(REFEREED RESEARCH)

A STUDY ON THE FRICTION BEHAVIOUR OF SPUNBOND NONWOVENS USED WITH DIFFERENT WEIGHTS

FARKLI GRAMAJLARDA KULLANILAN ISIL BAĞLANMIŞ YÜZEYLERİN SÜRTÜNME DAVRANIŞI ÜZERİNE BİR ÇALIŞMA

Osman BABAARSLAN[1*], Nazan AVCIOĞLU KALEBEK[2]

[1]*Çukurova University, Textile Engineering Department, Adana, Turkey*
[2]*Gaziantep University, Textile Engineering Department, Gaziantep, Turkey*

Received: 21.10.2010 Accepted: 18.07.2011

ABSTRACT

In addition to having the characteristics required according to their areas of use, fabrics must also show sufficient resistance to potential frictions that they are to be exposed to. Friction of a textile material with another textile material, or its friction with a non-textile surface, can cause losses in performance characteristics like fabric resistance; it also affects the appearance of fabric by creating some physical changes. In this paper, an experiment mechanism working based on horizontal principle which was designed and developed that has been used. Nonwoven fabrics produced with spunbond method, which were base on different weights of polypropylene (PP) and polyester (PES) used (filament-laying and thermal bonding). Samples with three different weights were used and an attempt was made to examine the friction characteristics of nonwoven fabrics. At the end of the study, it has been observed that fabric-abrasive wool fabric friction generated negative affecting of surface characteristics and friction coefficient value, and fabric-metal friction environment created less negative effect for friction surface and lowest friction coefficient.

Key Words: Friction force, Friction coefficient, Spunbond, Nonwoven fabrics.

ÖZET

Kumaşların, kullanım yerlerine göre istenen özelliklere sahip olmalarının yanında, kullanım sırasında maruz kalacakları sürtünmelere karşı yeterince dayanıklılık gösterebilmeleri mutlak suretle gereklidir. Tekstil materyalinin başka bir tekstil materyali ile sürtünmesi ve/veya tekstil olmayan bir yüzeye sürtünmesi sonucu kumaş dayanımı gibi performans karakteristiklerinde kayıplara neden olmasının yanı sıra, kumaşta bazı fiziksel değişiklikler yaratarak kumaş görünümünü de etkilemektedir. Bu çalışmada, tasarımı ve imalatı yapılmış olan yatay platform prensibine göre çalışan deney düzeneği kullanılmıştır. Numune olarak, farklı gramajlarda polipropilen (PP) ve poliester (PES) esaslı spunbond yöntemi (filament serme ve ısıl bağlama) ile üretilmiş dokusuz yüzeyler kullanılmıştır. Üç farklı gramajda numuneler kullanılarak dokusuz yüzeylerin sürtünme özellikleri incelenmeye çalışılmıştır. Çalışma sonucunda, en yüksek sürtünme katsayısı değeri ve yüzey özelliklerinin olumsuz etkilenme durumunun kumaş-aşındırıcı yün kumaş sürtünme ortamında, en düşük sürtünme katsayısı değeri ve sürtünme yüzeyin fazla olumsuz etkilenmemesi durumunun ise kumaş-metal sürtünme ortamında gerçekleştiği gözlemlenmiştir.

Anahtar Kelimeler: Sürtünme kuvveti, Sürtünme katsayısı, Isıl bağlama, Dokusuz yüzeyler.

* Corresponding author: Osman Babaarslan, teksob@cu.edu.tr, Tel: + 90 322 338 65 28 Fax: + 90 322 338 61 26

1. INTRODUCTION

As in other textile products, it is an inevitable fact that surfaces of nonwoven fabrics are exposed to several impacts during their production and usage periods; it is also desirable that under these impacts they would preserve their structure and characteristics at maximum level. Regardless of the cause that it serves (clothing, home textile, industrial fabrics etc.) each textile surface is exposed to some straining, tension and friction during production and? Fabrics must have some characteristics required by their places of usage; but they must also show sufficient resistance to the friction that they will be subjected to during usage. Performance of fabrics which are exposed to several external effects will gradually decrease. For this purpose, despite the decrease in performance, it is essential that sufficient friction level should be targeted and obtained during their usage period. Characteristic that affect this friction level can be listed as fabric direction (Machine direction (MD) and Course direction (CD), applied load, fabric weights, speed and different friction levels.

In this area, Das et al. (1) conducted a study on determination of static and kinetic friction coefficient between fabric-fabric and fabric-metal surfaces of polyester/viscose weaving fabric samples at different mixture rates. It was determined that kinetic friction coefficient values of all fabrics used in the study were lower than their static friction values. They found out that fiber type, fiber mixture rate, yarn and fabric type affected fiction on friction surfaces. Das et al. (2) examined the friction behaviour of nonwoven fabric samples produced with cotton plain weaving and hydroentanglement methods which are used for cleaning delicate surfaces like television screen, computer screen and glass materials, or tougher surfaces like table and car. As a result, it was found out that friction coefficient values of glass surfaces were much lower than friction values of wooden surfaces. It was seen that, as the surface structure of nonwoven fabric samples were roughened than woven fabrics, their friction coefficient was higher. Yaman and Şenol (3) used five different types of commercial baby diaper fabrics as sample. They conducted measurements with two different sled materials (steel, leather-coated sled), two types of sled sizes (6-10 cm^2), four different speeds (6, 10, 15, 20 mm/min) and seven different weights (50, 75, 85, 105, 120,140, 175 gr) so as to determine optimum measurement parameters. In this study, higher friction coefficient values with leather-coated sled were measured so as to make it more proper for skin. It was observed that, as applied force increased, so did friction coefficient values. Derler et al. (4) examined friction behaviour of fabrics which emerged as a result of their contact with skin in dry and wet conditions. Applied skin models (Lorica® Soft (0,9 mm), Silicon surface, vinylpolysiloxane-smooth surface, vinylpolysiloxane-dull surface, vinylpolysiloxane-rough surface) were not subjected to any process. In the study, lowest friction coefficient value was represented by silicon and lorica surface, whereas highest values were obtained vinylpolysiloxane-dull and vinylpolysiloxane-rough surfaces. In addition, it was observed that as level of humidity increased, so did friction coefficient values.

As shall be seen above, several studies have been and are being conducted on searching the impact of different fabric surfaces on the objects that they contact and/or can contact.

In this study, friction tests were applied using three different friction surfaces on nonwoven fabric samples produced with different weights of polypropylene and polyester-based spunbond technique. At the end of the study, it has been observed that fabric-abrasive wool fabric friction generated negative affecting of surface characteristics and friction coefficient value, and fabric-metal friction environment created less negative effect for friction surface and lowest friction coefficient.

2. MATERIAL AND METHOD

2.1. Material

In this study, 100% polypropylene (PP) and polyester (PES) nonwoven fabric samples produced with spunbond technique were used as test material. Samples were tested under conditions compatible with Textile-Test Methods For Nonwoven-Part 3: Determination of Tensile Strength and Elongation and Textile-Test Methods For Nonwoven, Part 2: Determination of Fabric Thickness, ISO 9073-2; 1995 standards (5,6), and values given in Table 1 were obtained. These tests were applied so as to determine some of the physical characteristics of nonwoven fabrics used for sampling purposes. In addition, surface views before friction tests of the samples used were taken by digital stereo microscope (Figure 1) and the computer connected to the microscope and examined.

These samples have a wide area of usage including medical packages, aprons, cleaning cloths, make-up cleaning peds, protective clothes, wet towels, home textiles included. Therefore friction behaviour of nonwoven fabrics are as an important factor in most of these usage areas. For this purpose, this study was conducted upon the importance of examining/researching friction behaviours of such samples.

2.2. Method

For the purpose of this study, frictional properties of nonwoven fabrics have been tested by using horizontal working principle devices. These devices are named as “Horizontal Platform Experiment Device” (7,8).

It is developed mechanism which is shown in Figure 2 by designing and extra changes upon conventional universal tensile tester in order to perform friction experiments. The designed and manufactured device consists of anti-friction rollers [3,4], non-stretch yarn [5], a sled [6] and a sled bed [7]. A Non-stretch yarn [5] is passed through rollers [3,4] to upper carrier claw [1] of tensile tester. Fastening the sample to the circular sled [6] made of circular 50 mm in diameter delrin material is ensured by using a clip in proper dimensions. Nonwoven fabric [10] sample which is covered on sled [6] is lay out in the same direction (MD and CD) with horizontal platform. Vertical load is applied by putting different weight on the surface of sled.

Tablo 1. Physical properties of nonwoven fabrics

Weight (g/m^2)	Raw Material	Thickness (mm)	Tensile Strength (N/5 cm)		Elongation (%)	
			MD	CD	MD	CD
12	Polypropylene (PP)	0.10	23.0	11.0	40.0	40.0
	Polyester (PES)	0.07	20.0	10.0	15.0	19.0
17	Polypropylene (PP)	0.11	45.0	40.0	65.0	65.0
	Polyester (PES)	0.09	30.0	14.0	18.0	21.0
100	Polypropylene (PP)	0.49	200.0	163.0	70.0	71.0
	Polyester (PES)	0.75	114.0	150.5	45.3	21.4

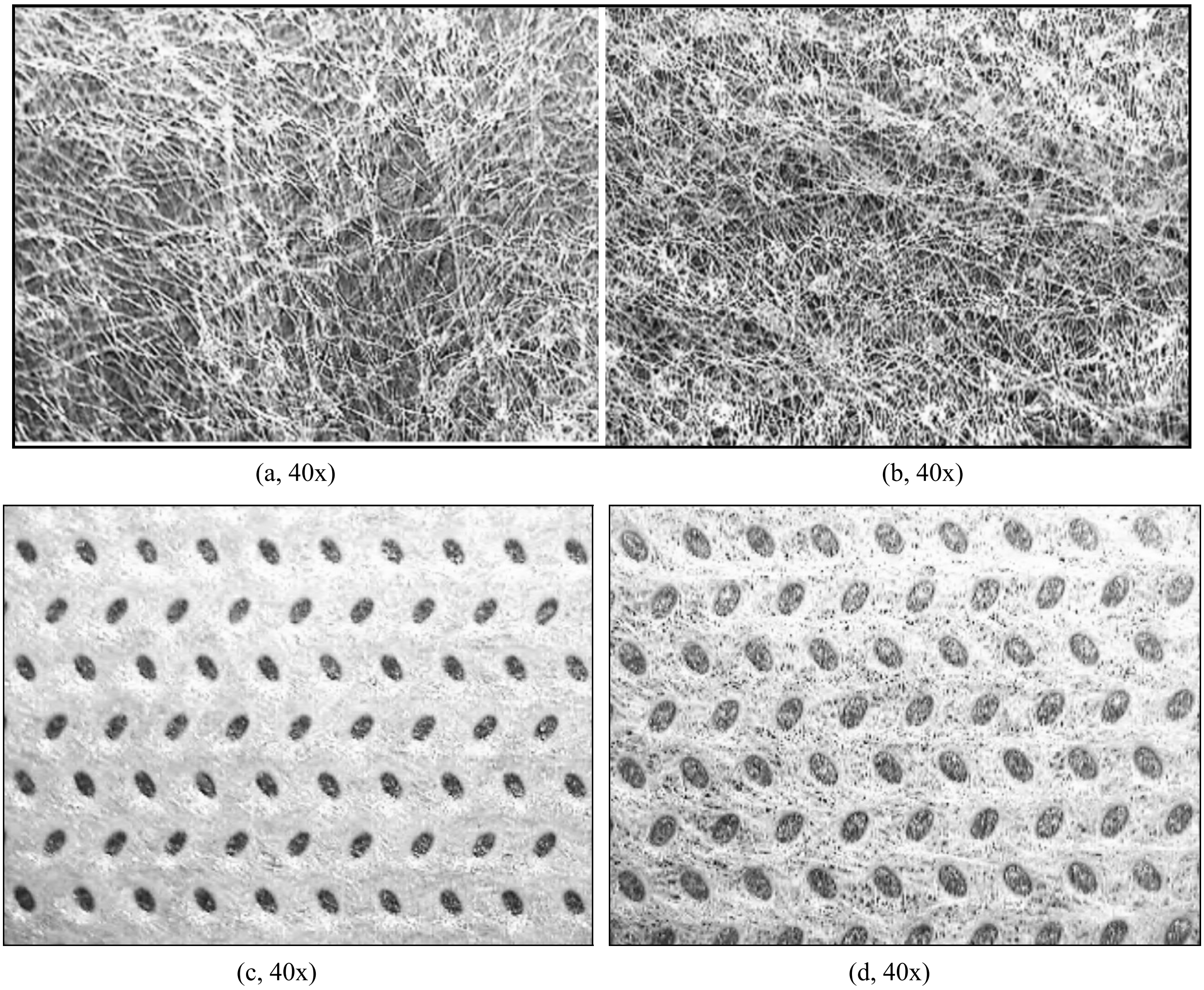

Figure 1. Microscope views of nonwoven fabrics (a) 12 g/m^2 Polypropylene, (b) 12 g/m^2 Polyester, (c) 100 g/m^2 Polypropylene, (d) 100 g/m^2 Polyester

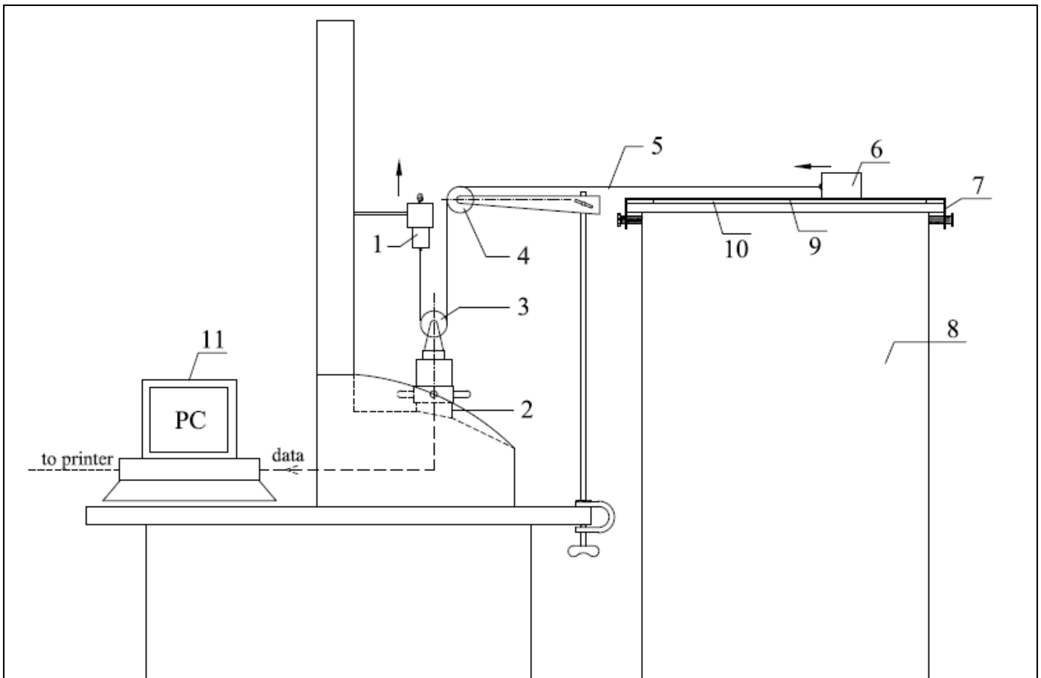

Figure 2. Horizontal Platform Experiment Device (7-9) (1. Upper Carrier Claw, 2. Load Cell, 3,4. Anti-Friction Roller, 5. Non-strectch Yarn, 6. Sled, 7. Sled Bed, 8. Experiment Table, 9. Sponge, 10. Fabric, 11. Computer)

Sled bed [7] is designed with the aim of stretching the experimental fabric [10] on experiment table [8] so as to hold it stable and to prevent slipping, curling, twisting or folding during the experiment. While the upper carrier claw [1] of developed device is moving at a specific speed, it also pulls delrin sled [6] and as a result a friction occurs between two surfaces. At the same time, the load changes stemming from fabric surface structure created during the movement are perceived by load cell [2] and created in graphical and numerical values by the computer [11].

3. TEST RESULTS AND EVALUATION

Friction tests were applied on spunbond nonwoven fabric samples within the study. All tests were conducted at 20±2 °C temperature, 65±5% relative humidity conditions, and after fabrics were conditioned for at least 48 hours.

3.1. Friction tests and obtained results

Friction tests were conducted under five different loads (7.4, 10.2, 14.5, 17.3, 20.2 N) and from three different points of the fabric for machine direction (MD) and cross direction (CD) of samples and under three different friction environment (fabric-abrasive wool fabric, wood and metal). At the end of friction tests, the highest value for the movement at its start was accepted as static friction resistance whereas the average of values read thereafter were accepted as kinetic friction resistance. Attention was paid to ensure that the sample attached to delrin part which was placed on horizontal platform was slightly strained and rubbed to different parts of the fabric. Figures obtained using the test results of friction behaviour of nonwoven fabric obtained in the tests are given in following figures (Figures 3-6).

In figures 3 and 4, the change against applied force (load) of static friction forces obtained as a result of friction tests conducted at machine direction (MD) and cross direction (CD) under 3 different friction platform of 100% PP and PES based nonwoven surfaces of 3 different weights are shown.

When these figures are examined, it can be observed that when the force in normal direction (vertical direction) applied on the sample increased, static friction coefficient values tended to decrease. The result for this effect is interpreted to be the more uniform fabric surface created by fabric friction interaction as load increased, as a result of which friction coefficient tended to decrease.

When the impact of fiber type on friction coefficient is viewed, it can be seen that friction coefficient values of polypropylene (PP) based nonwoven fabrics had much lower values than those of polyester (PES) based samples. This is believed to have been caused by the fact that polypropylene based samples had a tougher surface. As the surface is smoother, less force is required for sliding action so as to move when compared to polyester based nonwoven fabrics, in which case friction coefficient values were measured much lower.

In addition, we can see that fabric weights have a significant impact on friction values. As the fiber orientation of nonwoven fabrics with low weight is not smooth, they showed inconsistent increasing and decreasing behaviours and it has been seen that they had higher friction coefficient. However, it has been found out that as weight increases, friction coefficient values started to decrease as fiber orientation on nonwoven fabric surface was more stabile. When one looks at microscope views in Figure 1a and 1b belonging to fabric samples, it can be seen that fiber orientation distributed irregularly, and that as fabric weight increased (Figure 1c and 1d) surface smoothness deteriorated. This structure of the used samples helps us in understanding the obtained findings.

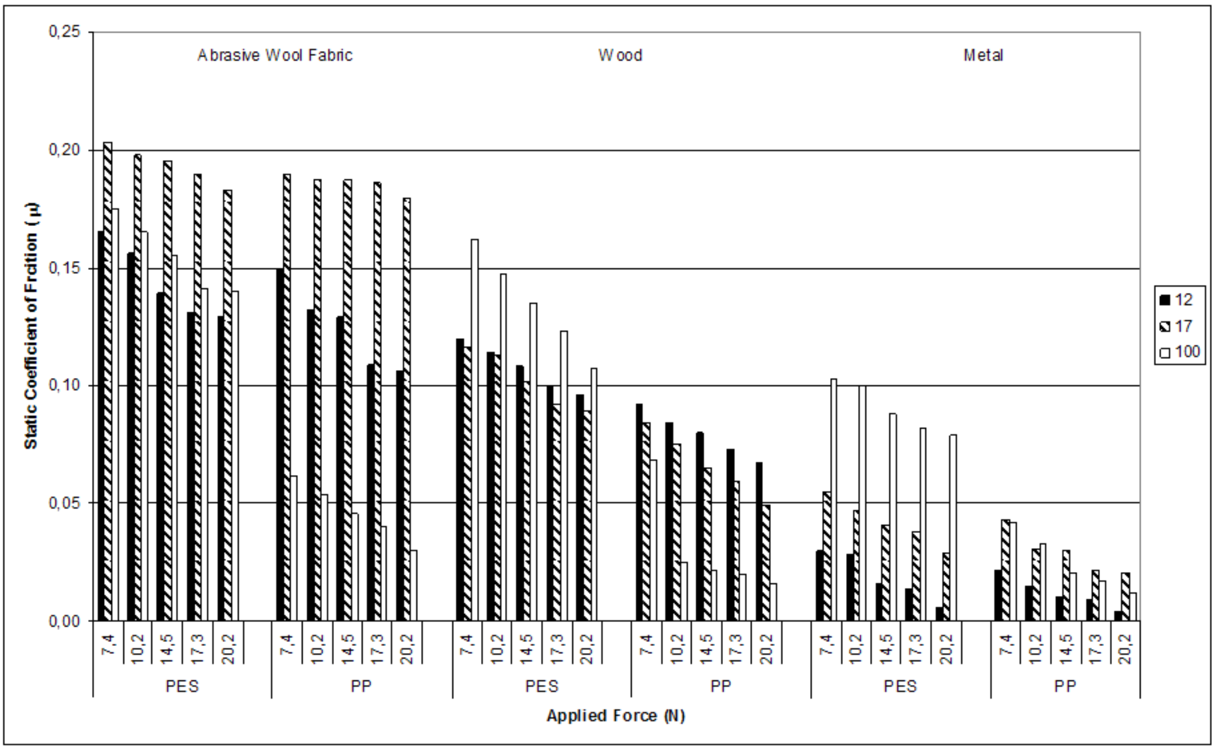

Figure 3. Static Coefficient of Friction (Fabric Direction: MD)

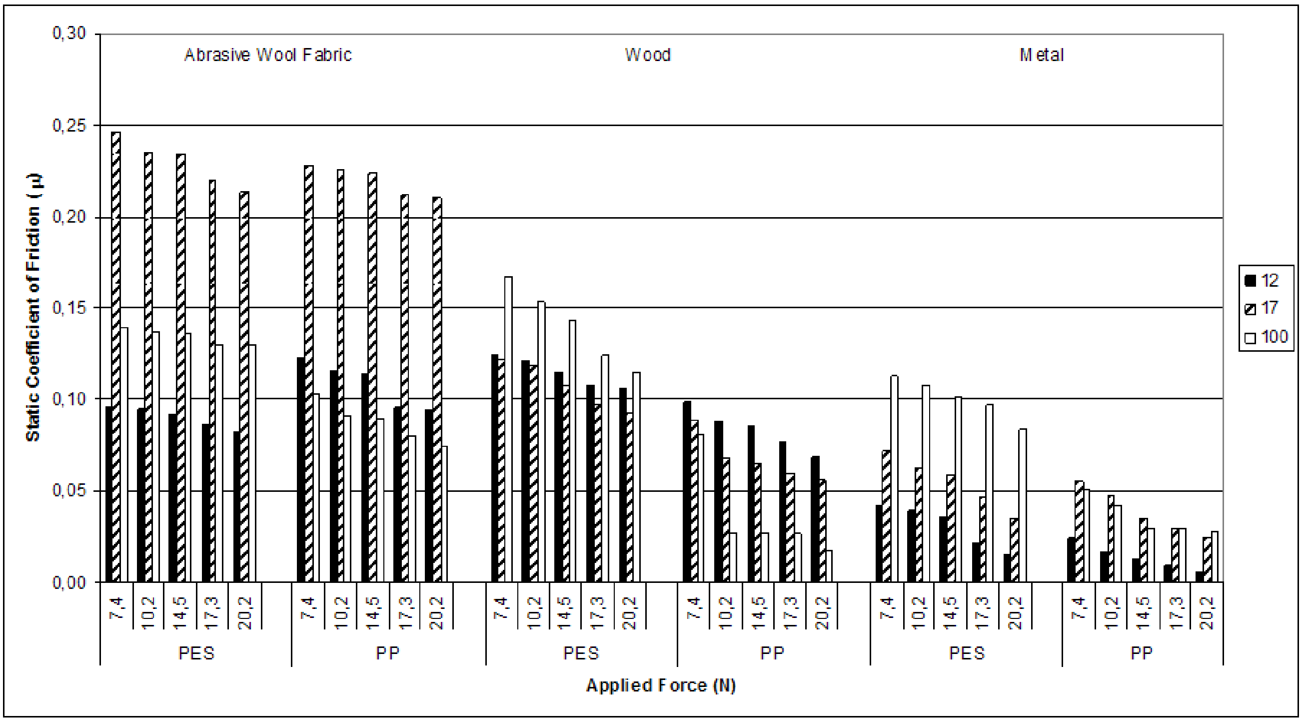

Figure 4. Static Coefficient of Friction (Fabric Direction: CD)

In figures 5 and 6, the change against applied force (load) of kinetic friction forces obtained as a result of friction tests conducted at machine direction (MD) and cross direction (CD) under 3 different friction platforms of 100% PP and PES based nonwoven surfaces of 3 different weights are shown.

When these figures are examined, it can be observed that kinetic friction coefficient values in CD direction of samples at different friction surfaces (abrasive wool fabric, wood and metal) is slightly higher when compared to MD direction. The reason for this result can be the fact that fiber orientation in CD direction is more preventive for friction movement in the formation of samples.

When each load group of same type of sample is examined in itself, it can be observed that as the force in applied normal direction (vertical direction) increases, kinetic friction coefficient values tend to decrease as like static friction. The result for this effect is interpreted to be the more uniform fabric surface created by fabric friction interaction as load increased, as a result of which friction coefficient tended to decrease.

As the impact of different friction environments on friction behaviour are examined, the lowest friction coefficient values were witnessed in fabric-metal friction environment, and the highest friction coefficient values were obtained in abrasive wool fabric friction environment. As metal surface is more smooth and slippery compared to wooden and abrasive wool fabric, it is observed that metal showed smaller resistance to friction, hence lower values for friction of metal in this interaction. In addition, in fabric-abrasive fabric friction environment, as a result of the tests applied in both machine and cross directions, higher kinetic friction coefficient values were measured especially in 17 g/m^2 weight nonwoven fabric sample compared to other samples. This is interpreted to have been caused by irregular distribution of fiber orientation in samples with low weight.

As a result of friction tests realized under fabric wooden friction environment, kinetic friction coefficient values were higher for polyester based samples (especially 100 g/m^2) as weight of surface structure in both machine and cross direction increased and gained a softer structure. As for Polypropylene based samples, on the other hand, as weight increased, surface structure became smoother and therefore friction coefficient tended to decrease.

In fabric-metal friction environment, as weight increased, friction coefficient values for both samples tended to increase as well, which is interpreted to have been caused by the softening of surface.

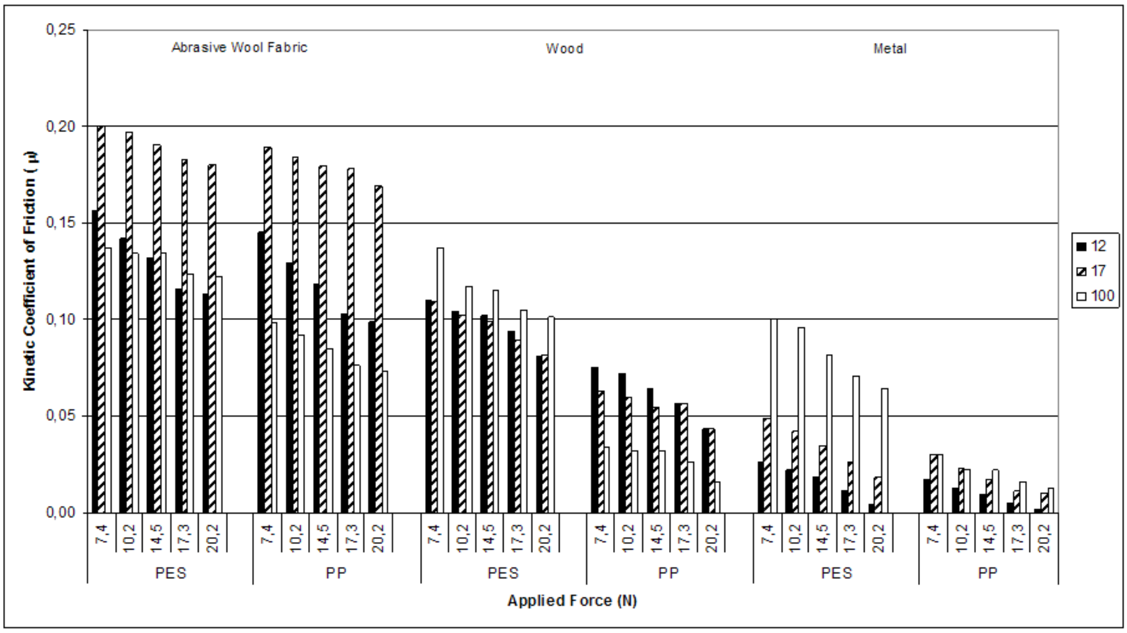

Figure 5. Kinetic Coefficient of Friction (Fabric Direction: MD)

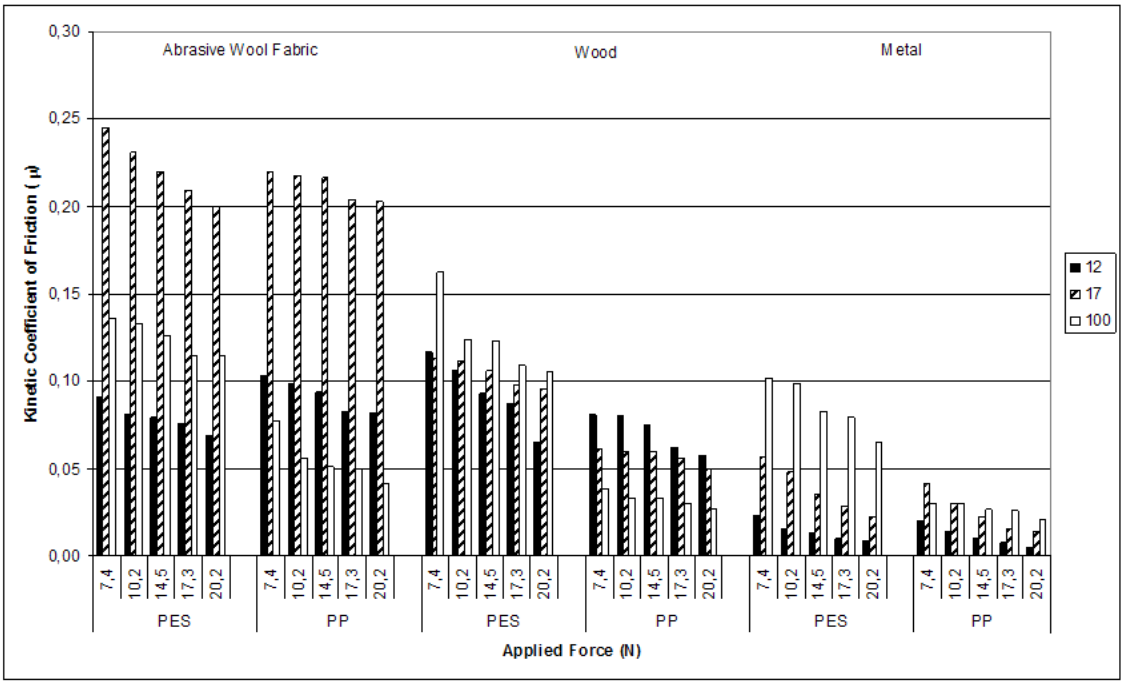

Figure 6. Kinetic Coefficient of Friction (Fabric Direction: CD)

3.2. Statistical Analysis (Significance Level of Results)

Data obtained by conducted experimental works were subjected to variance analysis at α = 0.05 significance using Design Expert 6.01 statistical package program. Obtained ANOVA table is summarized below, where p value below 0.05 means that mentioned assessed factor has significant impact.

While conducting statistical analysis, fiber type, contact surface, fabric direction were accepted as categorical, whereas fabric weight and applied force were accepted as numerical factors.

When ANOVA table is examined, it can be seen that weight, fiber type, applied force and contact surface of nonwoven fabrics have significant impact on friction coefficient values, whereas fabric direction showed no significant impact. In addition, according to the table, the R^2 value of the model turned out to be some 0.86. In this case, terms in the model can explain the model at 86% ratio. This case shows that the model created for friction coefficient can express with rather high accuracy the relation between independent variables and dependent variable and that experimental work results were acceptable as accurate.

Table 2. ANOVA table

Factor	Static		Kinetic	
	F value	Prob>F	F value	Prob>F
Model	91.58	< 0.0001	89.28	< 0.0001
Weight	5.40	0.0213	4.22	0.0415
Fiber Type	138.62	< 0.0001	111.04	< 0.0001
Applied Force	38.32	< 0.0001	31.58	< 0.0001
Contact Surface	318.75	< 0.0001	333.38	< 0.0001
Fabric Direction	3.32	0.0701	7.395E-004	0.9783
$Weight^2$	72.95	< 0.0001	83.57	< 0.0001
Weight x Applied Force	86.79	< 0.0001	57.47	< 0.0001
Weight x Contact Surface	50.17	< 0.0001	48.94	< 0.0001
Fiber Type x Contact Surface	7.83	0.0006	9.40	0.0001
R^2	0.8681		0.8651	
Adjusted R_d^2	0.8586		0.8554	
Predicted R_{pre}^2	0.8485		0.8456	

4. CONCLUSION

Within the scope of this study, friction and surface characteristics of nonwoven fabrics were examined from the point of the fact that quality values gain importance in terms of performance and consumer usage due to the importance in end-user location. As testing material, nonwoven fabrics, whose importance has increased in recent years and usage area became widespread, were used. As testing method, test mechanism created by modification of an existing tensile strength testing device accepted as an objective method was employed. After this modification, friction tests were conducted on nonwoven fabrics by means of determining different friction surfaces.

Experiments conducted during the study, conducted measurements and statistical applications generated the following results:

- Applied force, weight, rubbed surface (abrasive wool fabric, wood and metal), fabric direction (MD, CD), fiber type (PP, PES), are some of the factors that affect friction behaviour of fabrics.
- It can be seen that static friction coefficient obtained as a result of friction experiments is higher than kinetic friction coefficient values.
- It has been observed that, as applied force increases, friction coefficient values decrease. As the pressure applied on fabric sample increased, it causes tightening, flattening and therefore relative smoothening of fabric surface, which in turn decreases friction coefficient.
- At experimental studies conducted in different coefficient environments, it was found out that highest friction coefficient was represented by fabric-abrasive wool fabric, whereas lowest values belonged to fabric-metal surface.
- As the weight of the fabric increased, it can be obtained that polypropylene based nonwoven fabric specimens gained a more stabile structure and were subjected to lower friction force during friction, which in turn produced lower friction coefficient values. As for polyester based specimens, on the other hand, higher friction coefficient values are obtained due to softer and rougher surface structure as weight increases.
- All obtained results have shown that the tendency for kinetic and static friction coefficients is in similar direction.

Acknowledgements

We thank to the owners and workers of **Gaziantep General Nonwoven Textile Industry in Turkey** for their assistance in obtaining the raw material and Çukurova University-BAPKOM for founding of **MMF 2006 D 24** project.

REFERENCES

1. Das, A., Kothari, V.K. ve Vandana, N., 2005, "A Study on Frictional Characteristics of Woven Fabrics", *Autex Research Journal*, Vol.5(3), pp.133-140.
2. Das, A., Kothari, V.K. ve Mane, D., 2005, "Frictional Characteristics of Woven and Nonwoven Wipes", *Fibers and Polymers*, Vol.6(4), pp.318-321.
3. Yaman, N., ve Şenol, M.F., 2007, "Hacimli Materyallerin Sürtünme Testleri İçin Alternatif Ölçüm Metodu Üzerine Bir Araştırma", *Tekstil Teknolojileri Elektronik Dergisi*, 2007(3), pp.1-13.
4. Derler, S., Schrade, U. ve Gerhardt, L.C., 2007, "Tribology of Human Skin and Mechnical Skin Equivalents in Contact with Textiles", *Wear,* 263, pp.1112-1116.
5. ISO 9073-3;1989, *Textile-Test Methods for Nonwoven-Part 3: Determination of Tensile Strength and Elongation*
6. ISO 9073-2;1995, *Textile-Test Methods for Nonwoven-Part 2: Determination of Fabric Thickness*
7. Kalebek, N.A. ve Babaarslan, O., 2009, "Evaluation of Friction and Stiffness Behaviour of Nonwovens Produced with Spunbond and Spunlace Methods", *Tekstil ve Konfeksiyon*, April-June 2009, 19(2), pp.145-150
8. Babaarslan, O. ve Kalebek, N.A., 2008, "Horizontal Platform Experiment Device For Determination of Friction Coefficient on Fibrous Textile Surfaces", *Turkish Patent Institute (TPE),* TR 2008/01016 B.
9. Kalebek, N.A. ve Babaarslan, O., 2009, "Effect of Weight And Apllied Force On The Friction Coefficient of The Spunlace Nonwoven Fabrics", *Fibers and Polymers,* Vol.11(2), pp.277-284.

*Bu araştırma, Bilim Kurulumuz tarafından incelendikten sonra, oylama ile saptanan iki hakemin görüşüne sunulmuştur. Her iki hakem yaptıkları incelemeler sonucunda araştırmanın bilimselliği ve sunumu olarak **"Hakem Onaylı Araştırma"** vasfıyla yayımlanabileceğine karar vermişlerdir.*