(REFEREED RESEARCH)

INVESTIGATION OF THE PHYSICAL PROPERTIES OF MELTBLOWN NONWOVENS FOR AIR FILTRATION

HAVA FİLTRASYONU AMACIYLA ERİYİK ÜFLEME (MELTBLOWN) YÖNTEMİNE GÖRE ÜRETİLEN DOKUSUZ YÜZEYLERİN FİZİKSEL ÖZELLİKLERİNİN İNCELENMESİ

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ABSTRACT

Textile filters are industrial textiles used in filtration applications. Among textile materials, especially nonwovens are suitable for filtration applications, because of their complex structures and appropriate thickness. Nonwoven filters are used in various application areas of technical textiles such as medtech, mobiltech, protech, packtech and hometech. Meltblown nonwovens are a unique class of materials, characterized by high surface are, porosity, softness and absorbency due to their microstructure. In this study polypropylene meltblown nonwovens were produced for the purpose of air filtration. Physical properties, namely thickness, basis weight, tensile properties, air permeability, and fibre diameter of were measured and effect of various production parameters on the physical properties of PP meltblown nonwovens were investigated and possibility for using such materials in air filtration was discussed.

Key Words: Textile filters, Nonwoven, Meltblown, Microfiber nonwoven, Polypropylene.

ÖZET

Tekstil filtreleri filtrasyon uygulamalarında kullanılan endüstriyel tekstillerdir. Tekstil malzemeleri arasında özellikle nonwoven malzemeler kompleks yapıda olmaları ve uygun kalınlıklarda üretilebilmeleri bakımından filtrasyon uygulamaları için uygundur. Nonwoven filtreler teknik tekstillerin tıbbi tekstiller, koruyucu tekstiller, paketleme tekstilleri ve ev tekstilleri gibi birçok alanında kullanılabilmektedir. Meltblown nonwovenlar geniş yüzey alanı, gözeneklilik, yumuşaklık ve mikro yapılarından kaynaklanan absorbanlık gibi özellikleri nedeniyle benzersiz malzemelerdir. Bu çalışmada, hava filtrasyonu alanında kullanılmak üzere polipropilen meltblown nonwovenlar üretilmiştir. Bu malzemelerin fiziksel özellikleri ölçülerek, çeşitli üretim parametrelerinin PP meltblown nonwovenların fiziksek özellikleri üzerine etkileri incelenmiş ve bu malzemelerin hava filtrasyonunda kullanılabilme olasılıkları tartışılmıştır.

Anahtar Kelimeler: Tekstil filtreleri, Nonwoven, Meltblown, Mikrolifli nonwoven, Polipropilen.

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1. INTRODUCTION

Filtration can be defined as seperation of one material from another (1,2). The main purpose of filtration is to increase the pureness of the filtered material. Filtration process is used in many industrial applications. Textile filters are mostly used for solid-gas or solid-liquid seperation (2). Seperation of solid particles from liquid or gas by using textile filters increases the purity of the product and efficiency of the process, saves energy, enables the recycling of valuable materials and helps to decrease the environmental pollution in many industrial processes. Air filters, personal protective equipments such as surgial masks and gowns, oil and gas filters, filters used in waste water treatment and chemical dye recycling plants are examples of textile filters application areas. Filters can be produced from woven, knitted or nonwoven fabrics as well as composite structures where different fabric types are combined (3).

Filtration provides an important function in protecting life, materials, equipment and the environment (4). Table 1 shows the segments and subsegments of air filtration.

Table 1. Major segments and subsegments of air filtration (4)

Air Filtration Segments	Sub-segments
Building/indoor Air Quality	Commercial, Residential, Institutional
Transportation	Automotive, Heavy duty
Industrial Processes	Power generation, high temperature dust collection, Ambient/mid-range temperature dust collection
Personal Protection	Industrial face mask, Medical face mask, Respirators
Vacuum Cleaner Bags	
Other	Electronics and equipment, Medical (including devices)

1.1. Nonwoven Filters

Nonwoven are used commonly in air filtration applications. They can also be used as support for membrane structures. Besides the mentioned functions, their low cost makes them appealing for many applications (5). İncrease in the consumption of disposable products, increase in the population, higher performance/cost ratio made the nonwoven filters attractive since they have started to be produced commercially (6). The structural parameters which effect the performance of a filter are fibre diameter and geometry, surface area, porosity, surface structure, fabric thickness and density, bulkiness and weight per unit area (5,7).

Natural fibres as well as synthetic fibres can be used in the structure of nonwoven filters. The type of the fibre is chosen according to the requirements of the intended application area. Fibre properties effect the pore size and air permeability of the filter and thus the filtration efficiency (8). Nonwoven filters, produced from various fibres such as PET, PA, PP, PAN, have some advantages compared to woven filters, which can be summarised as higher flow speeds, higher porosity, better filtration efficiency, higher tightness, lower leakage and higher cost effectiveness (5,6).

Nonwoven filters can be produced by using various techniques including air laid, dry laid, wet laid, spunbonded and meltblown technologies (4).

1.2. Meltblowing Technology

Melt blowing is a kind of microfiber nonwoven production process which uses thermoplastic polymers to attenuate the melt filaments with the aid of high-velocity air. In the basic melt blowing process the polymer is melted in an extruder, pumped through die holes and then the melt enters high-speed, hot air streams. Web structure begins to develop when fiber entanglement first occurs and network structure becomes fixed when fibers contact the collector (9,10).

Polypropylene (PP) is the most widely used polymer for this process, since it is relatively inexpensive and versatile enough to produce a wide range of products. Others, such as polyethylene (PE), poly(ethylene terephthalate) (PET), poly(butylene terephthalate) (PBT), polystyrene, polyurethane (PUR), and polyamide (PA) can also be used to produce melt blown webs (10,11,12). Melt blowing has become an important industrial technique in nonwovens because of its ability to produce materials suitable for filtration media, thermal insulators, battery separators, oil absorbents, medical area, miscellaneous applications, apparel area, wipes, and many laminate applications (10,12).

2. MATERIAL AND METHOD

In this study, polypropylene meltblown nonwovens of different production parameters were produced, for the applications aiming at gas filtration and their physical properties were investigated (1).

Production of the samples were done by using a Biax Fiberfilm Meltblown machine. Polypropylene granules of 110 melt flow rate (MFR), 0.75 g/cm3 density, and 168,3 ˚C melting point was used as raw material. The main production settings of the machine are given in Table 2.

The effects of extruder pressure, collector drum speed, die air pressure and extruder speed on thickness, basis weight, tensile properties, air permeability, and fiber diameter of polypropylene meltblown nonwovens were investigated.

The production parameters of the PP melt blown nonwovens can be seen in Table 3.

Table 2. Main production setting of the meltblown process

Production Setting	Value
Extruder zone 1 temperature (°C)	148,9
Extruder zone 2 temperature (°C)	176,7
Extruder zone 3 temperature (°C)	204,4
Die temperature (°C)	193,3
Air temperature (°C)	232,2
Die hole diameter (inches)	0.09
Die-to-Collector Distance (cm)	50

Table 3. Production parameters of the PP melt blown nonwovens

Sample No	Collector drum speed (m/min)	Collector vacuum (%)	Die air pressure (PSI)	Extruder pressure (psi)
1	3,1	20	7	580
2	3,1	40	7	581
3	3,1	60	7	579
4	15,2	20	7	607
5	15,2	40	7	589
6	15,2	60	7	598
7	27,4	20	7	605
8	27,4	40	7	590
9	27,4	60	7	595
10	3,1	20	8	600
11	3,1	40	8	600
12	3,1	60	8	595
13	15,2	20	8	595
14	15,2	40	8	597
15	15,2	60	8	590
16	27,4	20	8	595
17	27,4	40	8	584
18	27,4	60	8	594
19	3,1	20	9	595
20	3,1	40	9	597
21	3,1	60	9	590
22	15,2	20	9	590
23	15,2	40	9	592
24	15,2	60	9	585
25	27,4	20	9	582
26	27,4	40	9	592
27	27,4	60	9	579

Basis weight was measured according to TS EN 29073–1 standard.Thickness was tested by using SDL Thickness Gauge according to TS 7128 EN ISO 5084 standart, with 20 cm2 measurement area under 200 g weight. Tensile properties were tested according to TS EN ISO 13934-1 standart by using Zwick Z010 Universal tensile strength with 200 mm measurement distance and 100 mm/min measurement speed. Air Permeability test was performed by using FX 3300 Air Permeability test device according to TS 391 EN ISO 9237 standart, with 20 cm2 measurement area and 100 Pa air pressure. Fiber Diameter was measured by using Leica DM EP light microscope with 400 zoom.

3. RESULTS AND DISCUSSIONS

In this study the effects of various production parameters namely; collector drum speed, collector vacuum, die air pressure and extruder pressure on thickness, basis weight, tensile properties, air permeability, and fiber diameter of polypropylene meltblown nonwovens produced for the purpose of air filtration were investigated. For statistical evaluations, variance analyses and sub group tests were performed by using SPSS software. Basing on the measurement results, filtration efficiency potentials of such materials were discussed (1).

3.1. Results of Basis Weight Measurements

Nonwovens with higher basis weight are expected to show higher filtration efficiencies. Results obtained from the basis weight measurements of the samples are given in Figure 1.

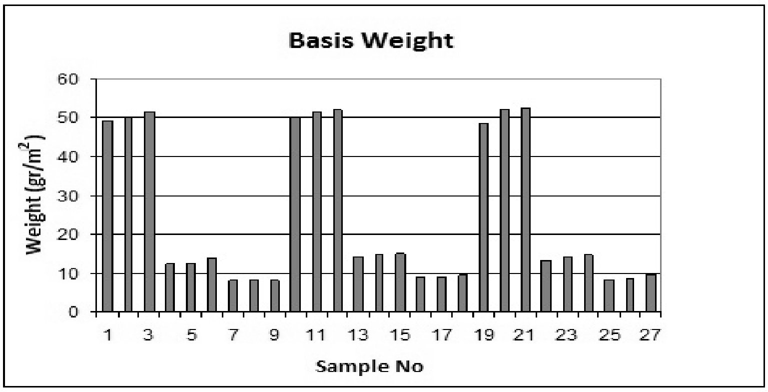

Figure 1.Basis weight results of the fabrics

Table 4. Results of the Variance Analyses

		Mean Square	F	Sig.
Collector Drum Speed	Thickness	3,600	5996,090	,000
	Basis weight	23891,802	15934,557	,000
	Air permeability	9316281,956	33633,686	,000
	Fiber diameter	8,323	42,736	,000
	Breaking Load (lengthwise)	607,421	517,799	,000
	Breaking Load (widthwise)	401,761	533,606	,000
	Elongation (lengthwise)	571,274	14,282	,000
	Elongation (widthwise)	857,166	33,648	,000
Collector Vacuum	Thickness	,123	205,351	,000
	Basis weight	23,261	15,514	,000
	Air permeability	197352,022	712,481	,000
	Fiber diameter	3,358	17,240	,000
	Breaking Load (lengthwise)	77,467	66,037	,000
	Breaking Load (widthwise)	79,277	105,293	,000
	Elongation (lengthwise)	2653,163	66,328	,000
	Elongation (widthwise)	1219,965	47,890	,000
Die Air Pressure	Thickness	,028	46,992	,000
	Basis weight	19,499	13,005	,000
	Air permeability	477239,467	1722,932	,000
	Fiber diameter	2,488	12,774	,000
	Breaking Load (lengthwise)	44,525	37,956	,000
	Breaking Load (widthwise)	6115,002	240,043	,000
	Elongation (lengthwise)	1804,195	45,104	,000
	Elongation (widthwise)	6115,002	240,043	,000

As it can be seen in Table 4, basis weight was effected by collector drum speed, collector vacuum and die air pressure significantly. Results of the subgroup analyses have shown that basis weight increased with decreasing collector drum speed, increasing collector vacuum and slightly with increasing die air pressure. As it can be seen in Figure 1, the highest results were obtained with sample 21 which was produced with 3,1 m/min collector drum speed, 60% vacuum and 9 psi die air pressure, as 52,6 gr/m2.

3.2. Results of Thickness Measurements

Thickness is a significant parameter effecting the filtration performance of nonwovens. While the thickness of the filter layer increases, more particles are caught through the thickness and therefore filtration efficiency is expected to increase. Results of the statistical analyses have shown that collector drum speed and collector vacuum are the most significant factors effecting the thickness. Thickness increased with decreasing collector drum speed and decreasing vacuum.

As it can be seen in Figure 2, the highest results were obtained with sample 1, produced with 3,1 m/min collector drum speed, 20% collector vacuum and 7 psi die air pressure, as 0,92 mm.

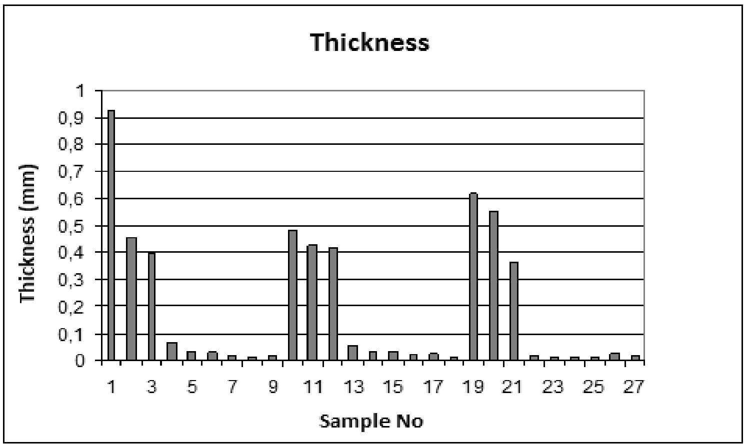

Figure 2. Thickness results of the fabrics

3.3. Results of Air Permeability Measurements

In most of the cases, lower air permeability adresses to a higher filtration efficiency, since the particles in the air are being captured more effectively. As it can be seen in Table 4, air permeability was effected by collector drum speed, collector vacuum and die air pressure significantly. Statistical analyses have shown that air permeability decreased with decreasing collector drum speed, increasing collector vacuum and increasing air pressure. Air permeability test results of the samples are shown in Figure 3.

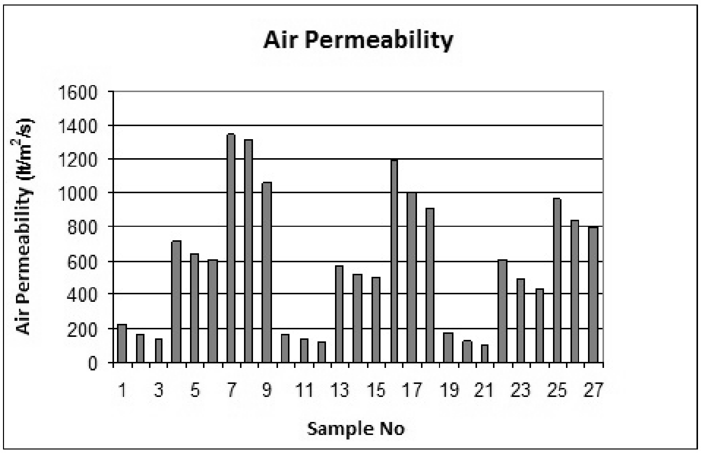

Figure 3. Air permeability results of the fabrics

When Figure 1 and Figure 3 are compared, it can be seen that air permeability decreased with increasing weight per unit area. Figure 3.shows that, the lowest results were obtained with sample 21 which was produced with 3,1 m/min collector drum speed, 60% vacuum and 9 psi die air pressure, as 103,5 l/m^2/sn.

34. Results of Tensile Properties

Figure 4 and Figure 5 show the breaking load and elongation results of the samples in production and width directions.

As it can be seen in Figure 4, higher results were obtained in production direction, compard to width direction. This is an expected result since the fibres are oriented towards this direction. Results of the statistical analyses have shown that the breaking load was effected by collector drum speed, collector vacuum and die air pressure significantly. Breaking load increased with increasing collector vacuum, decreasing collector drum speed and decreasing die air pressure. The highest results were obtained with Sample 3, which was produced with 3,1 m/min collector drum speed, 60% collector vacuum and 7 psi die air pressure; as 14,7 N in production direction and 13,4 N in width direction.

When Figure 5 is observed, it can be seen that highest results were obtained in width direction, compared to production direction. Elongation increased with increasing collector vacuum. In width direction, elongation increased with decreasing collector drum speed, whereas in production direction elongation increased with increasing drum speed up to 15,2 m/min and then started to decrease. In both production and width directions, elongation increased with increasing die air pressure up to 8 psi and then decreased till 9 psi. Highest results were obtained with Sample 3, which was produced with 3,1 m/min collector drum speed, 60% vacuum and7 psi die air pressure, as 63,6% in production direction and 65,4% in width direction.

3.5 Results of Fibre Diameter Measurements

Fibre diameter has significant effect on physical characteristics of nonwovens and it also affects their filtration efficiency properties. Lower fibre diameters lead to better filtration efficiencies, due to higher surface area. Figure 6 shows the fiber diameter results of the samples.

Fibre diameter decreased with increasing collector drum speed, decreasing collector vacuum and increasing die air pressure. As it can be seen in Figure 6, the fiber diameter of the meltblown nonwovens were found to be 5-7,5 m in our study, which adres to a unique microstructure, porosity and high surface area.

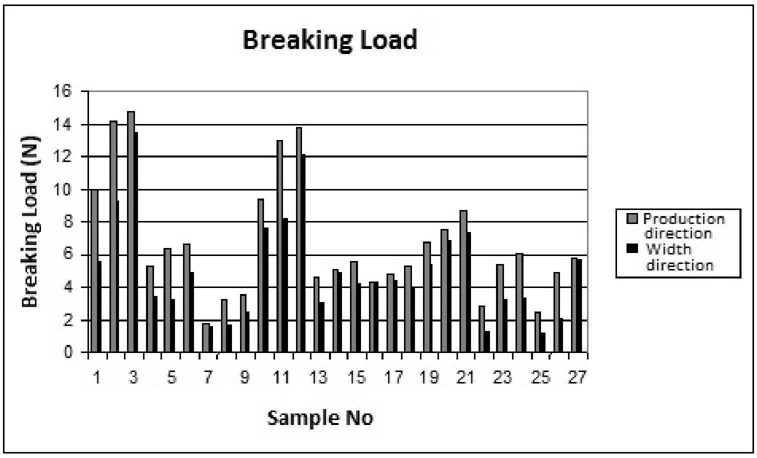

Figure 4. Breaking load results of the fabrics in production and width directions

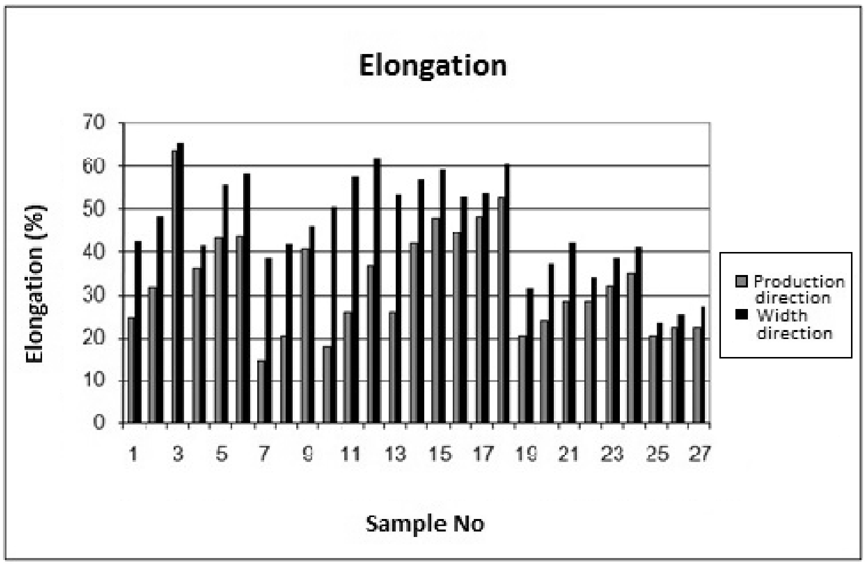

Figure 5. Elongation results of the fabrics in production and width directions

4. CONCLUSION

Meltblown nonwovens can be used in many industrial applications such as cleaning wipes, medical applications and filtration. Filtration is a big industrial field, where meltblown nonwovens can be used solely or in combination with other materials. It is known that filtration efficiency is effected by physical properties of the filter media. In this study, physical properties, namely thickness, basis weight, tensile properties, air permeability, and fiber diameter of polypropylene meltblown nonwovens produced for the purpose of air filtration were investigated and possibility of using these materials in air filtration was discussed.

As explained in the results and discussions part, high basis weight, high thickness and low air permeability is preferred for air filters, due to higher possibility of catching the solid particles in the air. Nonwovens with fine fibres are promising for better filtration efficiencies, since the surface area is enlarged. It is also preferred to have high tesnsile strength for the nonwovens which will be used as air filters for the performance and durability in end use. In the light of this data, materials which have shown high basis weight, thickness and tensile strength and low fiber diamater and air permeability, namely samples 1, 3, 17 and 21 were chosen to go on with further investigations.

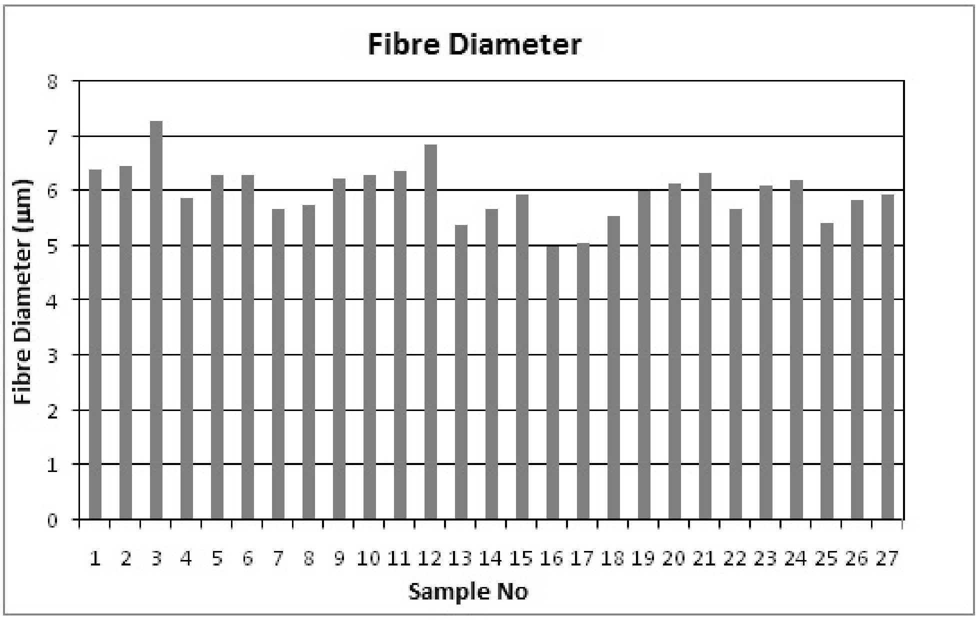

Figure 6. Fibre diameter results of the samples

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