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SOUND WAVE ABSORPTION PROPERTIES OF MULTI-LAYERS OF DIFFERENT WOVEN FABRIC STRUCTURES

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ABSTRACT

Nowadays, acoustic health is a priority issue in homes and offices. To address the problem, a variety of sound-absorbing materials are used, one of which is woven and nonwoven fabrics. This paper focused on the sound absorption analysis of two different woven fabric structures as an increasing layer and with base material nonwoven fabric. The fabrics' sound absorption properties were determined using an impedance tube across 80–5000 (Hz) frequencies. The result demonstrated that the absorption of sound energy through plain fabric decreases as the number of layers was increased. On the other hand, in the case of a sateen fabric structure, the absorption of sound energy increases with the number of layers. The absorption capabilities of sateen fabrics are particularly impressive in the high-frequency ranges. The double and triple layers of plain fabric, on the other hand, demonstrate high sound absorption results at frequencies below 1000 Hz in comparison to sateen fabric.

KEYWORDS

Acoustic, sound, woven fabric, fabric structure.

INTRODUCTION

The surrounding acoustic wellbeing plays an important role in social and economic development. Acoustic porous materials are frequently employed in noise control applications due to their excellent sound absorption in the mid and high-frequency ranges. The absorption phenomena in porous material are due to their capacity for sound dissipation through thermal and viscous losses. However, their low-frequency sound absorption is poor. Woven fabrics are fibrous materials that are classified as porous materials because of their structure. Several factors influence the amount of noise reduction provided by woven materials, such as fabric thickness, yarn type, and characteristics. Concerning fabric thickness, only the sound absorption in the low-frequency band is affected by material thickness. An increase in material thickness from 5 to 10 cm does not make a substantial difference above 500 Hz, but it does make a considerable difference in sound absorption below 500 Hz frequency [1–5].

The yarn parameters, and the gaps between the fibers and the fiber cross-section, have a significant influence on sound absorption. Furthermore, the nature or type of raw material affects the sound absorption capacity, lower yarn linear density, and finer yarns improve sound absorption, as explained in [6,7]. However, sound absorption is influenced more by the gaps between fibers in fabric than by fiber diameter or cross-section shape [6,8,9]. Additionally, the porous size has an influence on the determination of the absorption compacity of sound waves by the woven fabrics. The sound wave movement in the porous space of the fabric or in a complex structure leads to the construction of tortuous paths. As the tortuosity of the material increases, it indicates that more complicated paths through the material indicate high resistance to sound waves [10].

In this paper, the findings of a fabric sound absorption comparison between two distinct fabric structures as the number of layers increases are presented. Additionally, the discussion of the influence of physical characteristics of fabric thickness, mass per unit area, air permeability, and porosity on the efficiency of sound absorption phenomena is presented.

MATERIAL

The fabrics structures (S) sateen 1/4(3) and (P) plain (1/1) were formed from polyester (PES) dtex 167 × 2 (f 32 × 2) drawn textured yarn. The polyester yarn was employed as a raw material in both the warp and weft directions. The sound absorption of woven fabrics was examined by combining nonwoven (NW) fabric as the base material with a 30 mm thickness and a mass per unit area of 623 g/m^2. The publication [11,12] presents further details of the yarn characteristic, warp and weft density, yarn crimp, and weave structure discussions.

METHODS

The fabrics were woven on a Sample Dobby loom SL 8900S (CCI Tech Inc, Lodz, Poland) with 8 harness frames and 1500 warp yarns for each weave structure. The sound absorption coefficient (α) of porous material was measured using the transfer function method in accordance with PN-EN ISO 10534-2:2003. To understand the influence of layer increasing on the sound reduction phenomena, each samples type was examined as single, double, and triple layers combined with base material of nonwoven (NW) (Figure 1). The sample represented IP single plain fabric with NW, IIP double layers plain fabrics with NW, IIIP triple layers plain fabrics with NW and IS single sateen fabric with NW, IIS double layers sateen fabrics with NW, IIIS triple layers sateen fabrics with NW. Besides the sound absorption test, thickness, mass per unit area, air permeability, and porosity percentage of single materials were examined. Fabric thickness tests were conducted using a 20 cm^2 measurement area and a pressure of 1 kPa in accordance with PN-EN ISO 5084:1999. The fabric's mass per unit area was determined in accordance with PN-ISO 3801:1993 (at a temperature of 21 ± 0 ◦C and relative humidity of 66.5%). The air permeability of the samples was determined in accordance with ISO 9237:1995 guidelines. The tests were carried out at the Lodz University of Technology's Department of Materials Science, Commodity Science, and Textile Metrology laboratory (Lodz, Poland). The porosity of the sample was determined using the Textile Institute's Test Procedure No. 60. The quantity of light passing through the textile sample placed horizontally on the microscope table is measured. Passing light was used to illuminate the sample at a constant intensity of 1000 lux. The porosity of a sample image is defined as the ratio of the thresholded area to the total area of the sample image. The preparation of samples, sound absorption, fabric thickness, mass per unit area of fabric, and porosity determinations were performed at the Lukasiewicz Research Network-Textile Research Institute.

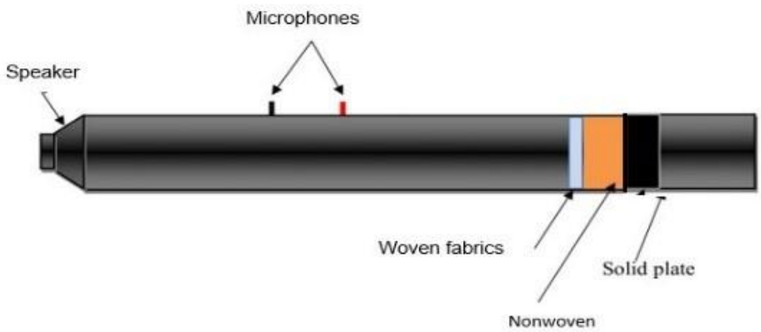

Figure 1. Schemata of samples set sequence inside impedance tube [12].

RESULTS AND DISCUSSION

The result of sound absorption and physical characteristics of fabrics

The plain and sateen fabric structures were compared in terms of sound absorption efficacy and physical properties. The result demonstrates that plain fabrics' sound absorption decreases with the increase of plain fabric layers, specifically at higher frequency ranges.

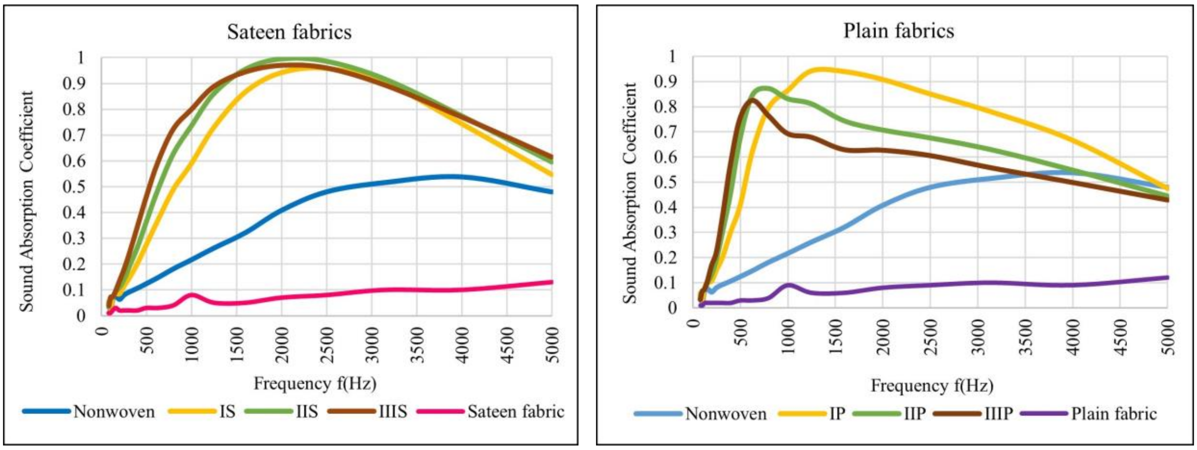

Figure 2. Sound absorption coefficient (α) versus frequency (Hz) for plain and sateen fabrics.

As illustrated in Figure 2, the IP fabric absorbs approximately 1 (α) at frequencies between 1000 and 2000 Hz. The fabric IIP exhibits the second-highest absorption, approximately 0.9, in the range of mid-frequencies (500–1000 Hz). Therefore, the IIIP fabric demonstrates lower sound absorption results when compared to the I and II layers of plain fabrics. The sateen fabric structure demonstrates that at higher frequencies between 1500 and 3000 Hz, higher sound absorption (α) it has approximately 1. At mid-frequencies, the IS fabric has very low absorption. However, as the layer of sateen fabric was added, the absorption at the mid-frequency level showed an improvement. Nonwoven fabric's sound absorption shows that it is more effective at absorbing sound at higher frequencies than plain fabric or sateen fabric (Figure 2). Furthermore, the nonwoven maximum absorption coefficient ranged between 0.5 and 0.6. Without nonwoven fabric, the sound absorption of plain and sateen fabrics is low. As a result, the combination of woven and nonwoven fabrics (IP, IIP, IIP and IS, IIS, IIIS) results in a win-win situation that increases the efficiency of both materials.

Table 1. Physical characteristics of woven fabrics [11,12].

Fabric types	Thickness of woven fabrics (mm)	Mass Per Unit Area (g/m^2)	Air permeability (mm/s)	Fabric porosity (%)
IP	0.52 ± 0.01	195 ± 1.5	95.5	11.5
IS	0.9 ± 0.03	213 ± 2.1	453.1	1.5

According to the fabric physical characteristics results, the thickness, mass per unit area, and air permeability of single-layer IP fabric are less than that of single-layer sateen fabric (Table 1). The porosity analysis reveals a more porous surface on the plain fabric structure than on the sateen structure. The Plain (1/1) fabric structure has more interlacement points, at the same time which increases the fabric's strength. The IS (1/4(3)) fabric has higher yarns floating over the fabric structure, which shows a lower interlacement degree. The fabric's thickness is also directly related to the yarn's compactness within the fabric structure. As the interlacement of yarns decreases, the thickness of the fabric increases. Besides, the lower interlaced fabric structure due to the loosely packed yarn strands can have higher coverage, or the propagation of light or sound energy into the material can be hindered due to the floated yarns in the fabric structure. This case is shown in the IS fabric structure. Additionally, in relation to the degree of interlacement, the air permeability result is greater in the IS fabric, which is attributed to the possibility of increasing pressurized airflow over the noninterlaced surface. The relationship between sound absorption and air permeability shows that, in comparison to IS fabric, a plain (IP) fabric has low air permeability and a high sound absorption coefficient, specifically < 1500 Hz. This is due to the higher porosity surface of the IP fabric structure. Sound waves can easily propagate into materials with enhanced porosity. As a result, the sound absorption performance of IP at low frequencies has improved. On the other hand, the IS fabric structure has low porosity and high sound absorption at higher frequencies.

CONCLUSION

The analysis of the sound absorption coefficient of test results for plain and sateen front materials, related to their physical characteristics, came up with the following summaries:

- A single plain fabric (IP) exhibits strong sound waves absorption below 1500 Hz. However, the result lowers as the number of fabric layers increases. This is because plain fabric's porous surface allows sound waves to propagate through it. As a result, low-frequency sound absorption increased. However, because of the way the fabric structure is woven, there is a possibility that the more layers there are, the less sound wave propagation will be able to get into the fabric structures.
- The sateen fabric shows a high sound absorption coefficient at higher frequencies and as the fabric layers increase.
- The weave structures determine the thickness of the fabrics and the number and distribution of porous areas. This phenomenon directly impacts the material's sound wave absorption capacity, especially at lower frequencies.
- The front materials' porosity and thickness properties are the main factors in determining the acoustic material's sound waves absorbed at different frequencies.

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