78 as shown in Figure 4. Apart from this, it is found that thicker material does not guarantee to obtain a wider sound absorption viz. comparison of S5, S3 and S4. In overall, the thickness and flow resistivity are inter-related to determine absorption behavior where the flow resistivity is density and fiber diameter dependent. These aspects will be discussed in specific in next sections.
Table 3. Sound absorption coefficient of now woven fabric

| Samples | Thickness, $d$ (mm) | Flow resistivity (Pa s/m$^2$) | The peak of Sound Absorption Coefficient ($\alpha_{\text{max}}$) | Half-Absorption Bandwidth, $\Delta\alpha_{0.5}$, (Hz) |
|---------|---------------------|-------------------------------|--------------------------------------------------|----------------------------------|
| S1      | 5                   | 29,168                        | 0.84                                             | 300                              |
| S2      | 10                  | 35,518                        | 0.87                                             | 2750                             |
| S3      | 10                  | 31,181                        | 1                                               | 4180                             |
| S4      | 10                  | 32,136                        | 0.92                                             | 4300                             |
| S5      | 25                  | 3,761                         | 0.78                                             | 4060                             |
| S6      | 25                  | 20,305                        | 0.99                                             | 5180                             |
| S7      | 20                  | 27,199                        | 0.95                                             | 5180                             |
| S8      | 50                  | 10,770                        | 1                                               | 5700                             |

Figure 4. Sound absorption coefficient of each sample

3.2. Effect of Flow resistivity

For the same thickness, there is a tendency that absorption coefficients are affected by the flow resistivity as shown in Figure 5 i.e., the case of 10 mm thick non-woven fabrics. Considering the peak of absorption coefficient and half-absorption bandwidth (see Table 2), setting flow resistivity around 31,000-32,000 Pa s/m$^2$ can lead to a good performance. Increasing flow resistivity can have benefit for low frequency performance but this reduces the performance at high frequency as indicated by S4 absorption behavior. This condition is useful for extending absorption bandwidth, but the absorption can suffer from maximum absorption. Meanwhile, increasing flow resistivity further can reduce absorption performance as indicated by sample S2. By contrast, the use of much lower flow resistivity can result in lower absorption. Such a situation can be seen from the case of 25 mm thick non-woven fabrics as shown in Figure 6. Moreover, a slightly lower flow resistivity is also useful to maintain absorber performance by compensating this with thicker material e.g. increasing thickness from 10 mm to 25 mm.
3.3. Effect of thickness

It is interesting to look at material thickness as some samples have a good performance although they have lower flow resistivity where S5 and S8 can be a good example. For both samples, the predicted flow resistivity is around 10,000 Pa s/m² or below but increasing thickness can help to achieve a good performance as shown in Figure 7. With thickness of 50 mm, S8 can have a good performance with absorption bandwidth of 5700 Hz and absorption peak of 1. For much lower flow resistivity, for example S5, the virtue of thicker material is still useful to maintain overall performance ($\alpha > 0.5$). This suggests that thicker material allows acoustic wave to undergo dissipative process intensively due to longer path. Meanwhile, thinner material with suitable flow resistivity represented by S1 can have a good performance at very high frequency (>6000 Hz) but poor at low, mid and high frequency. Hence, density, fiber diameter and material thickness can be considered to satisfy targeted absorption performance.
4. Conclusions
This paper has discussed sound absorption performance of non-woven fabrics and associated physical properties. It is found that non-woven fabrics can have a good performance in respect with absorption peak and absorption bandwidth. Apart from that, several findings are worth to note:

(1). Material density or gramacy is not only one parameter determining absorption performance of non-woven fabrics
(2). The use of appropriate fiber diameter and density can help to have optimal flow resistivity where material with flow resistivity of around 20.000-20.000 Pa s/m² is a good candidate depending on material thickness
(3). Using thicker material is advisable for lower flow resistivity to attain good performances.

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