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Acoustic Insulation Behavior of Composite Nonwoven

Dilan Canan Çelikel and Osman Babaarslan

Additional information is available at the end of the chapter

Abstract

Multilayer or multicomponent composite nonwoven structures provide great advantages for many technical applications. Spunbond-meltblown-spunbond (SMS) type multilayer nonwovens have significant commercial success in terms of end-use versatility. SMS type composite nonwovens, which can be produced with both continuous and discontinuous production technologies, are evolving day by day. Bulky, fibrous, porous nonwoven structures are widely used as sound absorbers for a variety of applications for instant building and automotive insulations, machine insulations, etc. The fibers interlocking in nonwovens are the frictional elements and provide resistance to acoustic wave motion. As many researchers reported, the most effective factors on sound absorption properties of fibrous materials are fiber diameter, airflow resistance, material thickness, tortuosity, porosity, and fiber surface area. In this research chapter, the sound absorption performance of SMS type composite nonwovens in relation to air permeability and pore sizes has been determined. The results show that SMS type nonwovens perform sound insulation at high frequencies. Spunmelt nonwovens with the advantages of short production line will create various alternatives with varieties of layering and compete with commercially used other sound absorbers.

Keywords: nonwovens, spunbond, meltblown, bicomponent fibers, sound absorption, permeability

1. Introduction

Today, textile materials are widely used in various technical applications including, but not limiting to transportation, agriculture, medical, filtration, and insulation. With the development of new materials, process technologies, combination of different processes, and innovative products have become the fastest growing area of the textile industry in recent years.

Combinations of different nonwovens, fiber combinations, and integration of process technologies are an increasingly beneficial option for new product developments.

The definition of nonwovens by EDANA (The European Disposables and Nonwovens Associations) and INDA (The North American Association of the Nonwoven Fabrics Industry), two leader associations in nonwovens market, "A nonwoven is a sheet of fibers, continuous filaments, or chopped yarns of any nature or origin, that have been formed into a web by any means, and bonded together by any means, with the exception of weaving or knitting." Nonwovens are engineered fabrics that can form the products that are disposable, for single or short-term use or durable, with a long life depending on the requirements and the intended product life [6, 7].

Multilayer or multicomponent nonwovens, also called as composite nonwovens, are the structures of various combinations of materials and processes providing great advantages. There are an increasing number of combinations of spunbonded (S) and meltblown (M) processes as SM, SMS, SMMS, SSMMMMSS, etc., where weaker meltblown fabrics are sandwiched between the stronger spunbonded fabrics. SMS (Spunbond + Meltblown + Spunbond) type multilayer nonwovens, has commercially success, are the best known products. These materials are produced continuously in a single line as well as a discontinuous line is also available.

Nonwovens with their bulky, fibrous, and porous structures, one of the most common textile materials, have an important role on sound absorption within the automotive, construction and a variety of industrial uses. Because of the porosity of the structure and the fibers interlocking in nonwovens are the frictional elements that provide resistance to acoustic wave motion. When sound enters into fibrous materials, its amplitude is decreased by friction as the waves try to move through the tortuous passages. Thus, the acoustic energy is converted into heat resulted with sound absorption [1].

In multilayer nonwovens, in accordance with the layers' structural parameters, different fiber intersections and fiber orientations occur. Pore connection and distribution become an important factor in determining acoustic properties because of the flow of sound wave through the material has been affected. Additionally as the number of layers increases or with different layer combinations in multilayer nonwovens, tortuosity and pore geometry will vary and different sound absorptions will be provided.

Many researchers studied and reported sound absorption characteristics of nonwovens/multilayer nonwovens in the literature. Ulcay et al. investigated sound absorption properties of spunbonded nonwovens produced from fibrillated islands in the sea bicomponent filaments with the various numbers of islands 1, 7, 19, 37, and 108. The results, as the effect of the number of islands on acoustical absorptive behavior, showed that spunbonded webs with 108 islands were better acoustic absorbers. Spunbonded nonwovens with the island in the sea bicomponent fibers were also compared with some high loft nonwovens; it has been reported that multilayer nonwovens with 108 islands have better sound absorbing performance [2].

Liu et al. studied the acoustic characteristics of dual-layered nonwovens by analyzing experimentally and theoretically. In experimental analysis, it was defined the sound absorption coefficients of 20 dual-layered nonwoven fabrics with four types of meltblown polypropylene

nonwovens and five types of hydroentangled e-glass fiber nonwovens at low frequency ranges. In theoretical analysis, the effect of thickness and porosity of top and bottom layer on sound absorption coefficient was detailed using numerical simulation method. Experimental results indicated that the measured and the calculated data have very similar trend with the change of thickness, porosity, and the sound frequency [3].

Sound absorption properties of some bilayered needle-punched nonwoven composites at low frequencies have been investigated by Kucuk and Korkmaz. Results showed that macrofibrous layer of polyester fibers backed with 70% wool and 30% bicomponent polyester fibers has the best sound absorption properties at all frequency ranges [4].

Factors influencing acoustic performance of sound absorptive materials have been researched by Seddeq. As a result, he reported that the fiber linear density, air permeability, thickness, compression, porosity, and the position of the material are the major factors effecting acoustic properties of needle-punched nonwovens [5].

2. Multilayer nonwoven structures for acoustic insulation

Nonwoven industry had growth substantially for decades prior to the global recession between 2008 and 2010. The worldwide production of nonwovens was primarily based in Europe, North America, and Japan until the last decade. Now, nonwovens are produced on thousands of lines around the world. Asia is now the dominant nonwoven producing region, accounting for 42% of the world's production in 2014 [8]. Nonwoven production by region is shown in **Figure 1**.

The production of nonwovens is carried out in three stages as seen in **Figure 2**. Web formation is the major determinant of the characteristic of final product. The choice of methods for forming webs is determined mainly by fiber type and fiber length. The methods for the web formation from staple fibers were based on the drylaid and wetlaid processes, as well as in spunmelt processes, polymer chips are converted into webs by filament laying.
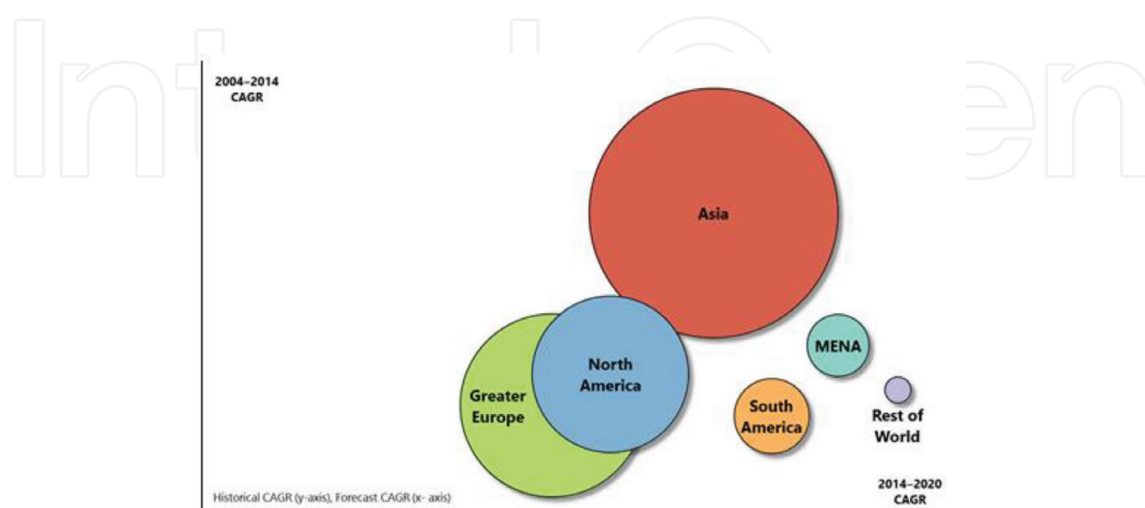

Figure 1. Nonwovens production by region (bubble size in tones of production) [8].

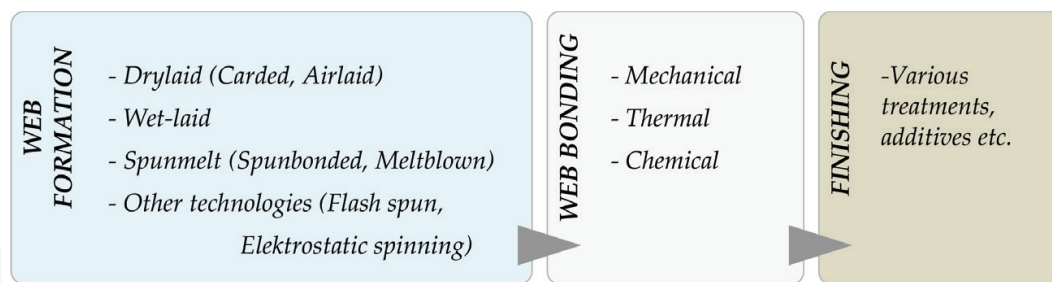| WEB FORMATION	- Drylaid (Carded, Airlaid) - Wet-laid - Spunmelt (Spunbonded, Meltblown) - Other technologies (Flash spun, Elektrostatic spinning)	WEB BONDING	- Mechanical - Thermal - Chemical	FINISHING	-Various treatments, additives etc.

Figure 2. Nonwovens production stages.

Multilayer or composite nonwovens are produced by a modern and innovative industry that have numerous applications including, but not limiting to, hygiene, medical, filtration, insulation, automotive, agriculture, home furnishing, and packaging. Hygiene is the basic usage of multilayer nonwovens used in numerous products including baby care, feminine care, and adult products. The automotive industry also represents a significant market for application. Also breathable composite nonwovens are available for agriculture market. These materials offer engineering solutions by creating multifunctional products as well as economic solutions [14].

Sound absorbing materials are used in almost areas of noise control engineering to reduce sound pressure levels. They are used in a variety of locations—close to sources of noise, in various paths, and sometimes close to receivers. To use them effectively, it is necessary to:

- Identify the important physical attributes and parameters that cause a material to absorb sound.

- Provide a description of the acoustical performance of sound absorbers used to perform specific noise control functions.

- Develop experimental techniques to measure the acoustical parameters necessary to measure the acoustical parameters of sound absorbing materials and the acoustical performance of sound absorbers.

- Introduction of sound absorbing materials in noise control enclosures, covers, and wrappings to reduce reverberant build up and hence increase insertion loss.

Synthetic fibrous materials made from minerals and polymers are used mostly for sound absorption and thermal isolation. However, since they are made from high-temperature extrusion and industrial processes based on synthetic chemicals, often from petrochemical sources, their carbon footprints are quite significant. Although polyurethane and melamine foams are probably the cellular porous sound-absorbing materials currently most in use, other types of foams have been designed for environments where heat or corrosion resistance is required. Perforated panel absorbers have been used for many years in noise control usually to confine porous absorbing materials. When spaced away from a solid backing, a perforated panel is effectively made up of a large number of individual Helmholtz resonators, each consisting of a neck, comprised of the perforated panel and a shared air volume formed by the total volume of air enclosed by the panel and its backing. When the sound waves penetrate the

perforated panel, the friction between the moving molecules of air and the internal surface of the perforations dissipates the acoustical energy into heat. The perforations are usually holes or slots, and as with a single resonator, porous material is usually included in the airspace to introduce damping into the system [30].

In this research chapter, it has been examined that the sound absorption characteristics of SMS type composite nonwovens. SMS structure is a spunmelt structure where the middle layer is the meltblown, sandwiched between the two top and bottom spunbonded layers.

Spunbonded and meltblown methods are both melt spinning method basically, with the shortest textile production line from polymer chips to a web. In the spunbonded method, continuous filaments are extruded directly from thermoplastic polymer chips. The formation of a web of continuous filaments deposited on the conveyor belt is assisted by air suction. Some residual temperature creates a weak bonding effect on the filaments but this is not considered as bonding. The web is then bonded directly by various means, normally thermal bonding. The web obtained is anisotropic. As thickness ranges from 0.2 to 1.5 mm, basis weights from 10 to 200 gsm. Filament thicknesses are between 10 and 80 μm [6, 13, 14].

Meltblown method is similar to spunbond. The hot, molten, low viscosity polymer is forced through nozzles to form a stream of polymer. At the nozzle tip, the filaments are picked up by hot, high velocity air streams that stretch the filaments by drag forces into very fine diameters. The filaments gradually cool as they travel across to the collector, a conveyor band or drum. The use of suction at the collector assists in web formation. The main typical characteristics for meltblown nonwovens are weak tensile properties, porous and capillary structure, isotropic formation, large surface area, etc. As the basis weight of the meltblown webs varies between 10 and 350 gsm, the fineness of the fibers ranges from 0.5 to 30 μm [9–11].

Spunbonded structures have a number of advantages as fabric's durability and lower cost in comparison to other nonwovens and woven and knitted fabrics. Meltblown nonwovens are made from microfibers that are much finer than in the spunbonded process. The fibers' fineness makes fabrics that are softer but much weaker than spunbonded materials. Due to the larger volume of fiber per unit weight, meltblown materials have improved fiber distribution and are important to a broad range of functional applications. For example, meltblown fabrics have good barrier properties and high insulating values and thus are used in filtration, barrier materials for medical and disposable apparel and apparel insulation. So together, the combination of spunbonded and meltblown structures can create a strong product which can also offer functional applications. Spunbonded layers act as protective layers for meltblown layers [10–12].

As the bonding method of spunmelt nonwovens, thermal bonding is usually available. Thermal bonding is the process to heat the web where heat is treated with hot rollers, hot air or sound waves. It can be carried out by means of heated calender rollers even after web formation in spunmelt systems. In these methods, fusing fibers act as thermal binders. Important process parameters affecting the web properties are roller temperature, roller speed or contact time and pressure applied to web. Additionally, roller pattern (flat, pointed, etc.) controls the fabric strength, drape, stiffness, and softness. Heating temperature of rollers should be suitable for melting point of the polymer consisting of web [9–11].

One of the applications in thermal bonding in spunbonded process is producing web consisting of bicomponent fibers. Bicomponent fibers contain two different polymers extruded together from the same spinneret to compose a single fiber cross section. The properties and applications of bicomponent fibers depend on both the properties and distribution of the polymers in the cross-sectional area. Accordingly, typical configurations are side by side, core/sheath, island in the sea, sliced, pie slice, etc. The most commonly used in nonwovens and well-known binding bicomponent fibers is sheath/core type. When a bicomponent nonwoven web is heated sufficiently to melt the sheath, polymer melts and flows to the nearest adjacent fiber and binds the structure. It is recommended that the melting temperature difference between the components should be at least 40°C for proper bonding. Lower bonding temperature is provided by bicomponent fibers than in a typical thermal bonding application. Additionally, with this method, some structural parameters of a nonwoven fabric, such as fabric density, fiber diameter, tortuosity, porosity, etc., will be affected [15, 20].

3. Materials and methods

3.1. Materials

In this research, all spunbonded and meltblown nonwoven fabrics were supplied by Mogul Nonwoven Company in Gaziantep/Turkey. Raw material of all layers was polyester with the advantages of availability, flexibility, and commercially success. Spunbonded layers, flat bonded thermally, having a basis weight of 40 gsm, were produced from homocomponent and bicomponent fibers in the diameter of 20–24 μm. Seven different meltblown layers had a basis weight of 50–200 gsm with homocomponent round fibers at the diameter of 5–8 μm. Meltblown nonwovens were bonded thermally at same conditions to form nonstiffer middle layer of multilayer structures. SMS compositions of two different spunbonded layers and seven different meltblown layers were prepared manually, resulting in 14 multilayer nonwoven structures. Layers were arranged loosely, adjacent to each other. Fabric design of multilayer structures has been illustrated in **Figure 3**.

Description of multilayer nonwoven samples is shown in **Table 1**. The thickness of the samples ranged from 1.28 to 1.79 mm. From **Table 1**, the samples were coded as HC and BC according to the change of fiber type in the spunbond layers; sample codes of 1, 2, 3, 4, 5, 6, and 7 defined the changes in basis weight of the meltblown layers. For instance, HC1 designates an SMS type three-layered nonwoven in which the outer spunbonded layers with homocomponent round fibers and a meltblown layer have a basis weight of 50 gsm; BC7 means spunbonded layers with bicomponent fibers and meltblown layer having a basis weight of 200 gsm.

In this research, bicomponent fibers, round core/sheath type, in the spunbonded layers have a polyester core with an outer sheath of copolyester. The composition of polymers in core/sheath type is 90% polyester (PET) core with 230–250°C melting point and 10% copolyester (Co-PET) sheath with 110–140°C melting point.
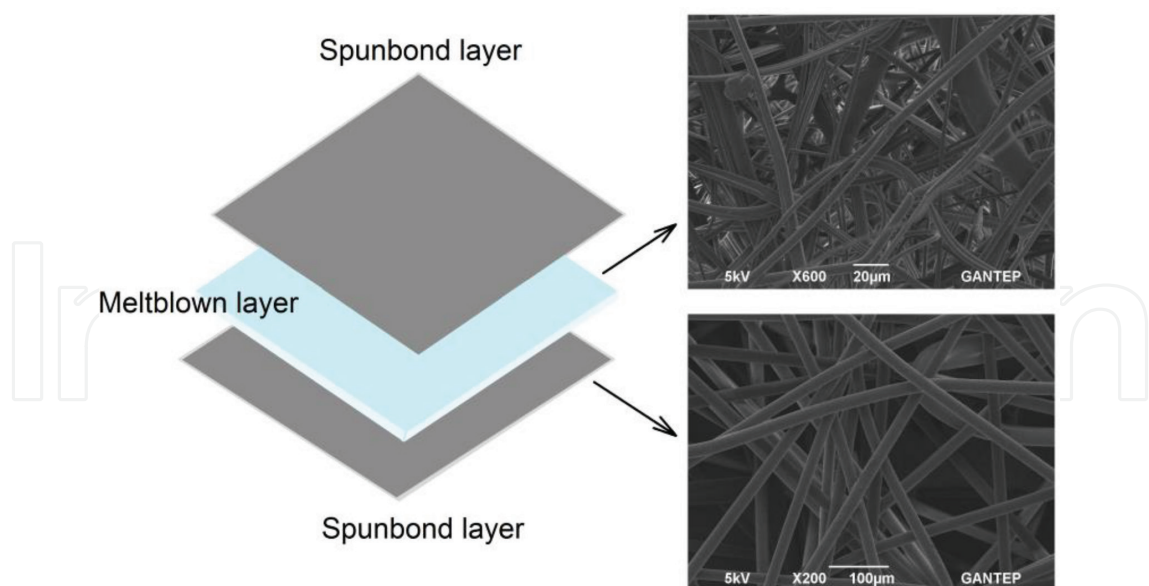
Figure 3. Schematic of multilayer structure and SEM micrographs of spunbonded layers (homocomponent fibers) and meltblown layer (in basis weight of 125 gsm).

Sample ID	Type of layer	Fiber type	Fiber content	Fiber cross section	Basis weight (gsm)	Thickness (mm)
HC	Spunbonded layers	Homocomponent	PET	Round	40	0.37 ± 0.07
BC		Bicomponent	PET/ Co-PET	Bico-round/ sheath-core type		0.35 ± 0.05
1	Meltblown layer	Homocomponent	PET	Round	50	0.59 ± 0.09
2					75	0.60 ± 0.08
3					100	0.62 ± 0.06
4					125	0.67 ± 0.07
5					150	0.84 ± 0.05
6					175	0.93 ± 0.06
7					200	1.1 ± 0.04

Table 1. Sample description and specifications of nonwoven layers.

3.2. Methods

All measurements were carried out at standard temperature (20 ± 2°C) and relative humidity (65 ± 2%). The thickness of the 10 different samples from each material was measured using a standard measuring device according to NWSP 120.6.R0 (15) [16].

Air permeability of multilayer nonwovens was obtained by using an SDL Atlas digital air permeability tester (SDL-Atlas Inc., USA). The test were conducted according to NWSP 070.1.R0

(15) [17]. The measurements were done on five different samples from each material by applying 200 Pa pressure through a 20 cm² test area. The reported results are the averages of the five measurements.

Sound absorption coefficients of multilayer nonwovens were measured according to ISO 10534-2 [18]. Nonwoven samples were cut into 100 and 29 mm diameters for the measurement of large and small tubes. Sound absorption coefficients of three samples (two replications from each material) were obtained by using a Brüel and Kjær impedance tube kit (**Figure 4**).

The capillary flow porometer (Porous Materials Inc., USA) has been successfully used to evaluate pore structures of multilayer nonwovens. Determination of porosity of samples according to ISO 15901-1 standard, 5 samples were prepared at 0.03 cm and determined by taking the average of the measurement values [19].

In statistical analysis, Design Expert Analysis of Variance (ANOVA) software (Stat-Ease, Inc., USA) was achieved. The effect of independent parameters, basis weight (A) and fiber type (B) on the dependent parameters of air permeability, mean pore diameter, and sound absorption has been examined with the analysis of variance at significance level of p value less than 0.05.
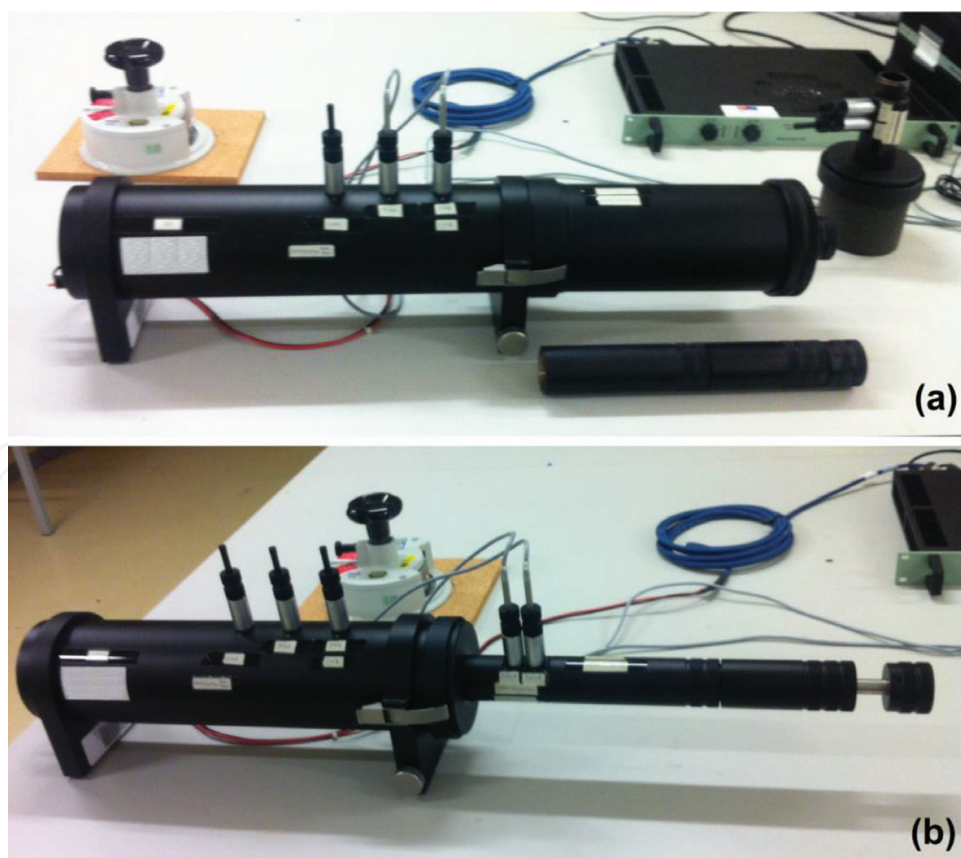

Figure 4. Impedance tubes for the two microphone transfer function methods: (a) large tube for 0.5–6.4 kHz and (b) small tube for 0.5–1.6 kHz.

4. Experimental results and discussion

4.1. Air permeability

Air permeabilities of nonwoven samples are presented in **Figure 5**, respectively, for increasing basis weights of multilayer nonwovens. As seen in **Figure 5**, the air permeabilities of the nonwoven samples with bicomponent fibers are lower than the air permeabilities of the nonwoven samples with homocomponent fibers. For each range of basis weight, BC samples are more resistant to air flow than the HC samples.

Air permeability is expressed as the ratio of air flow between the two surfaces of the fabric. The speed of the air flow passing vertically from a given area is measured by the pressure difference within the measuring area of the fabric. The degree of air permeability is one of the major affecting parameters of thermal and acoustic insulation capabilities of nonwoven fabrics. Higher air permeability results in higher sound absorption [21–23].

Co-PET polymer with low melting temperature in nonwoven samples containing bicomponent fibers melts during the thermal bonding and provides the binding by spreading to the fibers around the web. This attribute limits the cross sectional and connection between fibers, and when considering that it affects the fiber roughness, the decrease in pore diameters is determined by the pore size measurements. When the relationship between air permeability and pore structure is evaluated, it is thought that this will increase air flow resistance and create a decrease in air permeability values. This indicates that bicomponent structures restricted the size of air passages, so that air permeability decreased. At higher basis weights of the fabrics, the increase in the number of fibers creates more spaces and a longer tortuous path through which the air must flow. Thus fabric structure becomes more resistant to air flow resulted with lower air permeabilities.
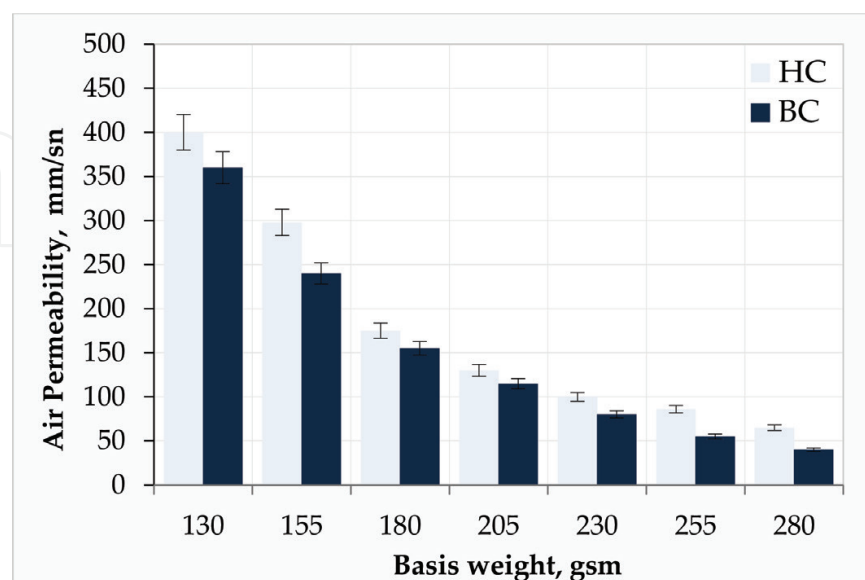

Figure 5. Air permeability of nonwoven samples.

In the statistical data analysis, the effect of independent parameters, basis weight (A) and fiber type (B), on the dependent parameter, air permeability, has been examined with the analysis of variance at significance level of p value less than 0.05. The model summary statistics and ANOVA results for the data obtained in the study are shown in **Table 2**.

As presented in **Table 2**, R-Squared (R^2) equals 0.9938, and predicted R-Squared (R_{pre}^2) equals 0.9865 for the model. It means that dependent parameters have been affected by independent parameters 99.38%, and this model predicts air permeability successfully at very high proportion of 98.65%. In the ANOVA results of BC and HC samples, both A and B are significant model terms. Contribution to model of significant terms according to F values, it has been determined that A-basis weight is more significant factor with higher F value for air permeability than B-fiber type. It can be specified that fiber type (bicomponent and homocomponent), is less effective parameter than basis weight to control air permeability of multilayer nonwovens statistically. Regression equation for air permeability of BC and HC samples obtained from the model is presented below in Eq. (1) according to codded factors. The high levels of the factors are coded as +1, and the low levels of the factors are coded as −1.

$$\text{Air permeability } = \ +121.00 - 124.34^* A - 14.93^* B + 97.23^* A^2 - 40.50^* A^3 \tag{1}$$

4.2. Mean pore diameter

The porosity of the fabrics is a complex feature characterized by parameters such as pore diameter, pore distribution, pore volume, while the porosity of the fabrics is associated with the total fabric volume area of the empty volume. Fabric porosity directly affects permeability properties, and the shape, layout, and size distribution of the media spaces are important considering the flow from porous structure [22].

In **Figure 6**, it is presented the mean pore diameter of nonwoven samples with the change of basis weight. As seen in **Figure 6**, nonwoven samples with bicomponent fibers had lower mean pore diameters than nonwoven samples with homocomponent fibers.

Source	Sum of squares	Degree of freedom (df)	Mean square	F	Significance
Model	1.748E + 005	4	43703.18	362.97	<0.0001
A-Basis weight	13084.75	1	13084.75	108.67	<0.0001
B-Fiber type	3120.07	1	3120.07	25.91	0.0007
Factors within group	20580.48	2			
Residual	1083.64	9	120.40		
Cor total	1.759E + 005	13			
Model	Std. deviation	10.97	R-Squared		0.9938
	C.V.%	6.68	Adjusted R-Squared		0.9911
	PRESS	2380.21	Predicted R-Squared		0.9865

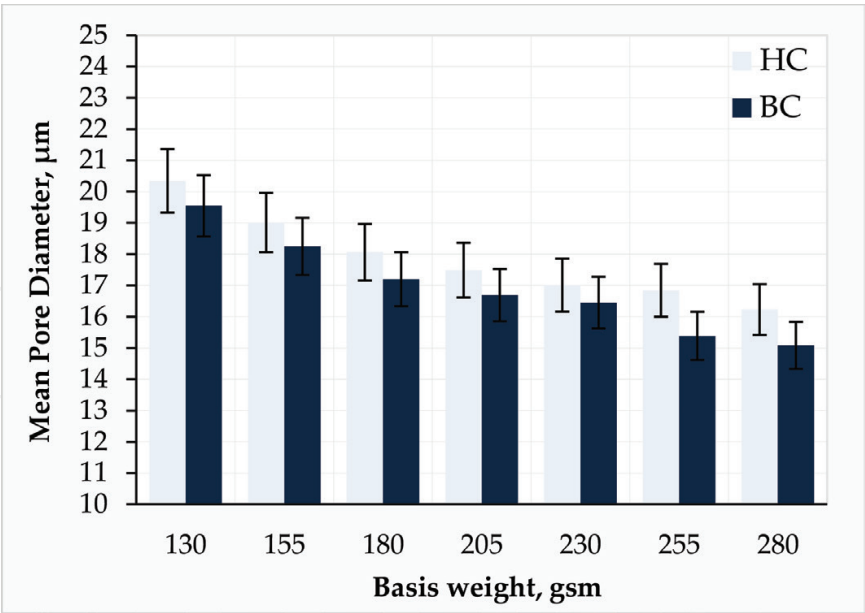**Table 2.** ANOVA for air permeability of samples.

Figure 6. Mean pore diameter of nonwoven samples.

Porosity, thickness, and fiber diameter are the factors that affect tortuosity of the structure [24]. Co-PET polymer with low melting point in the bicomponent nonwoven samples melted earlier and smeared the adjacent fibers during the bonding. The reason may be the variation of intersection of fibers, roughness, and tortuosity resulted with the change of the pore structure as smaller pore diameters for bicomponent nonwovens.

The statistical analysis of mean pore diameter of BC and HC samples exhibited in **Table 3** indicates the significant effect of fiber type with higher F values. Mean pore diameters have been affected by basis weight and fiber type 98.97%, and the model predicts the actual values of air permeability 97.60%. It can be specified that fiber type (bicomponent and homocomponent)

Source	Sum of squares	Degree of freedom (df)	Mean square	F	Significance
Model	29.47	4	7.37	216.22	<0.0001
A-Basis weight	1.92	1	1.92	56.46	<0.0001
B-Fiber type	2.91	1	2.91	85.34	<0.0001
Factors within group	1.28	2			
Residual	0.31	9	0.034		
Cor total	29.78	13			
Model	Std. deviation	0.18	R-Squared		0.9897
	C.V.%	1.06	Adjusted R-Squared		0.9851
	PRESS	0.71	Predicted R-Squared		0.9760

Table 3. ANOVA for mean pore diameter of samples.

is more effective parameter than basis weight to control mean pore diameters of multilayer nonwovens statistically.

Regression equation for air permeability of BC and HC samples obtained from the model is presented below in Eq. (2) according to codded factors. The high levels of the factors are coded as +1, and the low levels of the factors are coded as −1.

$$\text{Mean pore diameter} = +17.09 - 1.51*A + 0.46*B + 0.70*A^2 - 0.65*A^3 \tag{2}$$

4.3. Sound absorption

The performance of sound absorbing materials is generally explained by the sound absorption coefficient (α). It is defined as the ratio of acoustic energy that is trapped in the material by the material and ranges between 0 and 1. "α = 0" means 0% sound absorption so the reflection of all the sound waves, and "α = 1" means 100% sound absorption of all the sound waves.

The sound absorption results of nonwoven samples are observed in **Figure 7**. It is certain that as many researchers reported, the increase in basis weight influences the sound absorption positively. So also in this research, the higher sound absorption coefficients were proved for the higher weights. But it should be noted that BC samples have better sound insulation for each range of fabric weight. More effective sound absorption with bicomponent fibers is obvious.
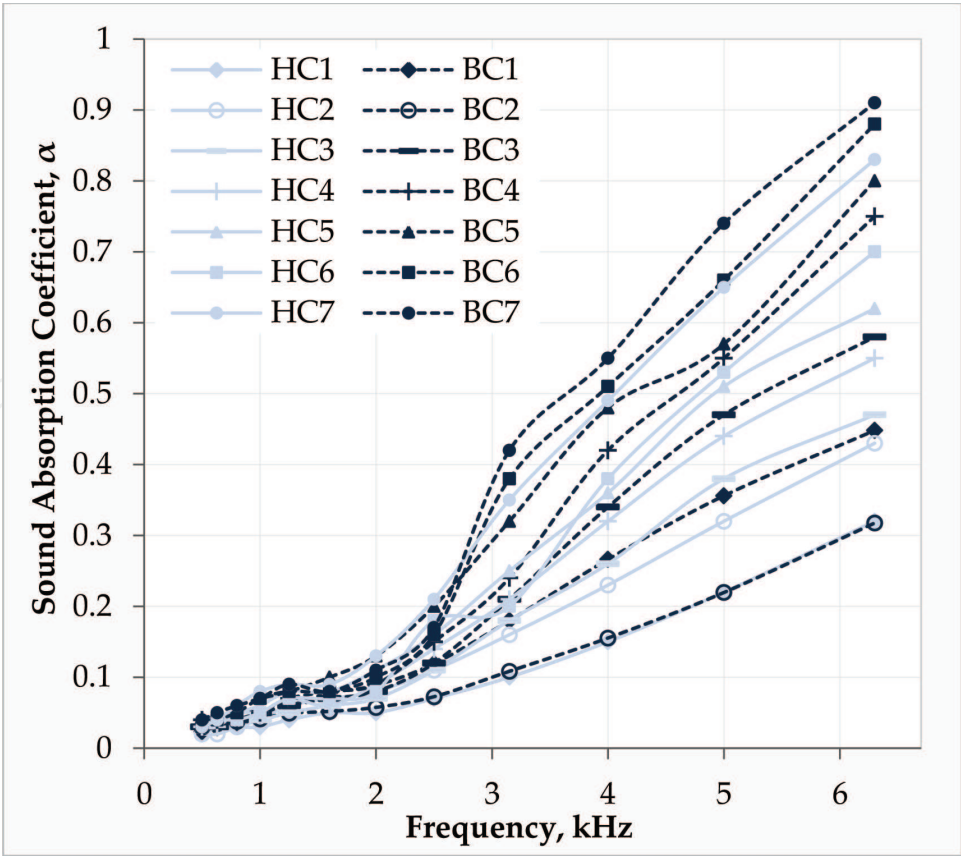

Figure 7. Sound absorption coefficients of nonwoven samples.

The effectiveness of a material in sound absorption depends mainly on the frequency of the sound wave subjected to the material, basis weight, air permeability, fiber geometry, and fiber arrangement [25–27]. Sound absorption occurs due to the impact of sound waves on material, friction losses while moving in the pores and channels of the structure, and the decrease in sound energy. As a result of increasing basis weight, fiber density, and porosity of random fibers, the sound wave will contact more fibers, and friction losses will increase [23]. As a result, the sound energy will be reduced, and higher sound absorption coefficients will be obtained. The results obtained from this research are evidence of this situation.

In bicomponent fibers with core/sheath type round cross section, melting Co-PET smeared to adjacent fibers to bind the nonwoven structure. It can be concluded that melting part of bicomponent fibers affects the cross-section area and fiber surface roughness, resulted with the variation of tortuous passages performed as higher sound absorption. As the result of restricted flow of sound waves, the sound absorption coefficients became higher [28, 29].

The statistical analysis of sound absorption of BC and HC samples presented in **Table 4** indicates the significant effect of fiber type with higher F values. Sound absorption has been affected by basis weight and fiber type 98.98%. It can be specified that fiber type (bicomponent and homocomponent) is more effective parameter than basis weight to control sound absorption of multilayer nonwovens statistically.

Regression equation for air permeability of BC and HC samples obtained from the model is presented below in Eq. (3) according to codded factors. The high levels of the factors are coded as +1, and the low levels of the factors are coded as −1.

$$\text{Sound absorption} = +0.65 + 0.25^* A + 0.10^* B + 0.01\,2^* AB - 0.25^* A^2 - 0.30^*$$
$$A^2 B + 0.24^* A^3 + 0.41^* A^3 B + 0.23^* A^4 + 0.25^* A^4 B - 0.25^* A^5 - 0.44^* A^5 B \quad (3)$$

Source	Sum of squares	Degree of freedom (df)	Mean square	F	Significance
Model	0.53	11	0.048	900.08	0.0011
A-Basis weight	0.012	1	0.012	230.51	0.0043
B-Fiber type	0.036	1	0.036	685.34	0.0015
Factors within group	0.005	9			
Residual	1.061E-004	2	5.303E-005		
Cor total	0.53	13			
Model	Std. deviation	7.282E-003	R-Squared		0.9998
	C.V. %	1.18	Adjusted R-Squared		0.9987
	PRESS	0.20	Predicted R-Squared		0.6143

Table 4. ANOVA for sound absorption of samples.

	A: Basis weight	B: Fiber type	Air permeability	Mean pore diameter	Sound absorption
A: Basis weight	1.000	0.000	−0.927	−0.921	0.911
B: Fiber type	0.000	1.000	−0.133	0.313	0.284
Air permeability	−0.927	−0.133	1.000	0.882	−0.869
Mean pore diameter	−0.921	0.313	0.882	1.000	−0.741
Sound absorption	0.911	0.284	−0.869	−0.741	1.000

Table 5. Correlation between variables and responses.

4.4. Correlations

The correlations between the independent parameters, basis weight (A) and fiber type (B), and the dependent parameters, air permeability (C), mean pore diameter (D), and sound absorption (E), has been examined and the results for the data obtained in the study are shown in **Table 5**. The statistical results have showed that air permeability, mean pore diameter, and sound absorption have significant correlation. Correlations between each of variables proved that sound absorption has an inverse relation with air permeability and pore sizes.

5. Conclusion

In this research, acoustic insulation behavior of SMS type composite nonwovens has been investigated. The results show that sound absorption has been affected by fiber type of homocomponent or bicomponent, and more effective sound absorption with bicomponent fibers is obvious. Higher sound absorption coefficients were provided with multilayer nonwoven samples containing bicomponent fibers.

The reason for these results may be because the different porosity, tortuosity, and roughness of bicomponent and homocomponent structures. Higher value of tortuosity would therefore indicate longer, more complicated, and sinuous path, thus resulting in greater resistance to sound wave flow. Tortuosity also directly influences propagation of acoustic waves and absorbance efficiency in fibrous porous media. It has also been said that the degree of tortuosity determines the high frequency behavior of sound absorbing porous materials.

Additionally, sound absorbent materials must be porous in order to allow sound waves to enter, spread, and decrease sound energy through friction. However, closed pores in the structure have little effect on the absorption of sound, while open pores directly affect the sound insulation properties of the material as they allow sound waves to penetrate into the material [21, 30].

It can be stated that this effect increases with the contribution of bicomponent fibers in the formation of nonwoven surface with filament laying methods, which constitute the basic character of the process of random fiber orientation and intersection [31–34]. As a result, while

the pore diameters and air permeability values of the samples containing bicomponent fibers decrease, friction of the sound wave by changing direction with the fiber surfaces can be said to cause loss of acoustic energy and increase of sound absorption coefficients.

When sound absorption and effecting factors are evaluated on nonwovens, the basis weight, thickness, fiber fineness, air flow resistance, pore structure, and tortuosity can be listed. Sound absorption performances of surfaces with high resistance to air flow up to a certain point will also be high. However, according to the studies in the literature, this situation may vary at various levels depending on the conditions of use and the frequency of the sound wave. The air permeability is mainly effective in determining the sound absorption, and the structural parameters that control the air permeability will also affect the sound absorption. The results obtained in this study show that the air permeability values of samples with smaller pore diameters are also lower, supporting the high sound absorption of these samples. In addition, it has been determined that this effect has become more pronounced with the increase of basis weight. As fabric basis weights ranged from 130 to 280 gsm for each sample group, as the increase in the number of fiber per unit area, the higher sound absorption coefficients were obtained. Increasing intersection of fibers in heavier nonwovens creates a tortuous path for sound wave to flow caused to acoustic energy loss and sound absorption.

Additionally, all samples had low sound absorption coefficient range between 0.0 and 0.3 up to the frequency of 3000 Hz.

At the high frequencies, as the wavelengths becomes smaller, the thinner fabrics control the sound absorption efficiently. Therefore, the thinner spunmelt nonwovens compared to needle-punched ones are good sound absorbers at high frequencies.

The results show that sound insulation at high frequencies can be improved by using spunmelt multilayer nonwovens. Spunmelt multilayer nonwovens offer opportunities to tailor fabrics to desired applications through variations in fiber type and basis weight.

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