(REFEREED RESEARCH)

AN EXPERIMENTAL STUDY ON SEWABILITY PROPERTIES OF 100% COTTON DENIM FABRICS

%100 PAMUKLU DENİM KUMAŞLARIN DİKİLEBİLİRLİK ÖZELLİKLERİ ÜZERİNE DENEYSEL BİR ÇALIŞMA

Gamze GULSEN BAKICI[1], Fusun DOBA KADEM[2]

[1]*Department of Textile, Technical Sciences Vocational School, Cukurova University, Adana, Turkey*
[2]*Department of Textile Engineering, Cukurova University, Adana, Turkey*

Received: 26.05.2017 Accepted: 20.04.2018

ABSTRACT

This paper presents an experimental study of the sewability properties of %100 cotton fabrics. In this study, denim fabrics woven with three different weft densities and three different weft count. Two different finishing processes were applied to all fabric samples. Therefore 18 samples having different specifications were obtained. Sewing needle penetration forces were determined for these fabrics for sewability properties. Also bending rigidity and air permeability tests were determined for these fabrics for investigated the relationship between sewability properties. This study investigated the effects of weft density, weft count, finishing process, bending rigidity and air permeability on the sewability properties of denim fabrics.

Keywords: Sewability, Denim, Cotton, Needle Penetration Force (NPF), Finishing

ÖZET

Bu makalede % 100 pamuklu kumaşların dikilebilirlik özelliklerine ait deneysel bir çalışma sunulmaktadır. Bu çalışmada denim kumaşlar üç farklı atkı sıklığı ve üç farklı atkı iplik numarası ile dokunmuştur. Tüm kumaş numunelerine iki farklı bitim işlemi uygulanmıştır. Bu nedenle farklı özelliklere sahip 18 numune elde edilmiştir. Bu kumaşların dikilebilirlik özellikleri için dikiş iğnesi penetrasyon kuvvetleri belirlenmiştir. Ayrıca, bu kumaşlarda dikilebilirlik özelliği ile arasındaki ilişkiyi incelemek amacıyla eğilme rijitliği ve hava geçirgenliği testleri yapılmıştır. Bu çalışmada, atkı sıklığı, atkı iplik numarası, bitim işlemi, eğilme rijitliği ve hava geçirgenliğinin denim kumaşların dikilebilirlik özelliklerine etkileri araştırılmıştır.

Anahtar Kelimeler: Dikilebilirlik, Denim, İğne Penetrasyon Kuvveti, Bitim işlemi

Corresponding Author: Gamze Gülşen Bakıcı, ggulsen@cu.edu.tr; efsun72@cu.edu.tr

1. INTRODUCTION

In nowadays, product quality is a basic factor for the factories for to protect and improve their competitive power both external and internal markets (1). Fabric quality alone does not fulfill all the criteria for the production of high-quality garments (2). Sewability of a fabric is considered to be one of the most important aspects of clothing science (3).

The penetration force of the sewing needle is a quantitative measure of the damage which appears in the garment as a result of the sewing process. A high penetration force means that the fabric has a high resistance and so there is a high risk of damage (4). The type of material, weave pattern, sewing needle size, shape of needlepoint, and the number of fabric layers have a profound effect on the needle penetration force (NPF). Also, the friction between the fabric and sewing needle has a great effect on the NPF. NPF increases proportionally with needle size. There is no noticeable difference in NPF when the samples are sewn with or without sewing thread (5). L&M Sewability Tester is a sensitive instrument which measures the penetration force under standard conditions and this measurement is then used in a special way to give a numerical indication of sewability (11, 12). It can be used to determine NPF and sewability properties of fabrics. This device measures thrusting force exerted by a sewing needle on the fabric and simulates a sewing machine by penetrating the tested fabric with an unthreaded needle, at a rate of 100 penetrations per min. A strip of fabric passes through a zone in which a sewing needle operates (6, 7). A pre-established threshold value is set into the device depending on the fabric weight before the test. Test device records the number of needle penetration exceeds pre-established threshold level. This number means sewability (%) value of fabric. The sewability becomes poor with increasing fabric weight, needle size, and the number of fabric layers (5). Sewing thread is not used because of the sewability tester construction. The basic principle of the device is to determine the force required for the needle to penetrating into the fabric and how many% of these values exceed the threshold value. An extensive research and development programme has shown excellent correlation between fabric sewability and the proportion of penetrations where the force is above some pre-established threshold level. For instance, if no more than 10% of penetrations exceed the threshold force, the fabric can be expected to sew well in practice. If the

figure is above 20% the fabric will be much more difficult or in some cases impossible to sew (12). There are some studies about sewability and seam performance in the literature (3, 5, 8, 9, 10).

This paper presents an experimental study about effects of finishing processes and fabric construction (weft count and weft density) parameters on needle penetration forces (NPF) of the denim fabrics with different constructions by using L&M Sewability Tester. Also, weight, bending rigidity and air permeability tests were carried out on fabrics, therefore, it is investigated correlations between NPF and those properties.

2. MATERIALS AND METHODS

The denim fabrics were woven with twill 3/1 Z in 9 different constructions using 3 different weft densities (18 weft/cm, 22 weft/cm and 26 weft/cm) and 3 different weft counts (20/1Ne, 16/1 Ne and 12/1 Ne). 2 different finishing processes were applied to the fabrics. Therefore 18 types of fabrics were obtained (Table 1). The warp yarn count is Ne 16/1 and warp density per cm was 28 warp/cm for all fabrics. 100% cotton yarn was used as weft and warp yarns.

Details of finishing operations applied to the fabrics are given in Table 2.

L&M Sewability tests were applied in Technical Sciences Vocational School Textile Laboratory of Çukurova University. The threshold value was determined due to the fabric mass per unit area (3). Generally, it is taken as the half of fabric mass per unit area. Because of fabrics which have vary weights in this study, half of the average weights (g/m^2) of all fabrics was chosen as the threshold level (110 gf) for all tests. Test parameters are given Table 3.

5 weft and 5 warp samples which have 35 mm x 350 mm dimensions were prepared. Since 2 tests can be performed on each sample, 10 test results were obtained in both weft and warp directions. Each test contains 100 needle penetrations. Therefore, averages of 1000 needle penetration values for each sample are given in the results section. Effects of finishing processes and fabric construction (weft count and weft density) parameters on needle penetration forces (NPF) of denim fabrics were examined using statistical package programme. Besides sewability test results which are obtained from the mentioned device are evaluated.

In high-porosity fabrics, the needle penetrates to the fabric more easily and NPF value is lower. Since the porosity of the fabric is a parameter which affects air permeability, correlation is investigated between air permeability and NPF. Air permeability test was carried out according to TS 391 EN ISO 9237:1999 (15).

Table 1. The physical properties of the denim fabrics

	Weft Count (Ne)	Weft Density (weft/cm)	Thickness (mm)	Weight (g/m^2)	Sample Code
Fabrics which is applied finish process 1	20/1	18	0.431	172.32	1-20-18
		22	0.434	180.83	2-20-22
		26	0.484	197.99	3-20-26
	16/1	18	0.471	186.63	4-16-18
		22	0.448	204.18	5-16-22
		26	0.525	219.90	6-16-26
	12/1	18	0.495	211.68	7-12-18
		22	0.495	232.23	8-12-22
		26	0.435	256.45	9-12-26
Fabrics which is applied finish process 2	20/1	18	0.433	177.93	1-20-18
		22	0.433	191.80	2-20-22
		26	0.483	208.20	3-20-26
	16/1	18	0.471	194.26	4-16-18
		22	0.451	212.12	5-16-22
		26	0.524	232.30	6-16-26
	12/1	18	0.496	220.61	7-12-18
		22	0.494	243.44	8-12-22
		26	0.434	271.31	9-12-26

Table 2. Finish processes

Finish Process	Finish Process 1	Finish Process 2
Singeing	Double face tangential singeing (Speed: 100 m / min)	Double face tangential singeing (Speed: 100 m / min speed)
Washing	Washing at 90°C and neutralization (Speed: 25 m / min)	Washing at 90°C and neutralization (Speed: 25 m / min)
Mercerization	-	16°Bome cold caustic
Drying	150°C (Speed: 25 m / min)	150°C (Speed: 25 m / min)
Sanforization	102°C steam temperature (Speed: 25 m / min)	102°C steam temperature (Speed: 25 m / min)

Table 3. L&M Sewability test parameters

Threshold (gf)	110
Needle Penetration Count (times)	100
Needle Count (Nm)	90
Needle Penetration Speed (penetrations/min)	100

Besides, the fabrics which have high bending rigidity will be rigid, the penetration of the needle into the fabric will be difficult. It is thought that there is a relationship between bending rigidity and NPF values. Bending rigidity test was carried out according to TS 1409:1973 with using a stiffness tester. Test specimens were cut 25 by 150 mm (+/- 1). Four samples with the long direction parallel to the warp and four samples with the long direction parallel to the weft were cut. Four observations from each sample were taken. The sample was slid between P-Plane and S-Bolt (Figure 1) (13).

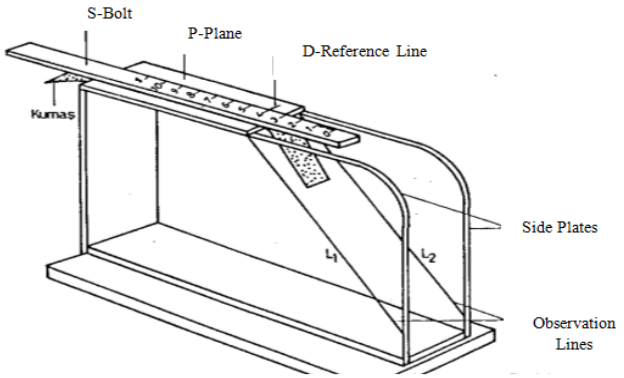

Figure 1. Bending Rigidity Test Device (13)

When it is aligned with observation lines (L1) and (L2), the length of overhang was read on S-Bolt as centimeter. Bending lengths of samples (Ca, Cç) were obtained using Equation (1). Warp and weft flexural (bending) rigidities (Ga, Gç) were calculated using Equation (2) and overall flexural (bending) rigidity was calculated using Equation (3) (13).

$C = X / 2$ Equation (1)

$G = 0{,}1 * W * C^{3}$ Equation (2)

$Go = (Ga * G ç)^{1/2}$ Equation (3)

C = Bending length

X= The length of overhang, cm

G = Flexural rigidity, mg.cm

W = Weight per unit area, g/ m^2

Go = Overall flexural (bending) rigidity

G ç = Warp flexural (bending) rigidity

G a = Weft flexural (bending) rigidity

3. RESULTS AND DISCUSSION

3.1. Needle Penetration Forces Test Results

Averages of needle penetration forces in weft and warp directions are given in Table 4.

Table 4 shows that increasing of the weft density (weft/cm) and decreasing of weft count (Ne) have increased the NPF values. According to the NPF results, it has been seen that the fabrics which are applied finish process 2 have higher NPF values than the fabrics which are applied finish process 1. Mercerization process has been applied to the fabrics which are applied finish process 2. Due to mercerization process, cross sections of the fibers swelled, therefore, the sewability has been worsened.

Effect of Finishing Process on NPF

Firstly, it is found that needle penetration force values have the normal distribution. Independent two samples t-test results, which were made to determine whether there is a statistical difference between classic and flat finish processes, are given in Table 5.

Table 5 shows that under the assumption of equality of variances; because of the calculated significance level for the NPFweft value is p (sig. (2-tailed)) = 0.017 <0.025 and NPFwarp value is p (sig. (2-tailed)) = 0.019 <0.025, there is a difference between finish process 1 and 2 in terms of the average of NPFweft and NPFwarp. It is concluded that there is a significant effect of finishing process on NPF values.

Effect of Fabric Construction (weft count and weft density)Parametres on NPF

The general linear model analysis was performed by taking the variables of NPFweft and NPFwarp as a dependent variable separately and taking the weft count and weft density as explanatory variables. Tests of Between-Subjects Effects which is obtained from the general linear model analysis is given in Table 6.

Table 6 shows that weft count and weft density parameters are effective on needle penetration forces in the weft and warp directions. Homogeneous subsets which are obtained from the general linear model analysis is given in Table 7.

Table 7 shows that Ne 20/1, Ne 16/1 and Ne 12/1 groups and also 18 weft/cm, 22 weft/cm and 26 weft/cm groups are devoted to three subsets by SNK, Tukey HSD and Duncan tests.

Table 4. Needle penetration forces (gf)

Finish Process 1			Finish Process 2		
Sample Code	**NPFweft**	**NPFwarp**	**Sample Code**	**NPFweft**	**NPFwarp**
1-20-18	6.37	8.05	1-20-18	16.87	17.53
2-20-22	10.19	10.84	2-20-22	23.53	27.56
3-20-26	14.99	16.39	3-20-26	32.00	37.27
4-16-18	8.25	9.63	4-16-18	19.33	21.72
5-16-22	14.64	16.28	5-16-22	28.60	33.20
6-16-26	22.70	25.74	6-16-26	48.63	48.67
7-12-18	11.86	14.42	7-12-18	33.18	33.35
8-12-22	20.23	24.94	8-12-22	50.72	51.08
9-12-26	43.87	48.94	9-12-26	76.14	76.22

*NPFweft: Needle Penetration Force Weft
*NPFwarp: Needle Penetration Force Warp

Table 5. Independent two samples t-test

		Levene's Test for Equality of Variances		t-test for Equality of Means						
		F	Sig.	t	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	95% Confidence Interval of the Difference	
									Upper Bound	Lower Bound
NPFweft	Equal variances assumed	2.286	.150	-2.656	16	.017	-19.54444	7.35940	-35.14568	-3.94320
	Equal variances not assumed			-2.656	13.123	.020	-19.54444	7.35940	-35.42832	-3.66057
NPFwarp	Equal variances assumed	.883	.361	-2.598	16	.019	-19.04111	7.32784	-34.57543	-3.50679
	Equal variances not assumed			-2.598	14.381	.021	-19.04111	7.32784	-34.71874	-3.36348

Table 6. Tests of Between-Subjects Effects for Classic and Flat Finished Fabrics

Fabrics which is applied finish process 1	Source	Type III Sum of Squares	df	Mean Square	F	Sig.
NPFwarp	Corrected Model	12844.545(a)	8	1605.568	348.020	.000
	Intercept	34114.555	1	34114.555	7394.602	.000
	Weft Count (Ne)	4914.249	2	2457.124	532.601	.000
	Weft Density	5995.990	2	2997.995	649.839	.000
	Weft Count* Weft Density	1934.307	4	483.577	104.819	.000
NPFweft	Corrected Model	10369.513(a)	8	1296.189	672.979	.000
	Intercept	26040.609	1	26040.609	13520.241	.000
	Weft Count (Ne)	3434.876	2	1717.438	891.691	.000
	Weft Density	5234.659	2	2617.330	1358.913	.000
	Weft Count* Weft Density	1699.978	4	424.995	220.656	.000
Fabrics which is applied finish process 2	Source	Type III Sum of Squares	df	Mean Square	F	Sig.
NPFwarp	Corrected Model	25816.096(a)	8	3227.012	577.688	.000
	Intercept	133470.269	1	133470.269	23893.375	.000
	Weft Count (Ne)	10926.766	2	5463.383	978.035	.000
	Weft Density	13438.767	2	6719.383	1202.880	.000
	Weft Count* Weft Density	1450.563	4	362.641	64.919	.000
NPFweft	Corrected Model	28624.933(a)	8	3578.117	1030.576	.000
	Intercept	120259.736	1	120259.736	34637.438	.000
	Weft Count (Ne)	13659.314	2	6829.657	1967.091	.000
	Weft Density	12959.118	2	6479.559	1866.255	.000
	Weft Count* Weft Density	2006.502	4	501.625	144.479	.000

3.2.Sewability Test Results

Averages of sewability values in weft and warp directions of the fabrics are given in Table 8.

Table 8 shows that sewability values have been deteriorated for the fabrics which is applied finish process 2. The mercerization process was applied to these fabrics. Due to the mercerization process, cross sections of the fibers swelled, therefore, the sewability has been worsened. For instance, if no more than 10% of penetrations exceed the threshold force, the fabric can be expected to sew well in practice. If the figure is above 20% the fabric will be much more difficult-in some cases impossible to sew (12). It is concluded that the fabrics (except 9-12-26 which is applied finish process 2) have good sewability in practice.

3.3.Bending Rigidity and Air Permeability Test Results

Bending rigidity and air permeability test results are given in Table 9.

Table 9 shows that the fabrics which are applied finish process 2 have higher bending rigidity and lower air permeability results than the fabrics which is applied finish process 1. Also increasing of the weft density and decreasing weft count have increased bending rigidity and decreased air permeability.

Correlations Between NPF and Weight, Bending Rigidity and Air Permeability Properties

The correlations between NPFweft, NPFwarp, weight, bending rigidity and air permeability values are given in Table 10.

Table 7. Homogeneous Subsets for Classic and Flat Finished Fabrics.

			N	Subset		
			1	2	3	1
Fabrics which is applied finish process 1	NPFwarp					
	Weft Count (Ne)	20	30	11.7600		
		16	30		17.2140	
		12	30			29.4337
	Weft Density (weft/cm)	18	30	10.6997		
		22	30		17.3537	
		26	30			30.3543
	NPFweft		N	Subset		
			1	2	3	1
	Weft Count (Ne)	20	30	10.5163		
		16	30		15.1950	
		12	30			25.3187
	Weft Density (weft/cm)	18	30	8.8267		
		22	30		15.0173	
		26	30			27.1860
	NPFwarp		N	Subset		
			1	2	3	1
Fabrics which is applied finish process 2	Weft Count (Ne)	20	30	27.4540		
		16	30		34.5277	
		12	30			53.5477
	Weft Density (weft/cm)	18	30	24.1967		
		22	30		37.2800	
		26	30			54.0527
	NPFweft		N	Subset		
			1	2	3	1
	Weft Count (Ne)	20	30	24.1337		
		16	30		32.1840	
		12	30			53.3453
	Weft Density (weft/cm)	18	30	23.1260		
		22	30		34.2827	
		26	30			52.2543

Table 8. Sewability values (%) (Threshold value: 110gf)

Fabrics which is applied finish process 1			Fabrics which is applied finish process 2		
Sample Code	Weft	Warp	Sample Code	Weft	Warp
1-20-18	0	0	1-20-18	0	0
2-20-22	0	0	2-20-22	0.1	0.1
3-20-26	0	0	3-20-26	0	0.1
4-16-18	0	0	4-16-18	0.1	0
5-16-22	0	0	5-16-22	0	0.1
6-16-26	0	0	6-16-26	1.1	0.6
7-12-18	0	0	7-12-18	0.1	0.2
8-12-22	0	0	8-12-22	1.3	1.5
9-12-26	0.6	0.8	9-12-26	10.6	11.3

Table 9. Bending rigidity and air permeability test results

Fabrics which is applied finish process 1			Fabrics which is applied finish process 2		
Sample Code	Bending Rigidity mg.cm	Air Permeability mm/s	Sample Code	Bending Rigidity mg.cm	Air Permeability mm/s
1-20-18	10.630	444.2	1-20-18	35.965	433.6
2-20-22	11.286	343.0	2-20-22	43.424	341.5
3-20-26	15.123	242.0	3-20-26	50.197	229.9
4-16-18	10.592	438.2	4-16-18	38.235	422.0
5-16-22	14.429	286.1	5-16-22	50.879	283.4
6-16-26	19.269	186.4	6-16-26	66.975	164.1
7-12-18	13.328	299.6	7-12-18	53.402	293.1
8-12-22	17.076	145.7	8-12-22	58.458	141.0
9-12-26	24.753	68.4	9-12-26	82.032	54.9

Table 10. Correlations

		NPFwarp	Weight	BendingRigidity	AirPermeability
NPFweft	Pearson Correlation	.995(**)	.867(**)	.860(**)	-.772(**)
	Sig. (2-tailed)	.000	.000	.000	.000
NPFwarp	Pearson Correlation		.882(**)	.847(**)	-.796(**)
	Sig. (2-tailed)		.000	.000	.000
Weight	Pearson Correlation			.564(*)	-.930(**)
	Sig. (2-tailed)			.015	.000
BendingRigidity	Pearson Correlation				-.432
	Sig. (2-tailed)				.074

** Correlation is significant at the 0.01 level (2-tailed).
* Correlation is significant at the 0.05 level (2-tailed).

According to correlation analysis in Table 10; when the pearson correlation coefficient approach to +1 or -1, it means that there is positive or negative strong relationship between data (16). There is a strong positive correlation between NPFweft and fabric weight, NPFweft and bending rigidity, NPFwarp and fabric weight, NPFwarp and bending rigidity. There is a strong negative correlation between NPFweft and air permeability, NPFwarp and air permeability.

4. CONCLUSION

This paper presents an experimental study about effects of finishing processes and fabric construction (weft count and weft density) parameters on needle penetration forces (NPF) of denim fabrics with different constructions by using L&M Sewability Tester. It is concluded that there is a difference between the fabrics which is applied finish process 1 and 2 in terms of the average of NPF in the weft and warp directions. Sewing needle penetration forces are affected by the weft count and weft density. The fabrics which is applied finish process 2 were applied mercerization process. Due to mercerization process, cross sections of the fibers were swell therefore the sewability is worsened. Also, weight, bending rigidity and air permeability tests were carried out on fabrics therefore it is investigated correlations between NPF and those properties. It is concluded that there is a strong positive correlation between NPF values and fabric weight, NPF values and bending rigidity. There is a strong negative correlation between NPF values and air permeability.

ACKNOWLEDGEMENT

This research is supported by Scientific Research Projects Coordination Unit of Çukurova University (FDK-2015-3826 project number). The researchers would like to thank to Islandenim Textile (Adana/Turkey).

REFERENCES

1 Guner, M., Akman, U., and Yucel, O., 2010, “Improving the man shirt production process using the six sigma method”, Tekstil ve Konfeksiyon, Vol: 20(1), pp:75-81.

2 Behera, B. K., Chand, S., Singh, T. G., and Rathee, P., 1997, “Sewability of denim”, International Journal of Clothing Science and Technology, Vol: 9(2), pp:128-140.

3 Pamuk, O., Kurtoglu, O., Tama, D., and Ondogan, Z., 2011, “Sewability properties of lining fabrics”, Journal of Textile & Apparel, Vol: 21(3), pp: 301-304.

4 Gurarda, A., and Meric, B., 2007, “The effects of elastane yarn type and fabric density on sewing needle penetration forces and seam damage of PET / elastane woven fabrics”, Fibres & Textiles in Eastern Europe, Vol: 15(4), pp: 73-76.

5 Haghighat, E., Mohammad Etrati, S., and Shaikhzadeh Najar, S., 2014, “Evaluation of woven denim fabric sewability based on needle penetration force”, Journal of Engineered Fabrics & Fibers (JEFF), Vol: 9(2), pp: 47-60.

6 Manich, A. M., Domingues, J. P., Sauri, R. M., and Barella, A., 1998, “Relationships between fabric sewability and structural, physical, and FAST properties of woven wool and wool-blend fabrics”, Journal of the Textile Institute, Vol: 89(3), pp: 579-590.

7 Saied, F., Abdel-megeid, Z.M., and El Gabry, L.K., 2011, “The relation between fabric construction, treatments and sewability”, Journal of American Science, Vol: 7(3), pp: 818-826.

8 Yildiz, E. Z., Pamuk, O., and Ondogan, Z., 2011, “A study about the effects of interlinings to sewability properties of the woven fabrics”, Journal of Textile & Apparel, Vol: 21(1), pp: 87-90.

9 Gurarda, A., and Meric, B., 2005, “Sewing needle penetration forces and elastane fiber damage during the sewing of cotton/elastane woven fabrics”, Textile research journal, Vol: 75(8), pp: 628-633.

10 Gurarda, A., 2008, “Investigation of the seam performance of PET/nylon-elastane woven fabrics”, Textile Research Journal, Vol: 78(1), pp: 21-27.

11 Munden, D. L., and Leeming, C. A., 1976, “U.S. Patent No. 3,979,951” Washington, DC: U.S. Patent and Trademark Office.

12 L&M sewability tester operating instructions. Retrieved from http://www.johngodrich.co.uk/product/l-m-sewability-tester/

13 Gulsen Bakıcı, G., Doba Kadem, F., “An Experimental Study About Sewability and Bending Strenght Properties of Cotton Fabrics”, Çukurova University Journal of the Faculty of Engineering and Architecture, Vol: 30(2), pp: 177-182.

14 TS 1409:1973-Stiffness determination of woven textiles. Retrieved from https://www.tse.org.tr/en/

15 TS 391 EN ISO 9237:1999-Textiles-Determination of permeability of fabrics to air. Retrieved from https://www.tse.org.tr/en/

16 Ala, D.M., Gulsen Bakıcı, G., Abdulvahitoglu, A., 2017, “Süprem Örme Kumaşlarda Kalınlık, Hava Geçirgenliği ve Boncuklanma Özelliklerinin İncelenmesi”, Çukurova Üniversitesi Mühendislik Mimarlık Fakültesi Dergisi, Vol: 32(3), pp: 103-109.