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Investigation of the Physical Characteristics of Polypropylene Meltblown Nonwovens Under Varying Production Parameters

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1. Introduction

Nonwovens are a unique class of textile materials, formed by bonding the fibers by various techniques. The demand through the nonwovens is increasing on the world day by day and nonwovens are getting integrated to more application areas rapidly. Today, nonwovens have achieved an excellent position among the products of daily use like hygiene, medicine, household and more. (Ebeling et al., 2006)

Meltblown nonwovens are a relatively new class of thermoplastic based nonwoven materials which integrate to new application areas to replace conventional textile materials. Due to their unique micro structure, low porosity, absorbency, light weight and high surface area, microfiber meltblown nonwovens are promising materials of the future. Meltblowing is a one step process which enables to produce microfiber nonwovens directly from thermoplastic polymers with the aid of high velocity air to attenuate the melt filaments. In this process high velocity air blows a molten thermoplastic resin from an extruder die tip onto a conveyor or take up screen to form a fine fiberous and self-bonding web. (Bang One Lee et al., 2010) It has become an important industrial technique in nonwovens because of its ability to produce fabrics of microfiber structure suitable for filtration media, thermal insulators, battery seperators, oil absorbents, wipes, apparel, medical applications and many lamination applications. (Zhang et al., 2002 , Duran&Perincek, 2010; Dutton, 2008)

Meltblowing is a unique process since it is used almost exclusively to produce microfibers rather than fibers the size of conventional textile fibers. Meltblown microfibers generally have diameters in the range of 2 to 4 µm, although they may be as small as 0.1 µm and as large as 10 to 15 µm. Differences between meltblown nonwoven fabrics and other nonwoven fabrics, such as degree of softness, cover or opacity, and porosity can generally be traced to differences in filament size. (Bang One Lee et al., 2010)

Meltblowing technology is used for producing light fiber webs directly from polymers. This process process allows the production of ultrafine filament nonwovens under very economical conditions. In the basic melt blowing process, a thermoplastic fibre forming polymer is melted in an extruder, pumped through die holes and then the melt enters high-speed, hot air streams. Streams of hot air exiting from the left and right sides of the die nosepiece rapidly attenuate the extruded polymer streams to form extremely fine filaments. The filaments then are blown by high-velocity air onto a collector screen, thus forming a fine-filtered, self-bonded nonwoven web. After that, they are bonded and wound to form roll goods for further processing. Web structure begins to develop when fiber entanglement first occurs, but network structure becomes fixed only when fibers contact the collector and their motion ceases. (Duran&Perincek, 2010; Randall et al, 2004; Rupp, 2008)

Because the meltblowing process employs high velocity air to impinge upon the polymer as it exits the orifices, it elongates the polymer strands from 500 μm diameter to diameters as small as 0.1 μm. Extreme entanglemet of fibres, characterizing meltblown fibrous webs, produces coherent fiber webs. Unique micrometer characteristics of meltblown structures produce a high surface area per unit weight and fine porosity. Therefore meltblown technology can be used to produce efficient filter materials that are able to filter particles as small as 0.5 μm. (Farer et al., 2003)

The melt blown process generally consists of five major components, which are the extruder, metering pump, die assembly, web formation, and winding. The extruder, which consists of a heated barrel with a rotating screw inside is one of the important elements in all polymer processing. In the extruder, the polymer pellets or granules are heated and melted until appropriate temperature and viscosity are reached. The extruder is divided in to three different zones. (Dahiya et al., 2004) The feed zone, is the zone where the polymer pellets are preheated and pushed to the next zone. The transition zone has a decreasing depth channel in order to compress and homogenize the melted polymer. The melting of the pellets in the extruder is due to the heat and friction of the viscous flow and the mechanical action between the screw and the walls of the barrel. The molten polymer is then fed to the metering pump to ensure uniform polymer feed to the die assembly. (Duran&Perincek,2010; Dutton, 2008; Dahiya et al., 2004) The metering zone is the last zone in the extruder whose main purpose is to generate maximum pressure in order to pump the molten polymer in the forward direction. (Dahiya et al., 2004) The metering pump is a device for uniform melt delivery to the die assembly. It ensures consistent flow of clean polymer mix under process variations in viscosity, pressure, and temperature. The metering pump also provides polymer metering and the required process pressure. At this point the breaker plate controls the pressure generated with a screen pack placed near to the screw discharge. The breaker plate also filters out any impurities such as dirt, foreign particle metal particles and melted polymer lumps. (Dahiya et al., 2004)

The die assembly is the most important element of the melt blown process. It has three distinct components: polymer-feed distribution, die nosepiece, and air manifolds. The feed distribution is usually designed in such a way that the polymer distribution is less dependent on the shear properties of the polymer. This feature allows the melt blowing of widely different polymeric materials with one distribution system. The feed distribution balances both the flow and the residence time across the width of the die. From the feed distribution channel the polymer melt goes directly to the die nosepiece. The web uniformity hinges largely on the design and fabrication of the nosepiece. Therefore, the die nosepiece in the melt blowing process requires very tight tolerances, which have made their fabrication very costly. The die nosepiece is a wide, hollow, and tapered piece of metal having several hundred orifices or holes across the width. The polymer melt is extruded from these holes to form filament strands which are subsequently attenuated by hot air to form fine fibers.

As soon as the molten polymer is extruded from the die holes, high velocity hot air streams blown from the top and bottom sides of the die nosepiece, attenuate the polymer streams to form microfibers. As the hot air stream containing the microfibers progresses toward the collector screen, it draws in a large amount of surrounding air that cools and solidifies the fibers. The solidified fibers subsequently get laid randomly onto the collecting screen, forming a self-bonded nonwoven web. (Duran&Perincek,2010; Dutton, 2008; Dahiya et al., 2004) Usually, a vacuum is applied to the inside of the collector screen to withdraw the hot air and enhance the fiber laying process. The combination of fiber entanglement and fiber-to-fiber bonding generally produce enough web cohesion so that the web can be readily used without further bonding. However, additional bonding and finishing processes may further be applied to these melt-blown webs. (Dahiya et al., 2004)

The properties of the meltblown webs are affected by various production parameters including air temperature, polymer/die temperature, die to collector distance (DCD), collector speed, polymer throughput, air throughput, die hole size and air angle. All of these affect the final properties of the nonwoven web. Both polymer throughput and air flow rate control the final fiber diameter, fiber entanglement, basis weight and the attenuating zone. Polymer/die and air temperatures combined with air flow rate affect the uniformity, shot formation which can be described as large globules of nonfibrous polymer larger in diameter than fibers in webs, rope and fly formation, fabric appearance and touch. (Dahiya et al., 2004) Because meltblowing uses an attenuating air stream to draw and orient the fibres, the distance between the polymer orifice and the collection surface includes the fiber characteristics and resulting fabric properties. This distance is commonly referred to as the die-to-collector distance (DCD). The period of time that fibres spend in flight before being collected influences fiber orientation, strength and surface properties. A varying DCD permits the production of structures with varying properties from stiff and brittle at close distance to soft and bulky at large distance. (Farer et al., 2003) Die hole size along with die set back affects the fiber size. Air angle controls the nature of air flow, i.e. as the air angle approaches 90° it results in a high degree of fiber separation or turbulence that leads to random fiber distribution. At an angle of 30°, roped or parallel fibers deposited as loosely coiled bundles of fibers are generated. This structure is undesirable. At angles greater than 30°, attenuation as well as breakage of fibers occurs. (Dahiya et al., 2004)

The melt blowing process is amenable to a wide range of polymers in terms of viscosities and blends. The type of polymer or resin used defines the elasticity, softness, wetability, dyeability, chemical resistance and other related properties of formed webs. Some polymers, which can be used for the formation of melt-blown webs are listed as polypropylene (PP), polyethylene (PE), polyethylene terephthalate (PET), polybutylene terephthalate (PBT), polyamide (PA) and polylacticacid (PLA). Polypropylene (PP) is the most widely used polymer for meltblowing process, because it has a low viscosity, a low melting point and is easy to draw into fibers. A lot of efforts have been made in the last 30 years on the process study, new resin and product development and process improvements. (Zhang et al., 2002; Dahiya et al., 2004)

The main characteristics and properties of melt-blown nonwovens can be summarised as follows:

- Random fiber orientation.
- Lower to moderate web strength
- Generally high opacity and a high cover factor
- Low porosity
- Good absorbency
- Fiber diameter in the range of 0.5 - 30 μm, typically 2-7 μm
- Basis weight in the range of 8-350 g/m^2, typically 20-200 g/m^2
- High surface area due to microfibers
- Good insulation and filtration characteristics
- Fibers with smooth surface texture
- Generally fibres with circular in cross-section but it can also be variable in some cases variable, ranging from circular to a flat configuration and other variations
- Variable fiber length over a broad range depending from a few millimeters to several hundred centimeters (Dahiya et al., 2004; Duran&Perincek, 2010; Dutton, 2008)

Meltblowing is a unique system since the process generates a fine fiber not available to the other nonwoven processes. Because the micro-denier fiber (less than 0.1 denier per filament) is not really available as a nonwoven fibrous raw material, the meltblown process, which can produce such a fiber, opens new vistas of products and applications. (Dahiya et al., 2004) Microfiber nonwovens produced via meltblowing technique are suitable to be used as thermal insulators, filtration media, oil absorbents, battery separators, medical area, wipes, apparel, laminates and many other applications. (Duran&Perincek, 2010, Dutton, 2008) Meltblown nonwovens find extensive use especially in absorbent cloths and wipes; oil absorption; and filtration for liquids, gas and air. Also, very important end uses of meltblowns include sanitary applications such as hygiene and incontinence products for babies, adults and feminine hygiene. The application areas of meltblown nonwovens can be summarised as follows: (Dahiya et al., 2004)

- Filtration media: surgical face mask filter media, liquid and gaseous filtration, cartridge filters, clean room filters and others
- Medical fabrics: disposable gown and drape market and sterilization wrap segment
- Sanitary products: feminine sanitary napkin, disposable adult incontinence absorbent products
- Oil adsorbents: sorbents to pick up oil from the surface of water, such as encountered in an accidental oil spill and for mats in machine shops and in industrial plants
- Apparel: thermal insulation, disposable industrial apparel and substrate for synthetic leather
- Hot melt adhesives
- Electronic Specialities: liner fabrics in computer floppy disks, battery separators and as insulation in capacitors
- Manufacture of tents and elastomeric nonwoven fabrics which have the same appearance as continuous filament spunbonded products

Beside many advantages they provide, meltblowns have limited strength characteristics and poor abrasion resistance. (Farer et al., 2003) Therefore, they often are combined with other nonwovens. Spunbonds and other types of nonwovens also can be covered and refined with meltblowns. Today it is possible to implement production lines not only with spunbonds, but also with a meltblown component, to produce different types of nonwovens with an even more of a textile feeling. Approximately 40 percent of meltblowns are manufactured using a stand-alone process. The remaining meltblowns are combined with spunbonds or laminated to form other materials. Combinations with spunbonded fabrics are primarily used to make nonwoven materials with barrier properties. Another variation is the combination of meltblown with cellulose or an absorbent powder to produce a soft, strong, but still absorbent material that can retain absorbed liquid while still keeping its strength. The outcome is a combination of spunbonds (S) and meltblowns (M), resulting in SMS, or even SSMMMSS or other combinations, depending on the final product. So many different products can be manufactured and implemented from SMS to SSMMMSS. Some examples of their applications are hygiene, baby and adult diapers, medical products, protective masks for medical use, general use as a barrier layers, paper composites, work safety, protective clothing, breathing masks and combination with other nonwovens. (Rupp, 2008)

2. Material and method

In this chapter, the results of a study about polypropylene microfibre meltblown nonwovens were covered. Aspects related to the production phase, properties of the materials produced and application areas were discussed. In the content of this study, effect of some production parameters namely die air pressure, collector drum speed, collector vacuum and extruder pressure on the physical properties of the web structure such as thickness, basis weight, air permeability, tensile properties, surface friction and fiber diameter were investigated.

As raw material, PP with 1100 melt flow rate (MFR), 0.75 g/cm^3 density and 335 F melting point was used. The main production settings namely; extruder temperatures, die temperature, air temperature (the air fed to the spinerette to spin the fibers), die hole diameter and die-to-collector distance were given in Table 1.

Production Setting	Value
Extruder zone 1 temperature (°F)	270
Extruder zone 2 temperature (°F)	320
Extruder zone 3 temperature (°F)	370
Die temperature (°F)	336
Air temperature (°F)	350
Die hole diameter (inches)	0.09
Die-to collector distance (cm)	50

Table 1. Main production settings and their values used in experiments

The sample codes and production parameters of the PP melt blown nonwovens investigated in this study can be seen in Table 2.

The produced samples were characterized for thickness, basis weight, air permeability, fiber diameter and tensile properties.

Fabric No	Collector drum speed (ft/min)	Collector vacuum (%)	Die air pressure (psi)	Extruder pressure (psi)
1	10	15	6	530
2	10	30	6	523
3	10	60	6	539
4	20	15	6	514
5	20	30	6	525
6	20	60	6	524
7	30	15	6	525
8	30	30	6	526
9	30	60	6	532
10	10	15	7	515
11	10	30	7	531
12	10	60	7	492
13	20	15	7	515
14	20	30	7	517
15	20	60	7	512
16	30	15	7	521
17	30	30	7	516
18	30	60	7	516
19	10	15	8	550
20	10	30	8	540
21	10	60	8	542
22	20	15	8	535
23	20	30	8	532
24	20	60	8	541
25	30	15	8	535
26	30	30	8	544
27	30	60	8	525

Table 2. Sample codes and production parameters of PP nonwovens

Thickness was tested by using SDL Thickness Gauge according to TS 7128 EN ISO 5084 standard, with 20 cm^2 measurement area under 200 g weight. Air permeability test was performed by using FX 3300 Air Permeability test device according to TS 391 EN ISO 9237 standard, with 20 cm^2 measurement area and 100 Pa air pressure. Fiber diameter was measured by using Leica DM EP light microscope with 400 zoom. Tensile properties were tested according to TS EN ISO 13934-1 standard by using Zwick Z010 Universal tensile strength with 200 mm measurement distance and 100 mm/min measurement speed.

The results were evaluated statistically by using SPSS software. To evaluate the differences between the subgroups in the collector drum speed, the collector vacuum and the die air pressure Student-Newman-Kleus test were performed. For the investigation of the effect of the extruder pressure 2-Tailed Pearson Correlation tests were performed.

3. Results and discussions

In this study, influence of some crucial production parameters namely die air pressure, extruder pressure, collector drum speed, and collector vacuum on the thickness, basis weight, air permeability, fiber diameter and tensile properties of polypropylene meltblown nonwoven webs were investigated.

3.1 Thickness

The results obtained from the thickness measurements were presented in Figure 1. The statistical analysis have shown that thickness of polypropylene meltblown nonwovens were effected mostly by the drum speed and the collector vacuum. An increase in the drum speed and an increase in the vacuum caused a decrease in the thickness. In other words, thicker surfaces were obtained with lower collector drum speeds and lover vacuum values. The highest values were obtained with 10 ft/min drum speed and %15 vacuum.

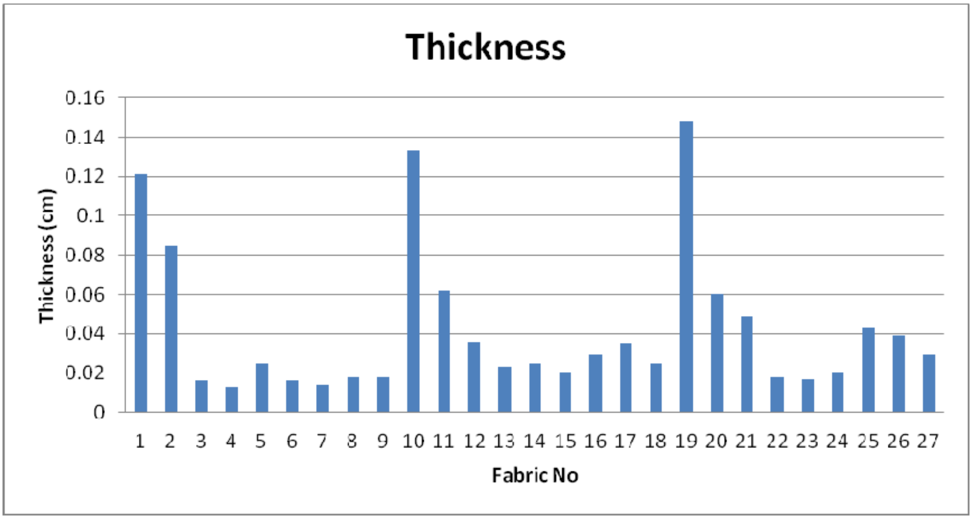


Fig. 1. Thickness values of polypropylene meltblown nonwovens

Statistical analyses also proved that the drum speed and collector vacuum on the thickness of meltblown nonwovens were statistically significant. The results of the tests between subgroups were shown in Table 3 and Table 4. As it can be seen in Table 3 and Figure 1, as a general trend the thickness increased with decreasing collector drum speed. Even though the thicknesses of the samples produced with 30 ft/min which were 0,0278 cm on average are slightly higher than the ones produced with 20 ft/min which were 0,0197 cm, the main trend did not change. The highest results were obtained with 10 ft/min as 0,0789 cm and the lowest results were obtained with 20 ft/min as 0,0197 cm.

As it can be seen in Table 4 and Figure 1, the effect of collector vacuum on the thickness was found to be statistically significant and the thickness increased with decreasing collector vacuum. The highest thickness results were obtained with 15% as 0,0602 cm and the lowest results were obtained with 60 ft/min as 0,0254 cm.

Collector DrumSpeed (ft/min)	N	Subset		
		1	2	3
20	45	,0197		
30	45		,0278	
10	45			,0789
Sig.		1,000	1,000	1,000
Alpha = 0,05				

Table 3. Student-Newman-Keuls test results related with the effect of collector drum speed on to the thickness

Collector Vacuum (%)	N	Subset		
		1	2	3
60	45	,0254		
30	45		,0407	
15	45			,0602
Sig.		1,000	1,000	1,000
Alpha = 0,05				

Table 4. Student-Newman-Kleus test results related with the effect of collector vacuum on to the thickness

The effect of air pressure on the thickness was also found to be statistically significant, when the difference between 6 psi and 8 psi were considered. Student-Newman-Keuls test results showed that an increase in the die air pressure caused the increase in the thickness. The results of the tests between subgroups were presented in Table 5. As it can be seen in Table 5, the thickness value increased from 0.362 cm to 0.431 cm by the increase of the die air pressure from 6 psi to 7 psi. Similarly, when the pressure increased to 8 psi, the average thickness increased to 0,047 cm.

Die Air Pressure (psi)	N	Subset	
		1	2
6	45	,0362	
7	45	,0431	,0431
8	45		,0470
Sig.		,061	,287
Alpha = 0,05			

Table 5. Student-Newman-Keuls test results related with the effect of die air pressure on to the thickness

The results obtained from the 2-Tailed Pearson Correlation test were given in Table 6. The results showed that there was a positive correlation of 19,7% between the die air pressure and the thickness, which means that increase in the die air pressure caused an increase in the thickness in 19,7%.

Correlations		Extruder Pressure	Thickness
Extruder pressure (psi)	Pearson Correlation	1	,197*
	Sig. (2-tailed)		,022
	N	135	135
Thickness (cm)	Pearson Correlation	,197*	1
	Sig. (2-tailed)	,022	
	N	135	135
*. Correlation is significant at the 0.05 level (2-tailed).			

Table 6. 2-Tailed Pearson Correlation test results related with the effect of extruder pressure on to the thickness

3.2 Basis weight

The results obtained from the basis weight measurements were given in Figure 2. The basis weight of the polypropylene meltblown nonwovens were effected mostly by the die air pressure, collector drum speed and collector vacuum.

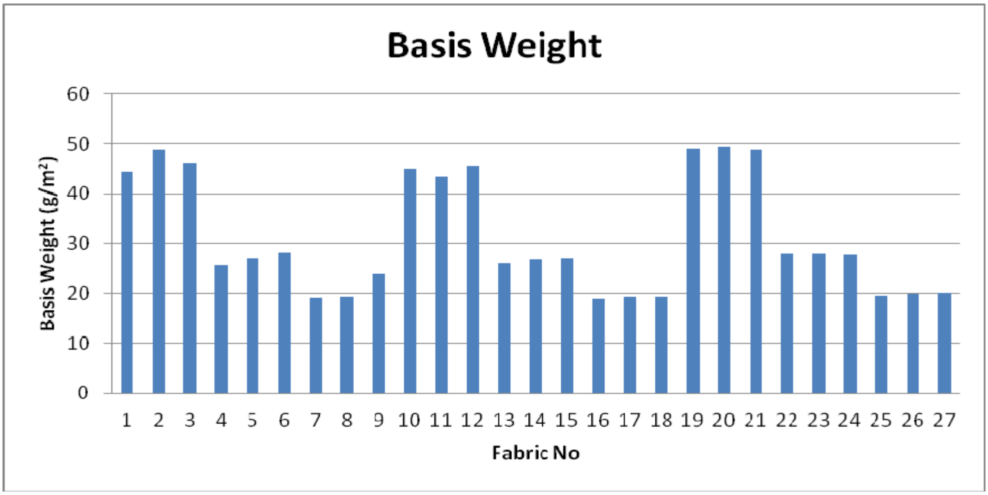


Fig. 2. Basis weight values of polypropylene meltblown nonwovens

Collector Drum Speed (ft/min)	N	Subset		
		1	2	3
30	45	137,033		
20	45		190,824	
10	45			239,769
Sig.		1,000	1,000	1,000
Alpha = 0,05				

Table 7. Student-Newman-Keuls test results related with the effect of the collector drum speed on to the basis weight

Table 7 and Figure 2 showed that the basis weight increased gradually with decreasing collector drum speed. The highest values were obtained with 10 ft/min collector drum speed as 239,769 g/m² on average and the lowest values were obtained with 30 ft/min collector drum speed as 137,033 g/m² on average.

As it can be seen in Figure 2 and Table 8, basis weight increased also with increasing die air pressure. The highest values were obtained with 8 psi as 322,711 g/m², whereas the lowest values were obtained with 6 psi pressure as 31,411 g/m².

Die Air Pressure (psi)	**N**	**Subset**		
		1	**2**	**3**
6	45	31,411		
7	45		213,504	
8	45			322,711
Sig.		1,000	1,000	1,000
Alpha = 0,05				

Table 8. Student-Newman-Keuls test results related with the effect of the die air pressure on to the basis weight

Student-Newman-Keuls tests have also shown that the collector vacuum had a significant effect on basis weight and also that when the vacuum increased the weight also increased. So the highest values were obtained with 60% vacuum as 220,720 g/m and the lowest values were obtained with 15% vacuum as 171,902 g/m as it can be seen in Table 9 and Figure 2.

Collector Vacuum (%)	**N**	**Subset**		
		1	**2**	**3**
15	45	171,902		
30	45		175,004	
60	45			220,720
Sig.		1,000	1,000	1,000
Alpha = 0,05				

Table 9. Student-Newman-Kleus test results related with the effect of the collector vacuum on to the basis weight

Correlations		**Extruder Pressure**	**Weight**
Extruder Pressure (psi)	Pearson Correlation	1	,151
	Sig. (2-tailed)		,080
	N	135	135
Weight (g/m)	Pearson Correlation	,151	1
	Sig. (2-tailed)	,080	
	N	135	135

Table 10. 2-Tailed Pearson Correlation test results related with the effect of extruder pressure on to the basis weight

The results of the 2-Tailed Pearson Correlation test applied to see the relationship between the extruder pressure and the basis weight were given in Table 10. The results showed that there was not any significant correlation, which means that the effect of extruder pressure on the basis weight was not statistically significant.

3.3 Air permeability

Air permeability is an important property for meltblown nonwovens, that effect their performance in many applications especially in filtration. The air permeability property of the meltblown nonwovens are mostly effected by the die air pressure, the collector drum speed, the collector vacuum and extruder pressure. The results obtained from air permeability results were presented in Figure 3.

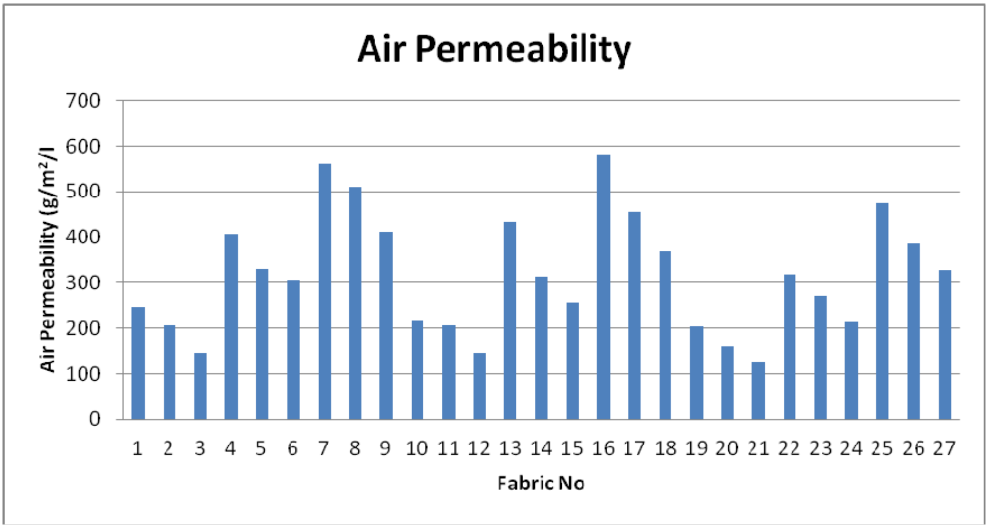


Fig. 3. Air permeability values of polypropylene meltblown nonwovens

As it can be seen in Table 11, the die air pressure had a significant effect on the air permeability of the polypropylene meltblown nonwovens. Table 11 and Figure 3 showed that the air permeability increased with increasing die air pressure. It can be also said that the air permeability was effected by the weight of the sample and it increased by decreasing weight. The highest results were obtained with 6 psi as 347,065 $g/m^2/l$, whereas the lowest values were obtained with 8 psi as 275,444 $g/m^2/l$.

Die Air Pressure	N	Subset		
		1	2	3
8	45	275,444		
7	45		330,789	
6	45			347,056
Sig.		1,000	1,000	1,000

Alpha = 0,05

Table 11. Student-Newman-Kleus test results related with the effect of the die air pressure on to the air permeability

Figure 3 and Table 12 show that, the air permeability increased with increasing collector drum speed. This result was thought to be related to the decrease in thickness and basis weight. The highest results were obtained with 30 ft/min as 452,267 $g/m^2/l$, whereas the lowest values were obtained with 10 ft/min as 184,122 $g/m^2/l$.

Collector Drum Speed	N	Subset		
		1	2	3
10	45	184,122		
20	45		316,900	
30	45			452,267
Sig.		1,000	1,000	1,000
c. Alpha =0,05				

Table 12. Student-Newman-Kleus test results related with the effect of the collector drum speed on to the air permeability

Regarding the effect of the collector vacuum on the air permeability, it can be said that the air permeability increased with decreasing vacuum. This can be due to the increase in the basis weight with increasing vacuum. The highest results were obtained with 15% as 382,156 $g/m^2/l$, whereas the lowest values were obtained with 60% as 255,689 $g/m^2/l$.

The results of the statistical subgroup analysis about the effect of the collector vacuum on the air permeability were presented in Table 13.

Collector Vacuum	N	Subset		
		1	2	3
60	45	255,689		
30	45		315,444	
15	45			382,156
Sig.		1,000	1,000	1,000
Alpha = 0,05				

Table 13. Student-Newman-Kleus test results related with the effect of the collector drum speed on to the air permeability

Correlations		Extruder Pressure	Air Permeability
Extruder_pressure	Pearson Correlation	1	-,174*
	Sig. (2-tailed)		,044
	N	135	135
Air_permeability	Pearson Correlation	-,174*	1
	Sig. (2-tailed)	,044	
	N	135	135
*. Correlation is significant at the 0.05 level (2-tailed).			

Table 14. 2-Tailed Pearson Correlation test results related with the effect of the extruder pressure on to the air permeability

Table 14 shows the correlation test results regarding the effect of the extruder pressure on the air permeability. As it can be seen in the table, the correlation was found to be statistically significant, evet though it was not very strong considering the value. It can be commented that there was a negative correlation of 17,4% between the extruder pressure and the air permeability. The air permeability decreased with the increasing extruder pressure.

3.4 Fibre diameter

Fibre diameter of meltblown nonwovens plays a critical role in some physical properties of the meltblown nonwovens, as it determines the surface area, which is a very important parameter for such applications as filtration and cleaning. Better filtration and cleaning performances are achieved with smaller fibre diameter, due to the increased surface are. Fibre diameter was effected by the collector vacuum and the extruder pressure. Figure 4 showed the fibre diameter properties of polypropylene meltblown nonwovens. In this study meltblown nonwovens with fibre diameter of 5-9 μm were achieved.

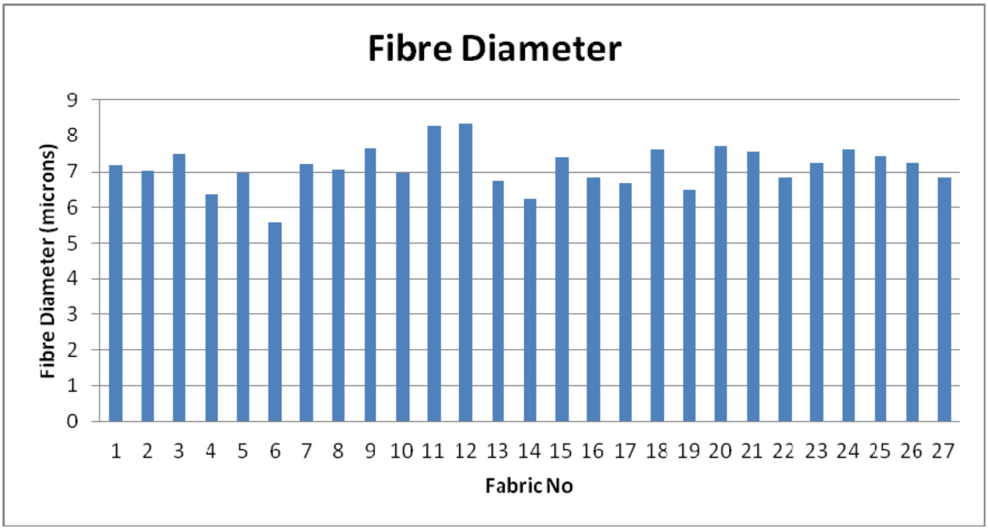


Fig. 4. Fibre diameter values of polypropylene meltblown nonwovens

As it can be seen in Table 15, results of the statistical analysis have shown that the die air pressure did not have a significant effect on the fibre diameter. It is also possible that the effect was not clear since the die air pressure values were very close to each other.

Die Air Pressure	N	Subset
		1
6	45	6,944
8	45	7,224
7	45	7,235
Sig.		,055
Alpha = 0,05.		

Table 15. Student-Newman-Kleus test results related with the effect of the die air pressure on to the air fibre diameter

The effect of the collector vacuum on the fibre diameter was found to be statistically significant. As it can be seen in Table 16, the fibre diameter slightly increased from 6,89 µm to 7,15 µm, when the collector vacuum increased from 15% to 30%. The reason of this increase might be the increasing pressure on the fibres. It can also be seen in Figure 4 and Table 15 that the fibre diameter did not change significantly with an increase in the collector vacuum from 30% to 60%. The highest results were obtained with 60% as 7,345 µm, whereas the lowest values were obtained with 15% as 6,900 µm.

Collector Vacuum	**N**	**Subset**	
		1	**2**
15	45	6,900	
30	45		7,159
60	45		7,345
Sig.		1,000	,140
Alpha = 0,05			

Table 16. Student-Newman-Keuls test results related with the effect of the collector vacuum on to the fibre diameter

Table 17 shows the correlation between the extruder pressure and the fibre diameter. As it can be seen in the table, the correlation was not found to be statistically significant, so the fibre diameter of the meltblown nonwovens investigated in this study were not influenced by the extruder pressure.

Correlations		**Extruder Pressure**	**Fibre Diameter**
Extruder Pressure	Pearson Correlation	1	,025
	Sig. (2-tailed)		,769
	N	135	135
Fibre Diameter	Pearson Correlation	,025	1
	Sig. (2-tailed)	,769	
	N	135	135
**. Correlation is significant at the 0.01 level (2-tailed).			

Table 17. 2-Tailed Pearson Correlation test results related with the effect of the extruder pressure on to the fibre diameter

3.5 Tensile properties

Breaking load and % elongation were investigated to evaluate the tensile properties of the meltblown nonwovens. The results of the measurements have shown that the breaking load and the elongation were significantly affected by the collector drum speed, collector vacuum, die air pressure and extruder pressure in production direction, where a the extruder pressure did not appear to be a significant factor for the tensile properties in the width direction.

Figure 5 shows the breaking load values of the polypropylene meltblown nonwovens in production and width directions. It can be seen in Figure 5 that the breaking load results in production direction were slightly higher than the results in the width direction. This was because orientation of the fibre were more towards the production direction around the collector drum and therefore the strength was more enhanced in this direction.

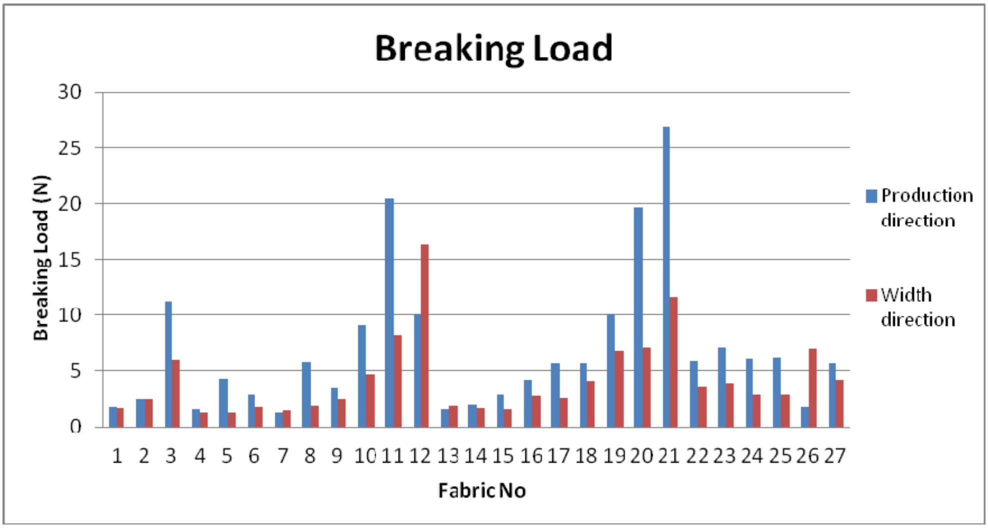


Fig. 5. Breaking load values of polypropylene meltblown nonwovens

Figure 6 shows the elongation values in the production and the width directions. As it can be seen in Figure 6, the elongation results in production direction were slightly lower than the results in the width direction. In general, the elongation decreased with increasing breaking load.

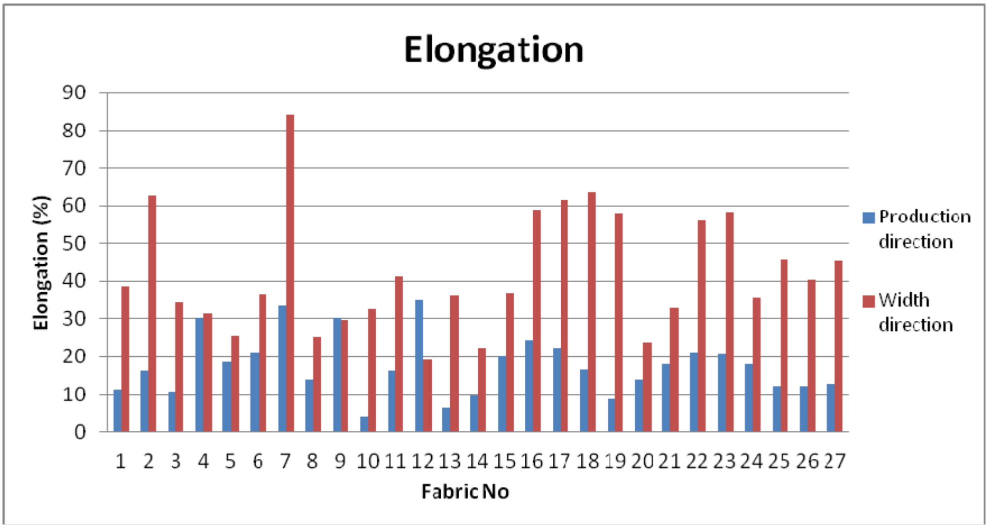


Fig. 6. Elongation values of polypropylene meltblown nonwovens

It can be seen in Figure 5 and Table 18 that the breaking load increased with increasing die air pressure both in the production and the width directions. This was caused by the increase in basis weight and thickness. The highest values were obtained with 8 psi as 9,904 N and the lowest values were obtained with 6 psi pressure as 3,859 N in the production direction, whereas highest values were obtained with 8 psi as 5,555 N and the lowest values were obtained with 6 psi pressure as 2,252 N in the width direction.

Die Air Pressure	N	Subset (production direction)			Subset (width direction)		
		1	2	3	1	2	3
6	45	3,859			2,252		
7	45		6,832			4,870	
8	45			9,904			5,555
Sig.		1,000	1,000	1,000	1,000	1,000	1,000
Alpha = 0,05							

Table 18. Student-Newman-Keuls test results related with the effect of the die air pressure on to the breaking load in the production and width directions

Table 19 shows the effect of the die air pressure on elongation both in production and width directions. It can be seen in Table 19 and Figure 6 that elongation decreased with increasing die air pressure in the production direction, due to incresing breaking load. The difference between 6 psi and other die air pressures were found to cause a statistically significant difference in the elongation whereas the difference between 7 psi and 8 psi were not found to be statistically significant. In the width direction this trend was not valid; increasing pressure caused an increase in the elongation in this direction. The highest values were obtained with 6 psi as 20,640 % in the production direction and as 44,040 % in the width direction, whereas the lowest values were obtained with 8 psi as 15,310 % in the production direction and as 40,993 % in the width direction.

Die Air Pressure	N	Subset (production direction)		Die Air Pressure	N	Subset (width direction)	
		1	2			1	2
8	45	15,310		6	45	40,993	
7	45	17,137		7	45	41,380	
6	45		20,640	8	45		44,040
Sig.		,090	1,000	Sig.		,742	1,000
Alpha = 0,05							

Table 19. Student-Newman-Keuls test results related with the effect of the die air pressure on to the elongation in the production direction and width directions.

Table 20 shows the effect of collector drum speed on the breaking load in production and width directions. For both of the directions as a general trend the breaking load decreased with increasing collector drum speed, due to the decrease in the basis weight. It can be seen both in the production and the width directions that when the collector drum speed increased from 10 ft/min to 20 ft/min the breaking load decreased sharply and slightly increased again when the collector drum speed increased to 30 ft/min. The reason of this slight increase was thought to be the increase in fibre strength due to the drawing with higher speed. The highest values were obtained with 10 ft/min as 12,408 N in the production direction and as 7,211 N in the width direction, whereas the lowest values were obtained with 20 ft/min as 3,787 N in the production direction and as 2,212 N in the width direction.

Collector Drum Speed	N	Subset (production direction)			Subset (width direction)		
		1	2	3	1	2	3
20	45	3,787			2,212		
30	45		4,400			3,254	
10	45			12,408			7,211
Sig.		1,000	1,000	1,000	1,000	1,000	1,000
Alpha = 0,05							

Table 20. Student-Newman-Kleus test results related with the effect of the collector drum speed on to the breaking load in the production and width directions

The effect of the collector drum speed on the elongation can be seen in Figure 6 and Table 21. The increase in collector drum speed caused an increase in the elongation both in the production and width directions, due to the decreasing basis weight and breaking load. In the production direction significantly lower elongation results were obtained with 10 ft/min compared to the other drum speeds. The difference between the results obtained with 20 ft/min and 30 ft/min were not found to be statistically significant. In the width direction significantly higher elongation results were obtained with 30 ft/min compared to the other drum speeds, whereas the difference between the results obtained with 10 ft/min and 20 ft/min were not found to be statistically significant. The highest values were obtained with 30 ft/min as 19,780% in the production direction and as 50,539% in the width direction, whereas the lowest values were obtained with 10 ft/min as 14,952% in the production direction and as 37,675% in the width direction.

Collector Drum Speed	N	Subset (production direction)		Collector Drum Speed	N	Subset (width direction)	
		1	2			1	2
10	45	14,952		20	45	37,675	
20	45		18,355	10	45	38,199	
30	45		19,780	30	45		50,539
Sig.		1,000	,185	Sig.		,656	1,000

Alpha = 0,05

Table 21. Student-Newman-Kleus test results related with the effect of the collector drum speed on to the elongation in the production direction and width directions.

The effect of the collector vacuum on the breaking load was shown in Table 22 and Figure 5. The breaking load increased with increasing vacuum in both directions, due to stronger bounding of the fibres in the web as a result of the increasing air pressure applied to the web by the vacuum. The highest values were obtained with 60% as 8,309 N in the production direction and as 5,654 N in the width direction, whereas the lowest values were obtained with 15% as 4,613 N in the production direction and as 2,994 N in the width direction.

Collector Vacuum	N	Subset (production direction)			Subset (width direction)		
		1	2	3	1	2	3
15	45	4,613			2,994		
30	45		7,673			4,029	
60	45			8,309			5,654
Sig.		1,000	1,000	1,000	1,000	1,000	1,000
Alpha = 0,05							

Table 22. Student-Newman-Kleus test results related with the effect of the collector vacuum on to the breaking load in the production direction.

Table 23 shows the effect of collector vacuum on the elongation in the production and the width directions. As it can be seen in Figure 6 and Table 23, the elongation increased with increasing collector vacuum in both directions, even though there has been a slight decrease in 30% in the width direction. The highest values were obtained with 60% vacuum as 20,253% elongation in the production direction and as 49,139% elongation in the width direction, whereas the lowest values were obtained with 15% vacuum as 15,978% elongation in the production direction and as 37,181% elongation in the width direction.

Collector Vacuum	N	Subset (production direction)		Collector Vacuum	N	Subset (width direction)		
		1	2			1	2	3
15	45	15,978		20	45	37,181		
30	45	16,856		10	45		40,094	
60	45		20,253	30	45			49,139
Sig.		,412	1,000	Sig.		1,000	1,000	1,000

Alpha = 0,05

Table 23. Student-Newman-Kleus test results related with the effect of the collector vacuum on to the elongation in the production direction and width directions

The correlation test results regarding the effect of the extruder pressure on the breaking load in the production and the width directions were presented in Table 24. As it can be seen in the table, there was a significant positive correlation of 33,3% between the extruder pressure and the breaking load in the production direction, whereas the correlation in the width direction was not found to be statistically significant. In other words, in the production direction the breaking load increased with increasing extruder pressure, but it did not have a significant effect in the width direction. Since the fibres were oriented more towards the production direction, the increase in the extruder pressure caused an increase in the fiber strength and it was reflected to the strength of the web in the production direction, but not in the width direction.

	Correlations		Extruder Pressure	Breaking Load
Production Direction	Extruder Pressure	Pearson Correlation	1	,333**
		Sig. (2-tailed)		,000
		N	135	135
	Breaking Load	Pearson Correlation	,333**	1
		Sig. (2-tailed)	,000	
		N	135	135
Width Direction	Extruder Pressure	Pearson Correlation	1	-,002
		Sig. (2-tailed)		,979
		N	135	135
	Breaking Load	Pearson Correlation	-,002	1
		Sig. (2-tailed)	,979	
		N	135	135

**. Correlation is significant at the 0.01 level (2-tailed).

Table 24. 2-Tailed Pearson Correlation test results related with the effect of the extruder pressure on to the breaking load in the production and width directions

Table 25 shows the correlations between the extruder pressure and elongation of the meltblown webs in the production and the width directions. As it can be seen in the table, there was a significant negative correlation of 30,5% between these two factors in the production direction, which means that the elongation decreased with increasing extruder pressure in this direction. The correlations between the extruder pressure and elongation were not found to be statistically significant in the width direction.

	Correlations		Extruder Pressure	Breaking Load
Production Direction	Extruder Pressure	Pearson Correlation	1	-,305**
		Sig. (2-tailed)		,000
		N	135	135
	Elongation	Pearson Correlation	-,305**	1
		Sig. (2-tailed)	,000	
		N	135	135
Width Direction	Extruder Pressure	Pearson Correlation	1	,124
		Sig. (2-tailed)		,153
		N	135	135
	Elongation	Pearson Correlation	,124	1
		Sig. (2-tailed)	,153	
		N	135	135

**. Correlation is significant at the 0.01 level (2-tailed).

Table 25. 2-Tailed Pearson Correlation test results related with the effect of the extruder pressure on to the elongation in the production direction

4. Conclusion

The MB technique for making nonwoven products has been forecast in recent years as one of the fastest-growing in the nonwovens industry. With the current expansion and interest, a strong and bright future is forecasted for this technology. The scope and utility of this technology will increase and meltblowing will become a major technique in nonwoven technology. The application of speciality polymer structures will no doubt offer new nonwoven materials unobtainable by other competitive technologies. (Dahiya et al., 2004)

In this chapter the results of a study regarding the investigations of the effect of die air pressure, extruder pressure, collector drum speed, and collector vacuum on the physical properties, namely thickness, basis weight, air permeability, fiber diameter and tensile properties of polypropylene meltblown nonwoven webs were presented.

The results have shown that thickness of polypropylene meltblown nonwovens were effected mostly by the drum speed and the collector vacuum. An increase in the drum speed and an increase in the vacuum caused a decrease in the thickness. Thicker surfaces were obtained with lower collector drum speeds and lover vacuum values.

The basis weight of the polypropylene meltblown nonwovens were mostly influenced by the die air pressure, collector drum speed and collector vacuum. The basis weight increased gradually with decreasing collector drum speed and increased with increasing die air pressure. The collector vacuum had a significant effect on basis weight; when the vacuum increased the basis weight also increased. The effect of extruder pressure on the basis weight was not statistically significant.

Air permeability is an important property for meltblown nonwovens, that effect their performance in many applications especially in filtration. The air permeability property of the meltblown nonwovens were influenced by the die air pressure, the collector drum speed, the collector vacuum and extruder pressure. The air permeability increased with increasing die air pressure, collector drum speed and decreasing vacuum. The air permeability decreased with the increasing extruder pressure.

Fibre diameter of meltblown nonwovens is a very important parameter for such applications as filtration and cleaning. Fibre diameter was effected by the collector vacuum and the extruder pressure. The die air pressure did not have a significant effect on the fibre diameter. The fibre diameter slightly increased, when the collector vacuum increased from 15% to 30%, but it did not change significantly with an increase in the collector vacuum from 30% to 60%. The fibre diameter of the meltblown nonwovens investigated in this study were not affected by the extruder pressure.

Breaking load and elongation were significantly influenced by the collector drum speed, collector vacuum, die air pressure and extruder pressure in production direction. The extruder pressure did not appear to be a significant factor for the tensile properties in the width direction. The breaking load results in production direction were slightly higher and therefore the elongation results were slightly lower than the results in the width direction. This is because orientation of the fibres were more towards the production direction around the collector drum and therefore the strength were more enhanced in this direction. The breaking load increased with increasing die air pressure both in the production and the width directions, due to the increase in basis weight and thickness. The elongation decreased with increasing die air pressure in the production direction, due to incresing breaking load. In the width direction this trend was not valid; increasing pressure caused an increase in the elongation in this direction. For both of the directions as a general trend the breaking load decreased with increasing collector drum speed, due to the decrease in the basis weight. The increase in collector drum speed caused an increase in the elongation both in the production and width directions, due to the decreasing basis weight and breaking load. The breaking load increased with increasing vacuum in both directions, due to stronger bounding of the fibres in the web as a result of the increasing air pressure applied to the web by the vacuum. The elongation increased with increasing collector vacuum in both directions. In the production direction the breaking load increased with increasing extruder pressure, but it didn't have a significant effect in the width direction. The elongation decreased with increasing extruder pressure in the production direction, whereas the correlations between the extruder pressure and elongation were not found to be statistically significant in the width direction.

Polypropylene meltblown nonwovens can be used in various application areas such as surgical face masks filter media, liquid and gaseous filtration, cartridge filters, clean room filters, hot melt adhesives, cleaning wipes and others. The properties of such materials should be investigated deeply for different applications.

5. References

[1] Ebeling, H.; Fink, H. P.; Luo, M.& Geus, H. G. (2006). Cellulose Meltblown Nonwovens Using The Lyocell-Process, In: *Lenzinger Berichte 86*, 21.11.2011, Available from <http://www.lenzing.com/fileadmin/template/pdf/konzern/lenzinger_berichte/ausgabe_86_2006/LB_2006_Ebeling_16_ev.pdf>

[2] Duran, D.; Perincek, S. (2010). The Effect of Various Production Parameters on the Physical Properties of Polypropylene Meltblown Nonwovens, *Industria Textila*, Vol.61, No.3, 2010, pp. 117-123, ISSN: 12225347

[3] One Lee, B.; Anko, J.& Won Han, S.(2010). Characteristics of PP/PET Bicomponent Meltblown Nonwovens as Sound Absorbing Material, *Advanced Materials Research*, Vols. 123-125, August 2010, pp. 935-938, DOI: 10.4028/www.scientific.net/AMR.123-125.935

[4] Zhang, D.; Sun, C.; Beard, J.; Brown, H.; Carson, I.; Hwo, C., (2002). Innovative Polytrimethylene terephthalate (PTT) Polymers for Technical Nonwovens, *Journal of Industrial Textiles*, Vol. 31, No.3, January 2002, pp. 159-178, DOI: 10.1106/152808302025393

[5] Dutton, K. C. (2008). Overview and Analysis of the Meltblown Process and Parameters, *In: JTATM Journal of Textile and Apparel* Technology and Management, Vol. 6, No. 1, Fall 2008, 21.11.2011, Available from < http://ojs.cnr.ncsu.edu/index.php/JTATM/article/viewFile/342/275>

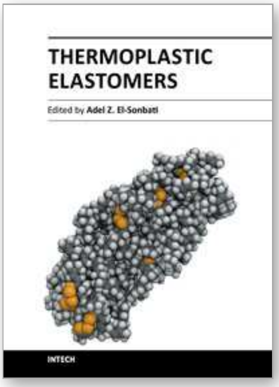
[6] Bresee, R. R., Qureshi, U. A. (2004). Influence of Processing Conditions On Melt Blown Web Structure: Part 1 – DCD, In: *INJ Spring 2004*, pp. 49-55, 21.11.2011, Available from: http://www.inda.org/subscrip/inj04_1/p49-55-bresee.pdf

[7] Rupp, J. (2008), Spunbond and Meltblown Nonwovens, In: *Nonwovens and Technical Textiles, Textile World*, 21.11.2011, Available from: http://www.textileworld.com/Articles/2008/May_2008/Nonwovens/Spunbond_x_Meltblown_Nonwovens.html

[8] Farer, R.; Seyam, A.M.; Ghosh, T.K.; Batra, S.K.; Grant, E.& Lee, G. (2003). Forming Shaped/Molded Structures by Integrating Meltblowing and Robotic Technologies,

Textile Research Journal, Vol. 73, No.1, January 2003, pp. 15-21, DOI: 10.1177/004051750307300103

[9] Dahiya A.; Kamath, M. G. & Hegde, R. R. (2004). Meltblown Technology, In: *The Official Website of the University of Tennessee*, 21.11.2011, Available from: http://web.utk.edu/~mse/Textiles/Melt%20Blown%20Technology.htm



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Thermoplastics can be used for various applications, which range from household articles to the aeronautic sector. This book, "Thermoplastic Elastomers", is comprised of nineteen chapters, written by specialized scientists dealing with physical and/or chemical modifications of thermoplastics and thermoplastic starch. Such studies will provide a great benefit to specialists in food, electric, telecommunication devices, and plastic industries. Each chapter provides a comprehensive introduction to a specific topic, with a survey of developments to date.

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