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A Comparative Study on Air Permeability Properties of Multilayered Nonwoven Structures

M. Kucukali Ozturk, B. Nergis, C. Candan

***Abstract*—**Air permeability plays an important role for applications such as filtration, thermal and acoustic insulation. The study discussed in this paper was conducted in an attempt to investigate air permeability property of various combinations of nonwovens. The PROWHITE air permeability tester was used for the measurement of the air permeability of the samples in accordance with the relevant standards and a comparative study of the results were made. It was found that the fabric mass per unit area was closely related to the air-permeability. The air permeability decreased with the increase in mass per unit area. Additionally, the air permeability of nonwoven fabrics decreased with the increase in thickness. Moreover, air permeability of multilayered SMS nonwoven structures was lower than those of single layered ones.

***Keywords*—**Air permeability, mass per unit area, nonwoven structure, polypropylene nonwoven, thickness.

I. Introduction

AIR permeability is a vital property in some end-use applications such as filtration, thermal and acoustic applications. Use of nonwoven structures in technical textiles is increasing day by day, therefore the air permeability property plays an important role for these applications [1]-[3].

Previous studies investigated the relationship between air permeability and structural characteristics of nonwovens such as fabric weight, thickness, density and fiber diameter [4]-[7]. These studies analyzed the effect of the structural characteristics of nonwoven such as mass per unit area, fabric thickness, fabric density and some fiber properties on the air permeability property. The results showed that air permeability decreases with the increase in mass per unit area, thickness, and density of fabric. Moreover, there have been various studies carried out on the effects of parameters such as fabric mass per unit area, fabric density, porosity, pore size and distribution, fiber properties, type and size of needles, depth of needle penetration, arrangement and density of needles, and punching density of fabric on the air permeability and filtration performance of needled nonwovens [8]–[11].

Spunbond (S) and meltblown (M) technologies are two of the most rapidly growing nonwoven technologies [12]. Spunbond fabrics are produced by a deposition of extruded spun filaments onto collecting belt in a uniform manner followed by the bonding of the fibers whereas meltblown fabrics are created by the injection of high velocity air while the fibers form polymers [13], [14]. In addition to them, spunlace nonwoven is used in applications which require high bulkiness, high strength and softness. The Spunlace (hydroentanglement) process is a nonwovens manufacturing system that employs jets of water to entangle fibers and thereby provide fabric integrity [3], [15].

In literature survey, most of the studies investigated air permeability of single layered nonwoven fabrics like needle-punched, spunbond, spunlace etc. They showed that, within the ranges of measurement made, the factor most closely related to the air-permeability was the fabric mass per unit area and the air-permeability was almost inversely proportional to the mass per unit area [4]. On the other side, there are limited number of the studies on air permeability properties of multilayered nonwoven fabrics. Therefore, the study focused on the effect of fabric characteristics such as fabric type, mass per unit area and thickness to air permeability property.

II. Experimental Study

A. Materials

The single (L_{single}) and multi (L_{multi}) layered polypropylene nonwoven fabrics were used in the study. Since multilayered nonwovens (composed of Spunbond and Meltblown layers) are utilized for thermal and applications to some extent [16], [17], various combinations of nonwovens (Spunbond Meltblown-SM and Spunbond Meltblown Spunbond-SMS) were included in the study. The SM and SMS multilayered nonwoven structures were produced by combining the layers (Spunbond and Meltblown) by ultrasonic bonding. Fig. 1 shows pictorial view of a multilayered nonwoven structure.

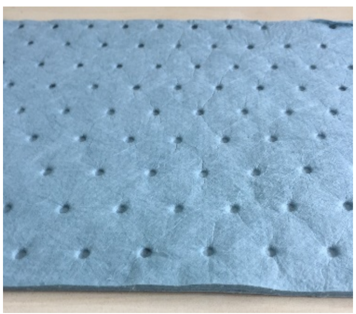

Fig. 1 A pictorial view of multilayered nonwoven structure (L_{multi}-6)

The combination of spunbond (S) and meltblown (M) nonwovens forms the structure of the SMS type. Its structure

M. Kucukali Ozturk is with the Textile Engineering Department, Istanbul Technical University, Inonu St., 34437, Istanbul, Turkey (phone: +902122931300-2768 fax: +90 212 251 88 29; e-mail: kucukalim@itu.edu.tr).
B. Nergis and C. Candan are with the Textile Engineering Department, Istanbul Technical University, Inonu St., 34437, Istanbul, Turkey (e-mail: uygunf@itu.edu.tr, candance@itu.edu.tr).

comprises two spunbond layers with a meltblown layer in between. Melt blown is often added to spunbond to form SM or SMS webs, which are strong and offer the intrinsic benefits of fine fibers such as fine filtration, low pressure drop as used in face masks or filters and physical benefits such as acoustic insulation. SM & SMS composites are produced by combining Spunbond and Meltblown fabrics by calendaring or ultrasonic bonding. Fig. 2 shows pictorial view of SMS nonwoven fabric [18].

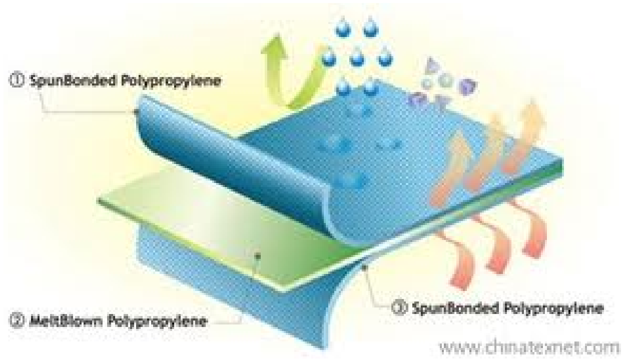

Fig. 2 SMS nonwoven fabric [18]

Mass per unit area of the nonwoven fabrics was measured in accordance with the relevant standard TS 7128 EN ISO 5084 and thickness of the fabric was measured with using Standard Gage 0-25 mm Digital Micrometer. They were reported in Tables I and II, respectively.

TABLE I
PROPERTIES OF THE SINGLE LAYERED (L_{SINGLE}) NONWOVEN FABRICS

Sample code	Fabric type	Mass per unit area (g/m²)	Thickness (mm)
L_{single}-1	Spunbond (S)	50	0.520
L_{single}-2	Spunlace	50	0.431
L_{single}-3	Meltblown (M)	50	0.655
L_{single}-4	Meltblown (M)	300	3.987

TABLE II
PROPERTIES OF THE MULTILAYERED (L_{MULTI}) NONWOVEN FABRICS

Sample code	Fabric type	Mass per unit area (g/m²)	Thickness (mm)
L_{multi}-1	SMS	45	0.379
L_{multi}-2	SMS	60	0.453
L_{multi}-3	SMS	90	0.635
L_{multi}-4	SMS	260	2.355
L_{multi}-5	SMS	280	3.220
L_{multi}-6	SMS	360	3.343
L_{multi}-7	SM	330	3.018

B. Methods

The air permeability test method contains the measurement of the rate of air flow passing perpendicularly through a pre-defined cross-sectional area under a prescribed air pressure. Circular fabric is clamped into the tester through vacuum pressure; the air pressure is applied on one side of the fabric. Circular fabric is clamped into the tester through vacuum pressure; the air pressure is applied on one side of the fabric. Airflow will take place from higher air pressure to lower air pressure. From airflow rate changes, the air permeability of the fabric is calculated. The air permeability of the combined structures with nonwoven substrate and covering in l/m²/s was measured according to the method specified by EDANA 140.1. The measurements were performed at a constant pressure drop of 196 Pa (per 20 cm² test area). In each test level, five specimens were tested and the average values were reported. Fig. 3 shows the air permeability tester.

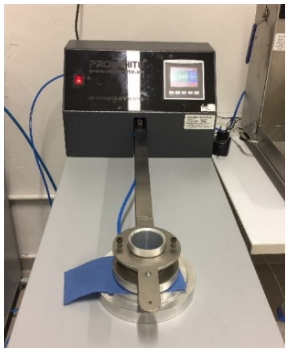

Fig. 3 Air permeability tester

III. RESULTS AND DISCUSSION

Air permeability properties of the single layered nonwoven fabrics having different fabric structures (spunbond, meltblown, spunlace) and the same fiber type, diameter, fabric mass per unit area and almost the same thickness are given in Table III.

TABLE III
AIR PERMEABILITY PROPERTIES OF SINGLE LAYERED NONWOVEN FABRICS

Sample Code	Air Permeability (l/m²/s)	CV %
L_{single}-1	490	2.85
L_{single}-2	889	2.04
L_{single}-3	384	3.97

When L_{single}-1, L_{single}-2 and L_{single}-3 were compared with each other, L_{single}-3 had the lowest air permeability. That may be explained with that meltblown technology enables production of webs having finer fibers with higher surface area, when compared to the webs produced using spunbond technology. This may result in less air permeability. Spunlace structure has the highest air permeability that was not preferred in filtration and acoustic applications. Therefore, spunlace structure was removed from the sample set. Additionally, the mass per unit area and thickness of the meltblown layer were increased to see its effect on the air permeability of structure.

TABLE IV
AIR PERMEABILITY PROPERTIES OF MELTBLOWN NONWOVEN FABRICS

Sample Code	Air Permeability (l/m²/s)	CV %
L_{single}-3	384	3.97
L_{single}-4	260	2.04

As seen in Table IV, an increase in mass per unit area provided a decrease in air permeability.

Table V shows the air permeability properties of multilayered SMS structures. As the result, L_{multi}-1 showed the highest air permeability which is unwanted for acoustic applications. The air permeability property decreased with the increase in mass per unit area and thickness.

TABLE V
AIR PERMEABILITY PROPERTIES OF MULTILAYERED NONWOVEN FABRICS

Sample Code	Air Permeability (l/m²/s)	CV %
L_{multi}-1	788	2.87
L_{multi}-2	451	2.15
L_{multi}-3	385	3.06
L_{multi}-4	160	3.84
L_{multi}-5	135	3.21
L_{multi}-6	64	2.51

The air permeability properties of L_{single}-4, L_{multi}-6 and L_{multi}-7 are given in Table VI. These structures had a meltblown component of the same mass per unit area. As can be seen from Table VI, the multilayered nonwoven fabrics had lower air permeability although they were thinner than single layered one. It may be explained with that multilayered structures behaved as a barrier to hinder the flow of air through the structure.

TABLE VI
AIR PERMEABILITY PROPERTIES OF L_{SINGLE}-4, L_{MULTI}-6 AND L_{MULTI}-7

Sample Code	Air Permeability (l/m²/s)	CV %
L_{single}-4	260	2.04
L_{multi}-6	64	2.51
L_{multi}-7	151	3.43

Figs. 4 and 5 show the air permeability properties of the single and multilayered nonwoven fabrics with standard deviations, respectively. As seen in figures, meltblown structure has the lowest air permeability when compared with other single layered structures. Moreover, SMS structure having highest mass per unit area and thickness (L_{multi}-6) had the lowest air permeability property. Thus, multilayered structures are mostly preferred in filtration, thermal and acoustic applications which require low air permeability.

IV. CONCLUSION

Air permeability of nonwoven fabrics with various combinations was investigated in this study. The air permeability of the samples was measured by the PROWHITE air permeability tester. A comparative study of the air permeability properties of nonwoven structures was made. As a result, it was found that the factor most closely related to the air-permeability was the fabric mass per unit area and the air permeability of nonwoven fabrics decreased with the increase in both thickness and mass per unit area. SMS nonwoven structures had lower air permeability compared with single layered ones, thus they were mostly preferred for airflow resistance. The study is useful to develop thermal and acoustic insulating material for industrial applications from polypropylene SMS nonwoven structure.

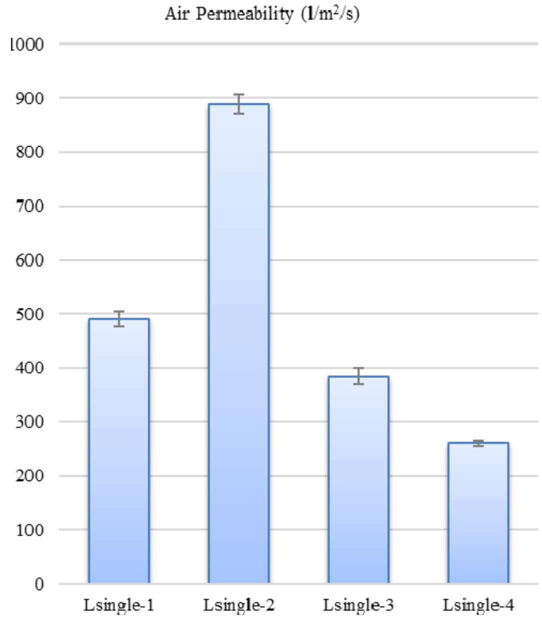

Fig. 4 Single layered nonwovens air permeability

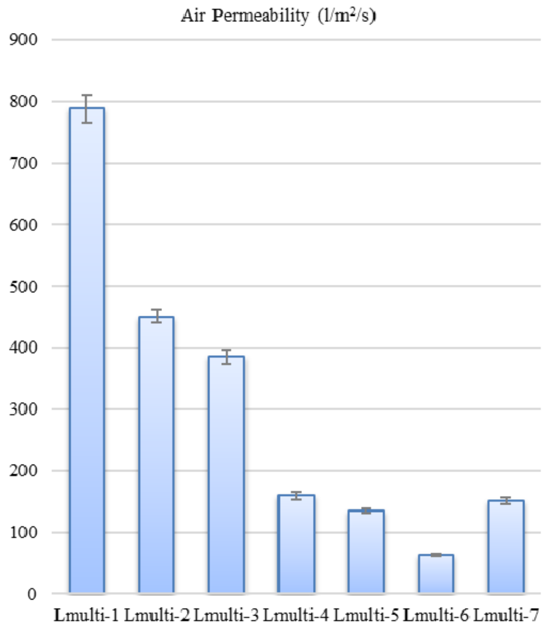

Fig. 5 Multilayered nonwovens air permeability

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M. Kucukali Ozturk was born in Istanbul, TURKEY, 1984. She graduated from Textile Engineering Department of Istanbul Technical University in 2007. She assumed the title of Master of Textile Engineering in 2010. Now, she is studying on PhD at the same department. Her thesis subject is about acoustic applications of nanofibrous membranes.

She has been working at Istanbul Technical University, Textile Technologies and Design Faculty, Textile Engineering Department for 8 years as a Research Assistant. She has been studying on acoustic textiles since 2009. She has also studies on comfort properties of textiles. She has such articles as;

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