ACOUSTIC PROPERTIES OF AEROGEL EMBEDDED NONWOVEN FABRICS

Mohanapriya Venkataraman, Rajesh Mishra, Veerakumar Arumugam, Hafsa Jamshaid, Jiri Militky

Department of Material Engineering, Faculty of Textile Engineering, Technical University of Liberec, Czech Republic

ABSTRACT

In recent years, silica aerogel has attracted great attention and been extensively used in different technical fields due to its remarkable properties in optics, mechanics, acoustics etc. On the other front, nonwoven fabrics in general are ideal acoustical insulator due to their high volume-to-mass ratio. The material thickness, density, airflow resistance and porosity are important factors in determining the absorption behavior of nonwovens materials. This research examined the sound absorption properties of aerogel embedded (Polyethylene/polyester) nonwoven fabrics at different frequencies from 50 to 6400 Hz in the third octave frequency band. The impedance tube method was used for measuring the acoustical properties of the nonwoven fabrics. In this method, sound absorption coefficient was determined at each frequency in accordance with the ISO 10534-2 standards. The results showed that the aerogel embedded nonwoven fabrics have higher sound absorption coefficient which is suitable for acoustic application. The results of measurements were statistically analyzed by ANOVA and found to be significantly different.

KEYWORDS

Acoustic properties, Sound absorption coefficient, Aerogel, Nonwoven

1. INTRODUCTION

Noise refers to the irregular and chaotic sound which disturbs people's work and impairs people's health. Noise control is a vital process in today's structural design. Urbanization and heavy growth of construction work in every neighborhood emphasize the need of new technologies for noise reduction. There are several methods to decrease noise and one of which uses sound absorption materials. The absorption of sound results from the dissipation of sound energy to heat. The sound energy can be dissipated owing to the viscous friction and heat exchange when sound waves propagate through the flexible porous structure. Many authors have explained this dissipation mechanism in the past [1]. Engineers always seek new materials and arrangements to enhance the sound absorption techniques. This work is based on previous studies on the use of textiles as noise control elements. The factors that chiefly determine a materials sound absorption property are its fibre type, fibre size, material thickness, density, porosity and air flow resistance [2] reports show that the use of nonwoven materials for noise reduction is based on inbuilt advantages such as porous fibrous structure, light weight, bulky in nature, economically low price and their versatility [3-6]. They are more suitable for automotive and building industries and they can also absorb sound in order to decrease sound pollution in the environment. Currently, sound absorption materials commercially available for acoustic treatment consisted of glass, mineral or synthetic fibres. A study on sound absorption characteristics of rock wool and glass fibre [7] indicated that these fibres behave alike. A composite structure with a combination of perforated panel, rubber particle, porous material, polyurethane foam and glass wool were found to demonstrate significant sound attenuation [1]. However, when the issue of safety, insulation, environment and health are considered, they pose interference to human health and surroundings. Thus, environmentally friendly materials of high flame resistance and high insulation as well as good sound absorption properties are needed. Aerogels are another form of microporous materials used in some complicated applications. Silica aerogel has a monolithic internal structure being made of a highly porous, extremely lightweight and translucent material in which most of its volume is filled with air. Several raw materials have been used to produce aerogels, but silica aerogels are the most common. Its structure is composed of small spherical silicon dioxide clusters from 3-4 nm in diameter that are linked to each other forming chains that in turn form a spatial grid with air-filled pores.The typical average size of the pores is 30 to 40 nm. The typical porosity of an aerogel is greater that 90%, and its melting point is 1,200° C. Due to their low acoustic property for noise abatement, aerogels could be used in buildings and automobiles. A different approach has been related to the aerogel incorporated in nonwoven fabrics with varying concentrations of silica and polymer materials, which increases the material's strength and stability.

In this study, it has been oriented towards aerogel in granular form incorporated in nowoven fabrics as sound-absorbing materials. Experimental results of multilayer absorbing fabrics incorporated with silica aerogels have been presented by some authors [8]. The average size and density of the pores can be controlled during the manufacturing process. Such composite aerogels have pore sizes between 5-20 nm, and experimental results have shown that these materials exhibit better sound-absorbing properties than those of commercial rockwool and fibreglass [9].

2. EXPERIMENTAL

2.1 Materials

In this study, polyester/polyethylene nonwoven thermal fabrics treated with amorphous silica aerogel were used, as they are most suitable for application in textile materials. Polyester and Polyethylene were chosen for the study due to its versatile qualities. Polyester has the ability to spring back into shape, does not absorb water, and dries quickly. Polyethylene floats, resists chemicals and water. High Molecular Weight Polyethylene (HMWP) is one of the world's strongest and lightest fibers. Polyethylene fiber is pound-for-pound 10 times stronger than steel [10]. The thermal wraps were chosen in three different thicknesses. Sample 1 (3.5mm), Sample 2 (6.2 mm), Sample 3 (6.6 mm). The details of samples are given in Table 2. All the samples were conditioned in standard atmospheric temperature of about 250±20°C and 65±2% relative humidity before testing.

Table 1 Sample details used for the experiment

Specifications	Sample 1	Sample 2	Sample 3
Type	*Nonwoven*	*Nonwoven*	*Nonwoven*
Thickness(mm)	*3.5*	*6.2*	*6.6*
Weight(GSM)	*272.6*	*499.5*	*440.7*
Density(kg/m3)	*79.65*	*80.42*	*66.73*

2.2 Methods

Thickness and Density

The thickness of the samples was measured using UNI-thickness meter. The weight of the fabrics cut to 10 cm x 10 cm dimension was measured. Fabric density is the factor of weight and thickness. To obtain an indication of the effect of fabric density on thermal properties, nonwoven fabrics with comparable densities in different thicknesses and their corresponding weights were measured for aerogel treated nonwoven fabrics. The density difference of samples may be attributed to the fabric structure and also the percentage of aerogel particles present in the fiber. Fabric density [kg/m^3] is calculated as ratio of areal mass [g/m^2] and thickness [mm]. Approximate volume porosity of all samples was around 93%.

Air-permeability

The principle of FX 3300 air permeability instrument shown on the measurement of air flow passing through the fabric at a certain pressure gradient Δ p. In this instrument any part of the fabric can be placed between the sensing circular clamps (discs) without the garment destruction. As the fabric fixes firmly on its circumference (to prevent the air from escaping), the fabric dimensions doesn't play any role. Here is also enough space between the clamps and the instrument frame, which allows the measurement on large pieces [11].

Measurement of Acoustical Properties

Measurement of sound absorption coefficient

The following measurement methods are divided according to the size of evaluated samples. Determination of sound absorption coefficient of laboratory samples acoustic material using two -microphone impedance tube deals with the evaluation of samples in a laboratory scale standards. The device is used to determine the sound absorption coefficient (sound absorption coefficient) laboratory circular samples with a diameter of 100 mm for the frequency range 50-1600 Hz and 29 mm for the determination of sound absorption coefficient of laboratory samples acoustic material using two -microphone impedance tube. This device is used to frequency range 500-6400 Hz in accordance with ASTM E1050-08. This method is based on the evaluation of the sound absorptive properties of materials at normal incidence sound waves.

Table 2 Parameters of the device

Norms	ISO Standard 10534-1 (730501) , ASTM E1050-08
The frequency range	50-6400 Hz
Size of sample 1	(100 mm diameter circular sample)
Sample Size 2	29 mm (diameter of the circular sample)

Coefficient varies from zero (0) to one (1). Sound absorption performance is a function of frequency and is performed generally with the increase in frequency. Performance improves with the increase in thickness. Material thickness should be at least 1/10 wavelength of sound to justify the use (i.e., offer any benefit) and ¼ wavelength of sound to be effective. Sound absorption coefficient is affected by parameters of material such as porosity, thickness, density, airspace between the absorber and the wall, perforation and facing.

Measurement of Noise Reduction Coefficient

The NRC is the percentage of sound that a surface absorbs (in other words, hits a surface and doesn't reflect back again into the room). The American standard ASTM 423 provides similar test criteria to EN ISO 354 and also provides a method for calculating a single figure result called a "Noise Reduction Coefficient" or" NRC". This is calculated using the following equation.

$$\mathrm{NRC} = \frac{\alpha_{250\mathrm{Hz}} + \alpha_{500\mathrm{Hz}} + \alpha_{1000\mathrm{Hz}} + \alpha_{2000\mathrm{Hz}}}{4} \quad (1)$$

3. RESULTS AND DISCUSSION

3.1 Influence of aerogel content on sound absorption

Audible sound waves have a frequency ranging from 20 to 20 000 Hz. Sound absorption increases with the surface area facing the sound. As aerogels have high porosity and high specific surface area, sound waves are strongly absorbed and attenuated. Sound velocity through a silica aerogel can be as low as 100 m/s, compared with 332 m/s in air at 0oC. Sound absorption and attenuation are related to wave frequency, material density and the size of pores (granules) etc. [12-14]. Sound absorption is significantly enhanced with fibre reinforcement and decrease in pore size [14]. From the Figures 2,3 & 4, it is evident that the aerogel present in the nonwoven fabrics influence the sound absorption properties.

Air Permeability

Air permeability is the measure of airflow passed through a given area of a fabric. This parameter influences the acoustic properties of fabrics to a large extent. It is generally accepted that the air permeability of a fabric depends on its porosity, which in turn influences its openness. Statistical analysis results show that the there is a significance on the air permeability values of the aerogel treated nonwoven fabrics ($p = 0.003$). Figure 1 shows the air permeability with respect to different pressure levels of the fabrics. The result indicates that air permeability is directly proportional to the pressure level. On comparison of three fabrics, the air permeability is higher in the case of sample 1. It may be due to the fact that air permeability is related to porous structure of the fabric which in turn influences the sound absorption coefficient. Even though the volume porosity of all the fabrics was around 93%, sample 2 & 3 has lower air permeability than sample 1 due its thickness.

3.2 Influence of material parameters on sound absorption

The various factors affecting the sound absorption coefficient of the fabrics are thickness, density, porosity and air flow resistance [2]. In this study we have considered thickness, density and air flow resistance as the main factors. Since the porosity of all the fabrics were more than 90%, the sound absorption coefficients of the fabrics were good. Most of the porous sound-absorbing materials commercially available are fibrous materials. Fibrous materials are composed of a set of continuous filaments that trap air between them. In this study, nonwoven fabrics embedded with aerogel were used for analysing the sound absorption coefficient. The aerogel embedded nonwoven fabrics has better sound absorption coefficient at higher frequency range as shown in Figure 3 . In lower frequency ranges (50-1500 Hz) the sound absorption coefficient of the fabrics is lower than the material made up of fiber glass and rock wool which is shown in Figure 2. The bicomponent fibre and aerogel present directly influences the sound-absorbing characteristics of the material. It is evident from the results shown in Figures 2, 3 & 4 that the Sound absorption coefficient, α, depend on the thickness of the fabric. Thickness of the fabric plays a major role in the sound absorption coefficient. Sample 1 (3.5 mm) has the lower sound absorption coefficient than sample 2 & 3. To examine the use of nonwoven fabric embedded with aerogel for sound absorbing materials, the studies have reported values of the sound absorption coefficient of the fabrics of different thicknesses and frequencies.

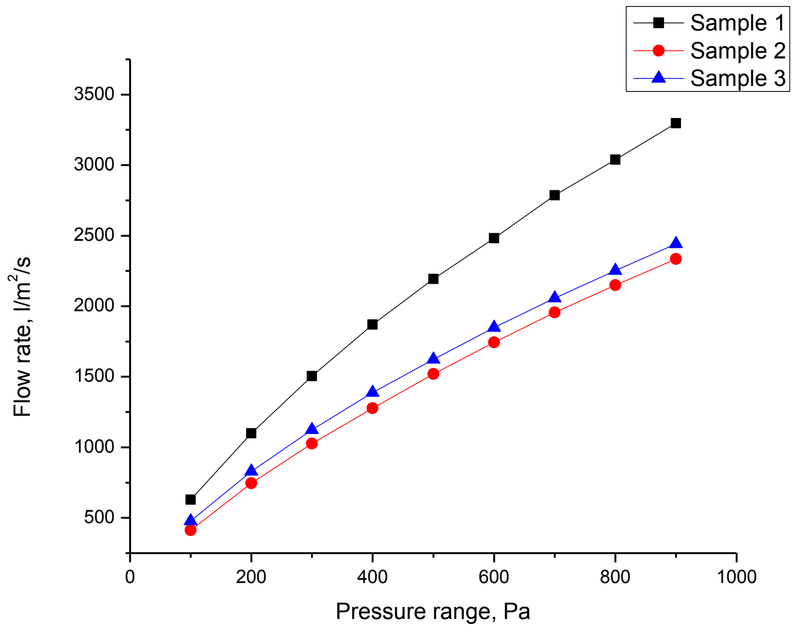

Figure 1 Air permeability of all fabric samples [13]

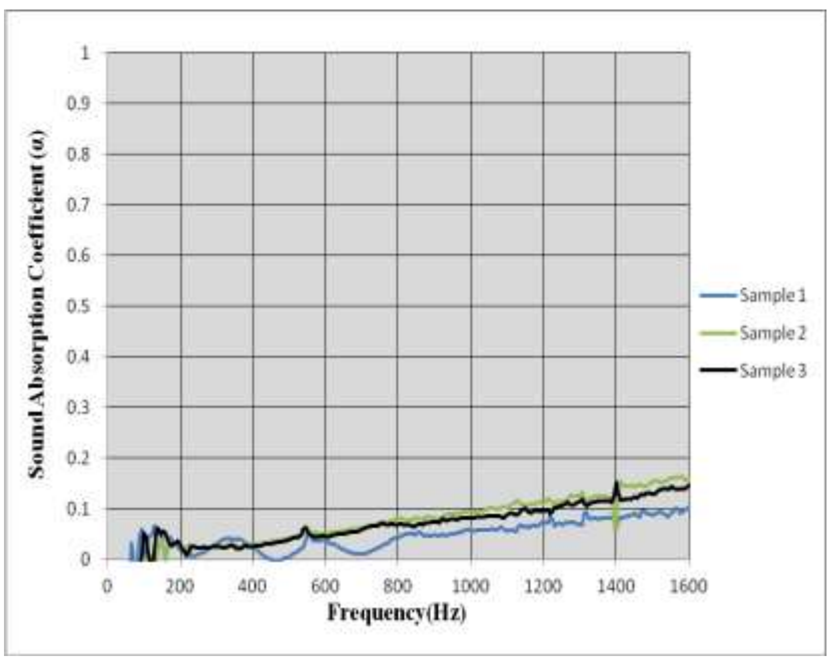

Figure 2 Sound absorption coefficient of fabrics with low frequency range (50-1600 Hz)

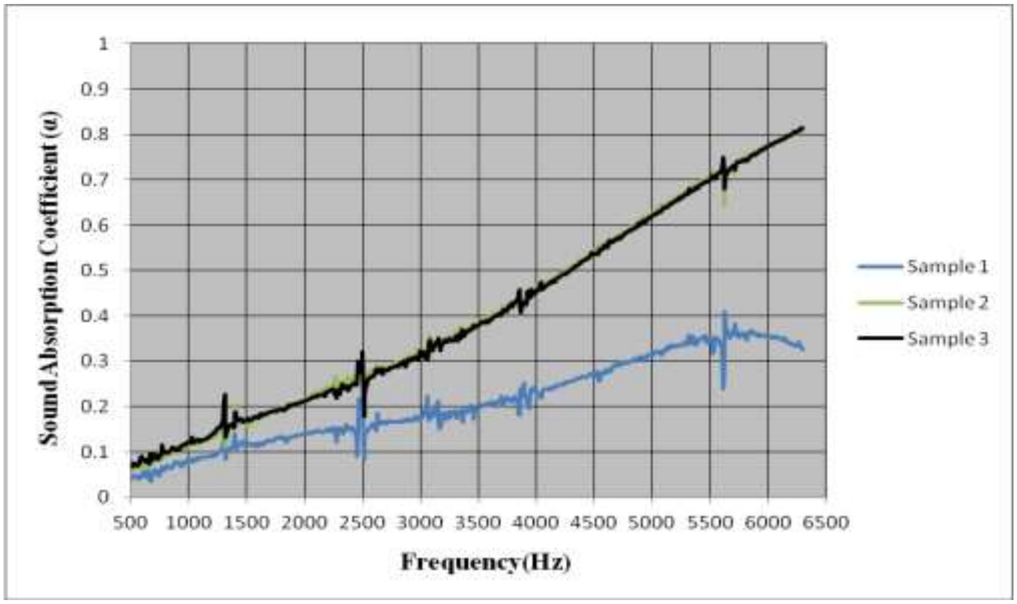

Figure 3 Sound absorption coefficient of fabrics with low frequency range (500-6400 Hz)

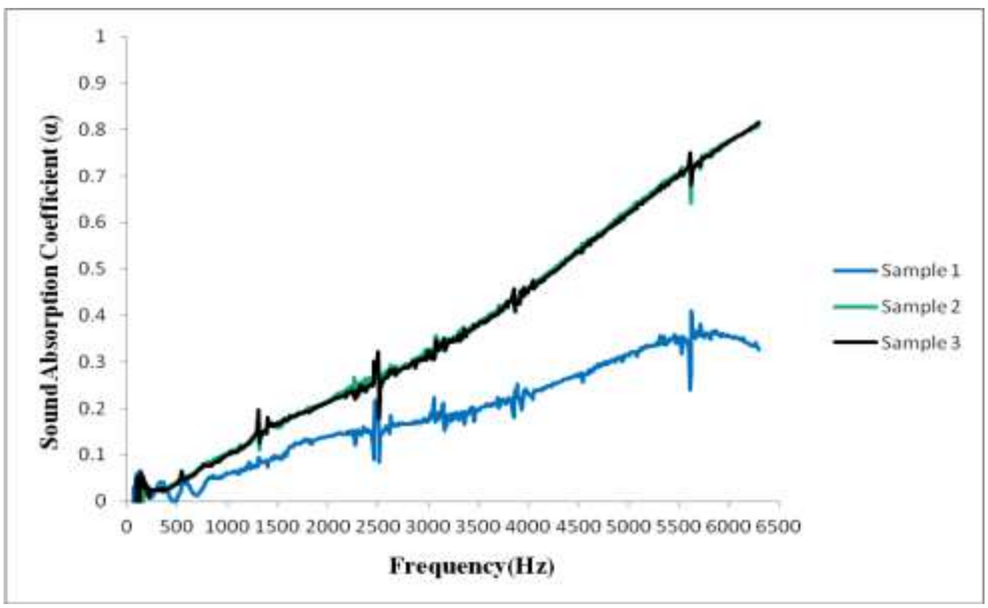

Figure 4 Sound absorption coefficient of fabrics with all frequency ranges (50-6400 Hz)

Acoustical materials are those materials designed and used for the purpose of absorbing sound that might otherwise be reflected. When a sound wave strikes an acoustical material the sound wave causes the fibers or particle makeup of the absorbing material to vibrate. This vibration causes tiny amounts of heat due to the friction and thus sound absorption is accomplished by way of energy to heat conversion. The more fibrous a material is the better the absorption; conversely denser materials are less absorptive. Noise reduction coefficient (NRC) was calculated from the equation (1). From the Figure 5, the sample 1 shows the low value of NRC than Sample 2 & 3.The sound absorbing characteristics of aerogel embedded nonwoven fabrics vary significantly with frequency. In general low frequency sounds are very difficult to absorb because of their long wavelength which is shown in Figure 2.

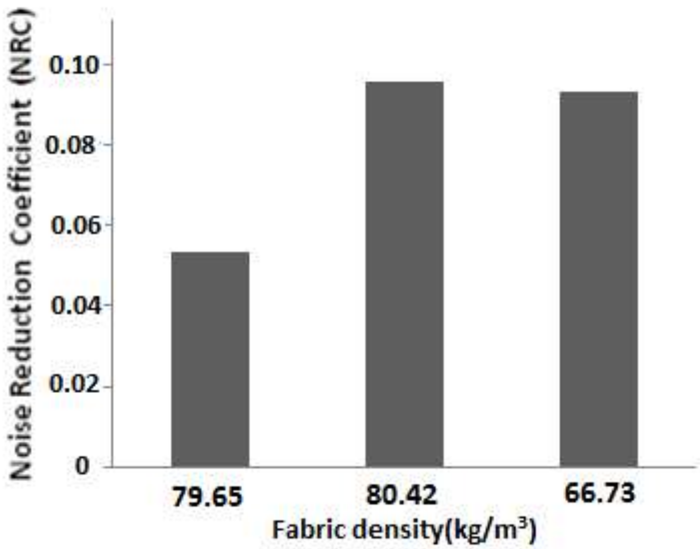

Figure 5 Noise reduction coefficients of all densities

4. CONCLUSION

Porous sound-absorbing materials have evolved into more advanced materials over the years. Compared with the older absorbing materials produced in the 1960s, the new materials have become safer, lighter and more technologically optimized. It was observed that the aerogel coated nonwoven fabric thickness had the greatest impact on the material's sound absorbing qualities. The inherent composition of the nonwoven fabric with the aerogel content determines the material's acoustical performance.

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