

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.

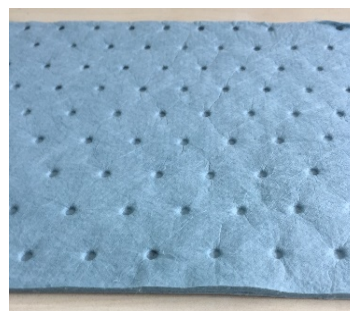


Fig. 1 A pictorial view of multilayered nonwoven structure ($L_{\text{multi-6}}$)

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

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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].

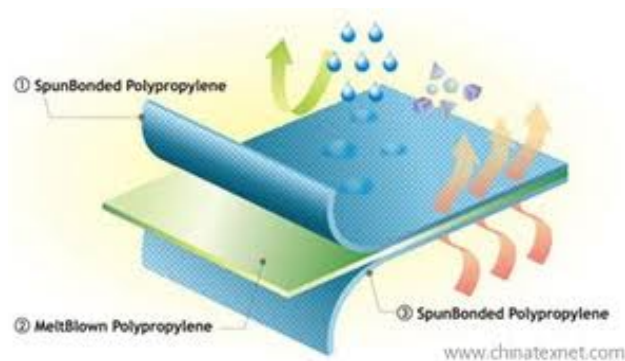


Fig. 2 SMS nonwoven fabric [18]

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/m^2)	Thickness (mm)
$L_{\text{single-1}}$	Spunbond (S)	50	0.520
$L_{\text{single-2}}$	Spunlace	50	0.431
$L_{\text{single-3}}$	Meltblown (M)	50	0.655
$L_{\text{single-4}}$	Meltblown (M)	300	3.987

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

Sample code	Fabric type	Mass per unit area (g/m^2)	Thickness (mm)
$L_{\text{multi-1}}$	SMS	45	0.379
$L_{\text{multi-2}}$	SMS	60	0.453
$L_{\text{multi-3}}$	SMS	90	0.635
$L_{\text{multi-4}}$	SMS	260	2.355
$L_{\text{multi-5}}$	SMS	280	3.220
$L_{\text{multi-6}}$	SMS	360	3.343
$L_{\text{multi-7}}$	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 $\text{l/m}^2/\text{s}$ 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 cm^2 test area). In each test level, five specimens were tested and the average values were reported. Fig. 3 shows the air permeability tester.

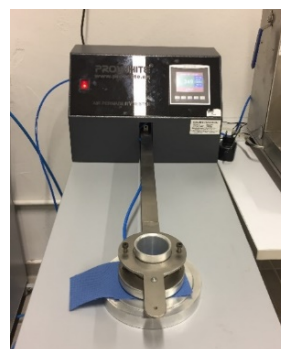


Fig. 3 Air permeability tester

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 ($\text{l/m}^2/\text{s}$)	CV %
$L_{\text{single-1}}$	490	2.85
$L_{\text{single-2}}$	889	2.04
$L_{\text{single-3}}$	384	3.97

When $L_{\text{single-1}}$, $L_{\text{single-2}}$ and $L_{\text{single-3}}$ were compared with each other, $L_{\text{single-3}}$ 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 ($\text{l/m}^2/\text{s}$)	CV %
$L_{\text{single-3}}$	384	3.97
$L_{\text{single-4}}$	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, $L_{\text{multi-1}}$ 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 ($\text{l/m}^2/\text{s}$)	CV %
$L_{\text{multi-1}}$	788	2.87
$L_{\text{multi-2}}$	451	2.15
$L_{\text{multi-3}}$	385	3.06
$L_{\text{multi-4}}$	160	3.84
$L_{\text{multi-5}}$	135	3.21
$L_{\text{multi-6}}$	64	2.51

The air permeability properties of $L_{\text{single-4}}$, $L_{\text{multi-6}}$ and $L_{\text{multi-7}}$ 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 $L_{\text{single-4}}$, $L_{\text{multi-6}}$ AND $L_{\text{multi-7}}$

Sample Code	Air Permeability ($\text{l/m}^2/\text{s}$)	CV %
$L_{\text{single-4}}$	260	2.04
$L_{\text{multi-6}}$	64	2.51
$L_{\text{multi-7}}$	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 ($L_{\text{multi-6}}$) 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.

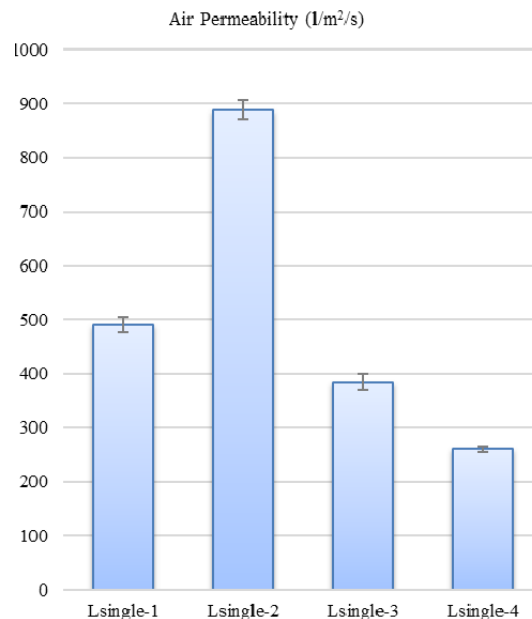


Fig. 4 Single layered nonwovens air permeability

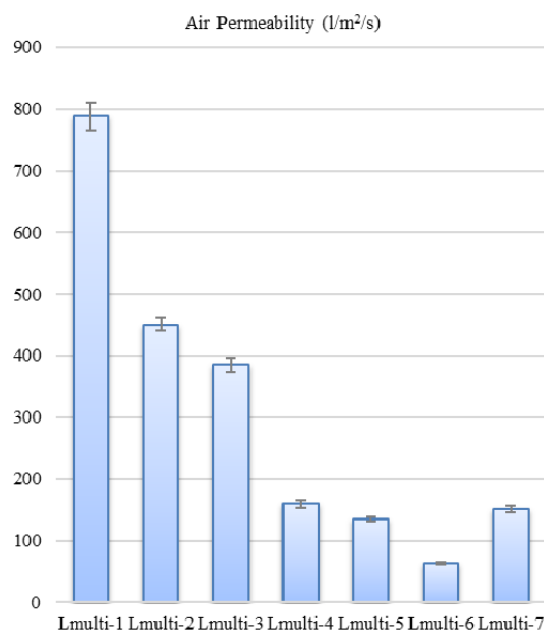


Fig. 5 Multilayered nonwovens air permeability

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REFERENCES

- [1] S. Sakthivel, J.J. Ezhil Anban, and T. Ramachandran, "Development of Needle-Punched Nonwoven Fabrics from Reclaimed Fibers for Air Filtration Applications", *J Eng. Fiber Fabr.*, vol. 9, no. 1, pp. 149-154, 2014.

- [2] E. Cincik, and E. Koç, "An analysis on air permeability of polyester/viscose blended needle-punched nonwovens", *Text. Res. J.*, vol. 82, no. 5, pp. 430-442, 2016.
- [3] O.B. Berkalp, "Air Permeability & Porosity in Spun-laced Fabrics", *FIBRES TEXT East Eur.*, vol. 14, no. 3, pp. 81-85, 2006.
- [4] V. K. Kothari, and A. Newton, "The Air Permeability of Nonwoven Fabrics", *J. Text. I.*, vol. 65, no. 8, pp. 525-531, 1974.
- [5] V. Subramaniam, M. Madhusoothanan, and C. R. Debnath, "Air Permeability of Blended Nonwoven Fabrics", *Text. Res. J.*, vol. 58, no. 11, pp. 677-678, 1988.
- [6] R. W. Dent, "The Air Permeability of Nonwoven Fabrics", *J. Text. I.*, vol. 46, no. 6, pp. 220-224, 1976.
- [7] H. H. Epps, and K. K. Leonas, "Pore Size and Air Permeability of Four Nonwoven Fabrics", *Int. Nonwovens J.*, vol. 9, no. 2, pp. 18-22, 2000.
- [8] M. Mohammadi, P. Banks-Lee, and P. Ghadimi, "Air permeability of multilayer needle punched nonwoven fabrics: Theoretical method", *J. Ind. Text.*, vol. 32, no. 1, pp. 45-57, 2002.
- [9] M. Mohammadi, P. Banks-Lee, and P. Ghadimi, "Air permeability of multilayer needle punched nonwoven fabrics: Experimental method", *J. Ind. Text.*, vol. 32, no. 2, pp. 139-150, 2002.
- [10] A. Rawal, "A cross-plane permeability model for needle-punched nonwoven structures", *J. Text. I.*, vol. 97, no. 6, pp. 527-532, 2006.
- [11] S. Y. Yeo, O. S. Kim, D. Y. Lim, S. W. Byun, and S. H. Jeong, "Effect of processing condition on the filtration performances of nonwovens for bag filter media", *J. Mater. Sci.*, vol. 40, no. 20, pp. 5393-5398, 2005.
- [12] P.P. Tsai, and Y. Yan, "The Influence of Fiber and Fabric Properties on Nonwoven Performance", in *Application of Nonwovens in Technical Textiles*, Woodhead Publishing Limited. New York, 2010, pp. 18-45
- [13] H. Lim, "A Review of Spun Bond Process", *J. Text. App. Tech. Manage*, vol. 6, no. 3, pp. 1-13, 2010.
- [14] Z. Bo, "Production of polypropylene melt blown nonwoven fabrics: Part II —Effect of Process Parameters", *Indian J. Fibre Text. Res.*, vol. 37, no. 4, pp. 326-330, December 2012.
- [15] A. M. Vuillame, "A Global Approach to the Economics and End-product Quality of Spun-lace Nonwovens", *Tappi J.*, vol. 74, no. 8, pp. 149-152, 1991.
- [16] M. Powers and R. Schmidt, *Acoustic material with liquid repellency*, Patent No: WO2012141671A2.WO2012141671A3.
- [17] J. R. Gross, J. S. Hurley, B. E. Boehmer, and R. T. Moose, *Nonwoven material for acoustic insulation and process for manufacture*, Patent No: US7918313 B2
- [18] www.chinatextnet.com
- Kucukali Ozturk M., Kalinova K., Nergis B., Candan C., "Use of nanofibrous membrane with spacer porous material to improve sound absorbency", *Tekstil&Teknik*, Mart 2014, 30(350); 192-195.
- Kucukali Ozturk M., Kalinova K., Nergis B., Candan C., A new noise protection system makes itself heard: A warp-knitted spacer textile in a composite with a nanofibrous membrane improves the sound-absorption capacity, *Kettenwirk-Praxis* 2014 (2); 28.
- Kucukali Ozturk M., Nergis B.U., Candan C., Kalinova K., 2015. "Effect of Fiber Diameter and Air Gap on Acoustic Performance of Nanofibrous Membrane", *Journal of Chemistry and Chemical Engineering*, 9(1), pp. 45-50.
- Kucukali Ozturk M., Nergis B.U., Candan C., Berkalp O., Design of a wool reinforced composite material for sound absorption, *Tekstil&Teknik*, Ocak 2015, pp.116-119.
- Kucukali Ozturk M., Beceren, Y., Nergis B., 2015. "Effects of Different Drying Methods on the Properties of Viscose Single Jersey Fabrics", *International Journal of Chemical, Nuclear, Materials and Metallurgical Engineering*, 9(5), pp. 684-687.
- Kucukali Ozturk M., Ozden Yenigun E., Nergis B., Candan C., 2016. "Nano Enhanced Light-Weight Composite Textiles for Acoustic Applications", *Journal of Industrial Textiles*, online published on 17 December, 2015.
- Kalinova K., Kucukali Ozturk M., Komarek M., 2016. "Open and closed tube method for determination of resonance frequencies of nanofibrous membrane", *Journal of Textile Institute*, 107(8), pp. 1068-1078.



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- Kucukali Ozturk M., Nergis B.U., Candan C., 2011. "A Study of Wicking Properties of Cotton-Acrylic Yarns & Knitted Fabrics", *Textile Research Journal*, 81(3); 324-328.
- Kucukali Ozturk M., Nergis B.U., Candan C., 2010. "Akustik Özellikleri Geliştirilmiş Örme Kumaş Tasarımı", *Tekstil ve Mühendis*, Sayı:78, 15-19.
- Kucukali Ozturk M., Nergis B.U., Candan C., 2011. "Application of multicriteria decision making approach to the analysis of comfort properties of wool/acrylic blended fabrics", *Journal of Chemistry and Chemical Engineering*, 5(12); 1069-1073.
- Kucukali Ozturk M., Nergis B., Candan, C., Sürdürülebilir Malzemelerin (Liflerin) Akustik Özellikleri, *Fiber&Yarn TRENDS*, Nisan 2012, Sayı:1; 64-66.
- Sezgin, H., Yalcin I., Kucukali Ozturk M., Kizildag, N., 2012. "Nanomaterials in Textile Applications", *Journal of International Scientific Publications: Materials, Methods & Technologies*, 6(2); 303-317.
- Kucukali Ozturk M., Kalinova K., Nergis B., Candan C., 2013. "Comparison of resonance frequency of a nanofibrous membrane and a homogeneous membrane structure", *Textile Research Journal*, , 83(20), 2204-2210.