



Statistical analysis of the effect of melt flow index and weight changes on strength properties of polypropylene spunbond fabrics

İsmail TİYEK^{1,*}, Emrah KAÇMAZ², Mustafa YAZICI³, Mahmut KILINÇKIRAN⁴

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¹Department of Textile Engineering, Faculty of Engineering and Architecture, Kahramanmaraş Sütçü İmam University, 46050, Kahramanmaraş, Turkey

²Department of Textile Engineering, Institute of Natural and Applied Sciences, Kahramanmaraş Sütçü İmam University, 46050, Kahramanmaraş, Turkey

³Department of Mathematics and Science Education, Faculty of Education, Kahramanmaraş Sütçü İmam University, 46050, Kahramanmaraş, Turkey

⁴Department of Textile, Clothing, Footwear and Leather, Vocational School of Technical Sciences, Kahramanmaraş Sütçü İmam University, 46050, Kahramanmaraş, Turkey

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*Corresponding author e-mail: ismailtiyek@ksu.edu.tr

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ABSTRACT

Spunbond method is widely used in the production of nonwoven fabrics. Melt flow index (MFI) is one of the most important polymer processing parameters. In this paper, tensile strength and elongation values of spunbond fabrics with four different weights produced from polypropylene polymers with two different MFI values were measured. Tensile strength tests were analyzed by two-way multiple variance analysis (Two-Way Manova) in the SPSS statistical package program, and the effects of MFI and weight values on the strength properties of spunbond textile surfaces were examined. As a result of the statistical analysis, it was observed that statistically significant differences ($p < 0.05$) occurred in both tensile strength and elongation values with the change of weight value. In addition, significant differences ($p < 0.05$) occurred in tensile strengths with the change of MFI value, but the differences in elongation values were not statistically significant ($p > 0.05$).

Keywords: Spunbond, melt flow index (MFI), weight, tensile strength, elongation.

Polipropilen bükülmüş kumaşların mukavemet özellikleri üzerine erime akış indeksi ve ağırlık değişimlerinin etkisinin istatistiksel analizi

ÖZ

Spunbond yöntemi dokusuz yüzey kumaşların üretiminde yaygın olarak kullanılmaktadır. Erime akış indeksi (MFI), polimerlerin işlenmesinde en önemli parametrelerden bir tanesidir. Bu çalışmada, iki farklı MFI değerine sahip polipropilen polimerinden dört farklı gramajda üretilen spunbond dokusuz tekstil yüzeylerinin kopma mukavemeti ve uzama değerleri ölçüldü. Kopma mukavemeti testleri SPSS istatistik paket programında iki yönlü çoklu varyans analizi (Two-Way Manova) ile analiz edildi ve MFI ve gramaj değerlerinin spunbond tekstil yüzeylerin mukavemet özellikleri üzerindeki etkileri incelendi. İstatistik analiz sonucunda ağırlık değerinin değişimiyle hem kopma mukavemeti hem de uzama değerlerinde istatistiksel açıdan anlamlı farklar ($p < 0.05$) meydana geldiği gözlemlendi. Ayrıca, MFI değerinin değişmesi ile kopma mukavemetlerinde anlamlı farklılıklar ($p < 0.05$) oluştu, fakat uzama değerlerindeki farklılıklar istatistiksel olarak anlamlı değildi ($p > 0.05$).

Anahtar Kelimeler: Spunbond, eriyik akış indeksi (MFI), gramaj, kopma mukavemeti, uzama.

1. INTRODUCTION

Nowadays, with the emergence of various developments in the variety of fabric technology, it has become difficult for both manufacturers and consumers to choose and use them for different purposes. Conventional textile producers and consumers consider long lifespan as an important factor along with comfort.^{1,2}

Spunbond nonwoven surfaces are used in a wide spectrum such as home textiles, special clothings, medical products, construction and geotextile applications, shoe and leather industry, automotive industry, industrial applications, advertisement and packaging industry.^{3,4} Therefore, strength is the first and foremost quality parameter expected from spunbond surface used in all of these areas. Several differences may occur in the variance and strength qualities of non-woven polypropylene in terms of Melt Flow Index (MFI). Polypropylene (PP) is one of the widely used polymers in creating spunbond nonwoven surfaces.⁵ PP is a thermoplastic polymer and a material the most widely used after polyethylene in the polymer industry. Melting temperature of polypropylene is about 160°C and it is usually processed at temperatures over 200°C. In the production of spunbond textile surfaces, PP polymer melted by heating in the extruder to ensure suitable viscosity is extruded to cold air zone from spinnerets under certain pressure and formed webs by laying on the collector.^{2, 5-8}

PP has been first introduced to the industry by Montecatini in 1957. Studies aimed to increase its application areas and to decrease its cost have continued until 1968 when it has started to be used and produced more frequently.^{8,9} MFI is directly related to the molecular weight of polypropylene.¹⁰ MFI is a measure of the capacity of the molten polymeric materials to flow under the pressure and it is inversely proportional to their viscosities at the conditions of the test.^{9, 11,12}

MFI values are the most important features of the flow used after density when determining the physical, chemical and thermomechanical properties of plastics and especially when creating catalogs by plastic raw material manufacturers.¹³⁻¹⁵ MFI is one of the important elements in the production process because MFI value is directly proportional to molecular weight of polymer. it affects the definition of the processing properties of the polymer and the material to be produced.^{10,12,14} MFI test measures the mass of plastic material passed through a capillary tube at a specific diameter and length under a suggested temperature and press conditions for 10 minutes in accordance with ASTM D1238 and TS EN ISO 1133. MFI test result is expressed as $g\ 10\ min^{-1}$.^{14, 16-18}

In this study, spunbond textile surfaces with four different weight were produced from polypropylene polymer with two different MFI value. Depending on MFI of polypropylene polymers and weight of spunbond fabrics, the change in the strength and elongation (%) values of spunbond fabrics were analyzed by statistical analysis. The originality of this article and its difference from other studies is the use of advanced statistical analysis methods. Statistical analyzes both scientifically strengthened the results of the study and provided mathematical models that can be used practically in the industry where strength properties can be predicted before production.

2. MATERIALS AND METHODS

2.1. Materials

In this study, spunbond fabrics produced by Teknomelt Teknik Mensucat San. Tic. A.Ş., polypropylene polymers (Exxon Mobil) of 25 MFI and 35 MFI values at weights of $10\ g\ m^{-2}$, $30\ g\ m^{-2}$, $50\ g\ m^{-2}$ and $70\ g\ m^{-2}$ were used.

2.2. Methods

2.2.1. Formation of spunbond nonwoven surfaces

In the spunbond method, which is known as one of the most common methods of forming texture, fiber formation takes place simultaneously with the texture formation. As shown in Figure 1, the thermoplastic polymer in the form of chips is melted and is extruded from the nozzle at a constant pressure similarly to the synthetic fiber production.^{19,20}

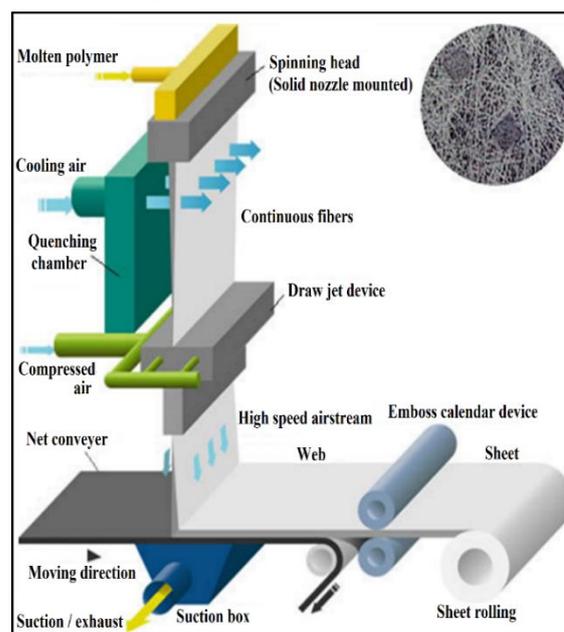


Figure 1. Spunbond surface production.²⁰

Table 1. Test values of spunbond surfaces

Material Properties		Tensile Strength (TS)				Elongation (E)			
		Machine Direction		Cross Direction		Machine Direction		Cross Direction	
Weight (g m ⁻²)	MFI (g 10 ⁻¹ min ⁻¹)	(MD.TS)		(CD.TS)		(MD.E)		(CD.E)	
		Mean	St.Dev.	Mean	St.Dev.	Mean	St.Dev.	Mean	St.Dev.
10	25	18.70	1.93	10.89	1.60	69.25	11.44	44.68	10.43
	35	16.23	2.01	7.94	0.97	79.90	15.14	40.33	13.14
30	25	61.52	8.68	35.17	5.21	127.62	24.36	118.02	21.84
	35	51.87	5.08	28.82	3.70	110.27	20.07	103.08	19.46
50	25	124.47	8.43	83.21	9.41	129.61	15.96	125.15	13.10
	35	105.48	11.06	65.78	10.67	134.63	17.15	130.00	17.23
70	25	182.27	13.27	125.65	14.38	126.92	15.46	125.75	18.01
	35	164.60	9.16	101.91	7.97	150.03	14.10	149.25	10.54

Then, the filaments formed are cooled with cold air and the macromolecules within the fiber structure are drawn to ensure a proper orientation. The flow in the venturi tube causes the filaments to pass through the distributor ring and to distribute randomly because of ventilation. Afterwards, the formed fibers are laid on the conveyor belt with a porous structure. Following the formation of texture, nonwoven surface is produced by connecting the filaments to each other via thermal, mechanical or chemical methods.¹⁹⁻²¹

The formation of spunbond surfaces was performed via spunbond machine with slot system at nozzle (spinneret) pressure of 3.2 bar, nozzle temperature of 235°C, cooling air temperature of 22°C and calendar temperature of 150°C for 10 g m⁻², 30 g m⁻², 50 g m⁻² and 70 g m⁻².

2.2.2. Tensile Strength

The tensile test stands out as one of the most common test methods used to determine the mechanical properties of materials. The tensile strength and elongation of spunbond surfaces with different weights and MFI values were measured by Zwick Roell tensile strength testing device in accordance with EDANA WSP 110.4 (05) standard. Tensile tests were carried out under the conditions of 5 N pretension, 10 mm/min jaw speed and 200 mm jaw distance.²²

3. RESULTS AND DISCUSSION

Tensile strength (TS) and Elongation (E) tests were carried out in the machine direction (MD) and cross direction (CD). The average values of tensile strength and elongation test results of 10 g m⁻², 30 g m⁻², 50 g m⁻² and 70 g m⁻² spunbond fabrics produced from polypropylene polymers of 25 MFI and 35 MFI are given in Table 1.

Bar charts (Figures 2-5) were prepared to visually show the effect of weight and MFI on tensile strength and elongation values by Microsoft Excel. In addition, the line graphs showing the trend of weight–tensile strength and weight–elongation changes were drawn on bar charts, and trend equations and R^2 values of these graphs were also given.

The bar charts of the tensile strengths in the machine direction and in the cross direction of spunbond fabrics with different MFI and weight values are shown in Figures 2 and 3, respectively.

For all MFI values, it was observed that the tensile strength values in both the machine and cross direction increased regularly with the increase of the weight values and the highest R^2 values were found for linear trend equations. For all weight values, it was seen that

the tensile strength decreased slightly with the increase of MFI values. However, since there were only two different MFI values, it was not appropriate to calculate any trend equation.

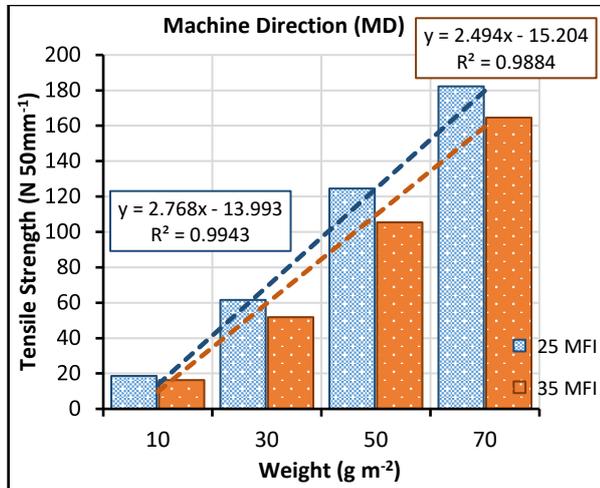


Figure 2. Tensile strengths of spunbond surfaces in the machine direction (Left equation is for 25 MFI, right equation is for 35 MFI).

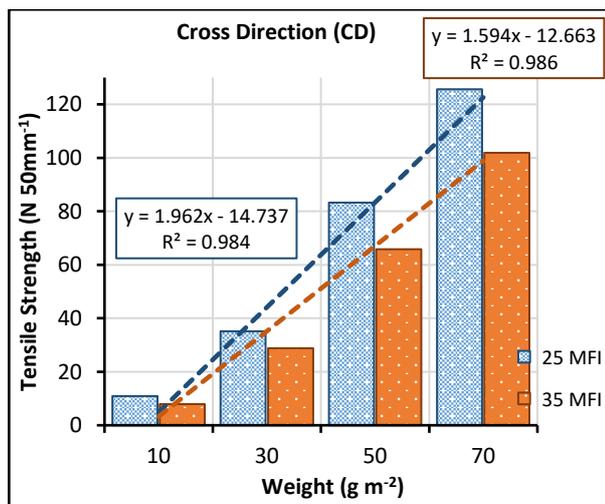


Figure 3. Tensile strengths of spunbond surfaces in the cross direction (Left equation is for 25 MFI, right equation is for 35 MFI).

The bar charts of the elongation values in the machine direction and in the cross direction of spunbond fabrics with different MFI and weight values are shown in Figures 4 and 5, respectively.

For all MFI values, it was observed that the elongation values in both the machine and cross direction increased with the increase of the weight values and the highest R^2 values were found for quadratic polynomial trend equations. Therefore, it was concluded that there was a quadratic relationship between weight and

elongation values. For all weight values (except 30 g m⁻²), it was seen that the elongation values in machine direction generally increased with the increase of MFI values. In the cross direction, it was observed that the

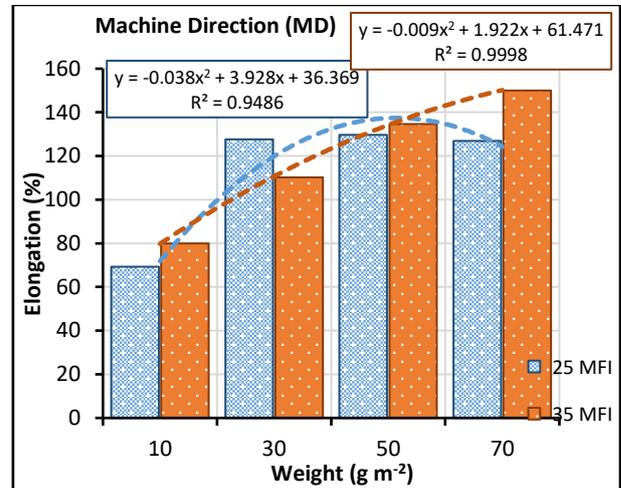


Figure 4. Elongation (%) of spunbond surfaces in the machine direction. (Left equation is for 25 MFI, right equation is for 35 MFI).

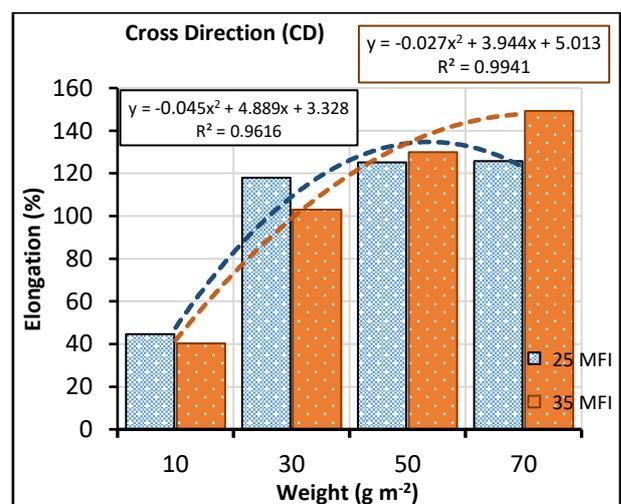


Figure 5. Elongation (%) of spunbond surfaces in the cross direction (Left equation is for 25 MFI, right equation is for 35 MFI).

elongation values decreased at low weights (10 g m⁻² and 30 g m⁻²) and increased at high weights (50 g m⁻² and 70 g m⁻²) with the increase of MFI value.

In this study, it was also aimed to examine the effect of MFI*Weight interaction besides MFI and weight values on the tensile strength and elongation values of the spunbond fabric samples at the machine direction and cross direction by multiple comparison. For this purpose, Two-Way Manova test was carried out at a significance level of $\alpha = 0.05$, in other words, with

95% confidence interval by statistical package program of SPSS. In the analysis of Two-Way Manova, while variables of the weight and MFI were selected as independent variables, the variables of the tensile strength and elongation in both machine and cross directions were also selected as dependent variables. The multivariate test results obtained from the Two-Way Manova analysis are summarized in Table 2.

Table 2. Multivariate test results

Effect	Wilks'		Partial Eta Squared	
	Lambda	F	p	Squared
MFI	0.480	46.281	0.000	0.520
Weight	0.006	228.75	0.000	0.822
MFI*Weight	0.534	10.111	0.000	0.189

In Table 2, significance value indicates whether the effect of independent variables on dependent variables is statistically significant and is also expressed as p. It can be seen from Table 2 that significance (p) values of MFI, Weight and MFI*Weight interaction are 0.000, that is, all p values are less than 0.05 ($p < \alpha$). This situation shows that there are statistically significant differences in both tensile strength and elongation values with the change of MFI and Weight values. This means that MFI, weight and MFI*Weight interaction have an effect on the tensile strength and elongation in general.

In addition, Partial Eta Squared expresses the effect value of independent variables on dependent variables. It is observed that the effect of weight (0.822) on the tensile strength and elongation values is higher than the effect of MFI (0.520), and also the combined effect of the MFI and weight (MFI*Weight) is at a very low level compared to their individual effects.

However, the details of the effects of independent variables on dependent variables are given in Table 3. It can be seen in Table 3 that only the P values of MFI-MD.E (0.086), and MFI-CD.E (0.423) are greater than 0.05 ($p > \alpha$). This shows that there are no statistically significant differences in elongation values in both machine direction and cross direction with the change of MFI value. This means that the effect of MFI value on elongation values (MD.E and CD.E) is not statistically significant. However, all the other p values (0.000) are less than 0.05 ($p < \alpha$). Consequently, the effect of MFI values on tensile strengths (MD.TS and CD.TS), the effects of weight values and MFI*Weight interaction values on both tensile strengths (MD.TS and CD.TS) and elongation values (MD.E and CD.E) are statistically significant.

When the Partial Eta Squared values are examined; it is observed that the weight has the highest effect values on both tensile strength and elongation values. It is seen that MFI has almost no effect on elongation values while the effect values of MFI on tensile strength values is at medium levels. It is also seen that MFI*Weight interaction has a very weak effect on both tensile strength and elongation values.

Table 3. Tests of between-subject effects

Source	Dependent Variable	F	p	Partial Eta Squared
MFI	MD.TS	94.703	0.000	0.352
	CD.TS	133.893	0.000	0.435
Weight	MD.E	2.986	0.086	0.017
	CD.E	0.646	0.423	0.004
	MD.TS	2660.831	0.000	0.979
MFI*Weight	CD.TS	1605.944	0.000	0.965
	MD.E	106.113	0.000	0.647
	CD.E	288.576	0.000	0.833
MFI*Weight	MD.TS	10.652	0.000	0.155
	CD.TS	18.174	0.000	0.239
	MD.E	9.354	0.000	0.139
	CD.E	7.598	0.000	0.116

4. CONCLUSIONS

In this study, it was aimed to investigate the effect of the change of MFI and weight values on the tensile strength properties of nonwoven textile surfaces with different weight values produced from polypropylene polymers with different MFI values by spunbond method. It was observed that the MFI value of the PP polymer had a negative effect on the strength properties on both the machine direction and the cross direction of the spunbond fabrics. When the elongation values were analyzed, it was observed that the elongation values decreased at low weights and increased at high weights with the increase of MFI value. It was observed that all strength and elongation values of PP spunbond fabrics increased with the increase in weight values. That is, the weight values of the spunbonded fabrics were found to have a greater effect on the strength properties of spunbonded fabrics. These results were also confirmed by Two-Way Manova statistical analysis. Consequently, the relationship of the strength

properties of the spunbond R^2 values were found to be between weight and strength properties. Fabrics with the fabrics' weight and MFI values of PP polymer was revealed with advanced statistical analysis. Thanks to these mathematical models, it will be possible to estimate the strength of spunbond fabrics very close to reality before production.

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Conflict of interests

Authors declare that there is no a conflict of interest with any person, institute, company, etc.

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ORCID

-  <https://orcid.org/0000-0002-1643-8977> (İ. Tiyek)
-  <https://orcid.org/0000-0001-5857-2077> (E. Kaçmaz)
-  <https://orcid.org/0000-0003-1071-0316> (M. Yazıcı)
-  <https://orcid.org/0000-0002-0550-4668> (M. Kılınçkiran)