(REFEREED RESEARCH)

INVESTIGATION OF PERFORMANCE AND STRUCTURAL PROPERTIES OF SINGLE JERSEY FABRICS MADE FROM OPEN-END ROTOR SPUN YARNS

OPEN-END ROTOR İPLİĞİNDEN ÜRETİLMİŞ SÜPREM KUMAŞLARIN YAPISAL VE PERFORMANS ÖZELLİKLERİNİN İNCELENMESİ

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ABSTRACT

In this study, the performance and structural properties of single jersey fabrics are investigated. The yarns, Ne 30/1 and 20/1 which are commonly used in production of these fabrics in Turkey, made of a 100% cotton open-end spun yarns manufactured under the same conditions using the same fibres. The fibre characteristics evaluated by HVI-900, a fibre testing system, are given in the material section of the paper. The performance and structural properties were determined as the fabric weight, the dimensional stability and other structural parameters, spirality, bursting strength, and pilling tendency. It was aimed to perform the test in two ways. Testing the fabrics before any treatments just as knitted and taken them up from the machine. In the second case, they were tested after the sanforization process applied on the same fabrics.

For the purpose of study, six single jersey fabrics have been produced using Ne 30/1 and five fabrics for Ne 20/1 with different fabric weights, that the weight can preliminary adjustable by setting the yarn length of loops in knitted structures on the circular knitting machine used, a Monarch type 22 fine and 32" diameter with positive feed systems. The overall results obtained from these tests have been compared and discussions evaluated are given in the end of the paper.

Key Words: Single jersey fabrics, Fabric weight, Spirality, Bursting strength, Pilling.

ÖZET

Bu çalışmada, süprem kumaşların yapısal ve performans özellikleri incelenmiştir. Çalışmada aynı hammaddeden, %100 pamuk elyafı kullanılarak, Türkiye'de süprem örgü yapımında en çok kullanılan Ne 30/1 ve Ne 20/1 numaralarda üretilmiş olan iplikler kullanılmıştır. Pamuklar HVI-900 test cihazında test edilmiş olup sonuçlar çalışmanın malzeme kısmında verilmiştir. Performans ve yapısal özellikler kumaş gramajı, boyutsal stabilite ve diğer yapısal parametreler, may dönmesi, patlama mukavemeti ve boncuklanma eğilimi olarak ele alınmıştır. Kumaşlara sanfor öncesi ve sanfor sonrası olmak üzere iki aşamada testler uygulanmıştır.

Çalışmanın amacına yönelik olarak Ne 30/1 numaralı ipliklerden altı ve Ne 20/1 numaralı ipliklerden beş farklı makine üstü gramaj değerinde, süprem kumaşlar üretilmiştir. Hedeflenen makine üstü gramajlar örme kumaş yapılarında ilmek iplik uzunluğunu değiştirmek suretiyle üretim öncesi ayarlanabilmektedir. Üretimde Monarch tipi, 22 makine inceliğinde, 32 inç çapında, pozitif beslemeli bir yuvarlak örgü makinesi kullanılmıştır. Çalışmanın sonucunda tüm testler karşılaştırılmış ve sonuçlar yorumlanarak değerlendirilmiştir.

Anahtar Kelimeler: Süprem kumaşlar, Kumaş ağırlığı, May dönmesi, Patlama mukavemeti, Boncuklanma.

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1. INTRODUCTION

Knitting is one of the most frequently used methods in fabric formation. The popularity of knitting has grown tremendously within recent years. This is because of the increased versatility of techniques, the adaptability of the new manmade fibers, and the growth in consumer demand for wrinkle-resistant, stretchable, snug fitting fabrics, particularly in the greatly expanding areas of sportswear and other casual wearing apparel. Knitted fabrics are popular for their shape fitting properties, softer handle, bulkier nature and high extension at low tension.

It was reported (1) that many studies have been worked out on the geometry and dimensional properties of knitted fabrics produced from different kinds of yarns. Although the problem of knitted fabric shrinkage can be solved to some extend by replacing 100 % cotton with a cotton/synthetic fiber blend yarn, the severity and longevity of pilling, in turn, greatly increases, and pilling has become a much more serious problem for the knitted apparel industry. The technical and economic advantages of open-end spinning mean that more staple fibers are being converted into yarns by this method. Many workers (1-5) have investigated the dimensional behavior of knitted structures and the dependence final dimensions on the spinning system, count number, raw material and other related subjects.

Candan and Önal (1) studied on the dimensional, pilling and abrasion properties of a series of plain Jersey, lacoste, and two thread fleece fabrics made from cotton ring and open-end spun yarns as well as from blend yarns. It was shown that both the structural differences and fiber type play a large part in determining the dimensions of these fabrics. It was observed that knits from blend yarns have a lower dimensional stability compared to fabrics from 100 % cotton ring and open-end spun yarns. Findings for the two thread fleece fabrics suggested that the inlay yarns mainly govern their dimensional behavior in the widthwise direction. The dimensional behavior of the lacoste and two thread fleece fabrics after the laundering cycles revealed that further research to determine more appropriate washing regimes for these structures would be beneficial. The pilling rates of the samples indicated that unlike plain jersey fabrics, lacoste fabrics perform very well, and that in general, fabrics knitted from open-end and blend spun yarns have a lower propensity to pill.

Araujo and Smith (2, 3) studied the effect of machine, yarn and fabric properties on the fabric spirality. They determined that spirality depends on machine cut, feed density, machine rotation direction, loop shape; yarn twist value, (twist liveliness) and yarn twist direction. They suggested using S-twist yarn in machines rotating counterclockwise and Z twist yarn in machines rotating clockwise. Plied yarns, plating techniques and yarns with different twist directions can be used to solve or reduce this problem. They also presented an emprical model to predict fabric spirality on the fabric.

Marmaralı (4) researched the dimensional and physical properties of cotton/spandex single Jersey fabrics. The results compared with fabrics knitted from cotton alone examined. The loop length and amount of spandex were used to determine the dimensions and properties of the knits. It was shown that when the amounts of spandex increases, loop length values remain nearly the same and the course and wale spacing values decreases. Furthermore, because spandex-containing fabrics tend to be tighter, the weight and thickness of the fabrics are higher but air permeability, pilling grade and spirality are lower.

Quaynor, Nakajima and Takahashi (5) studied the deformation by laundering for jersey and rib flat knit silk and cotton fabrics with yarns of varying linear densities and fabric tightness. They subjected the fabrics to relaxation processes and an extended series of wash and tumble dry cycles. The experimental data were statistically analysed to work out the effect of yarn types as well as linear density and tightness factor on the linear and area shrinkage behavior of silk as compared to cotton. Multiple washing and tumble-dry cycles resulted in an almost complete relaxation state especially for cotton. With cotton plain knits, shrinkage in laundering decreases with tightness. The area shrinkage of rib knits increases with fabric tightness in the case of cotton. With plain knits, cotton shrinks more than silk. With rib knits, the dimensional stability is good for cotton, while with silk there is a poor shape retention in the form of stretching. In addition, from silk, one laundering cycle after wet relaxation is required to bring the fabric to a fully relaxed state for both plain and rib fabric knitted from the silk.

This paper gives an investigation results on the performance and structural properties of single jersey fabrics. The yarns, Ne 30/1 and 20/1 made of a 100% cotton open-end spun yarns manufactured under the same conditions using the same fibres. The properties were determined as the fabric weight, the dimensional stability and other structural parameters, spirality, bursting strength, and pilling tendency. The tests were performed in two ways. Testing the fabrics before any treatments just as knitted and taken them up from the machine, and then, they were tested after the sanforization process applied on the same fabrics. For the purpose of study, six single jersey fabrics have been produced using Ne 30/1 and five fabrics for Ne 20/1 with different fabric weights, that the weight can preliminary adjustable on the circular knitting machine used by setting the yarn length of loops. The overall results obtained from these tests have been compared and discussed

2. MATERIALS

The fabrics with Ne 30/1 have been produced for six different weights preliminary adjusted on the machine as 90, 100, 110, 120, 130 and 140 (gr/m^2) before knitting, which are the applicable limits depending on the machine, yarn, fabric types and etc. Actually, the weigth adjustment is supplied by adjusting or setting the yarn length of loops on the machine before knitting the fabric. From this point of view, for the above weigth values, the fabric course density values measured after knitting have been found as 12, 14, 16, 18, 20 and 22 (courses/cm) respectively before sanforizing process.

In the same way, the fabrics with Ne 20/1 adjusted for 140, 150, 160, 170 and 180 (gr/m^2) and the corresponding fabric course density values measured after knitting have been found as 14, 16, 18, 20 and 22 (courses/cm) respectively before sanforizing process.

It was used a Monarch type circular machine with a 22 fine and 32" diameter with positive feed systems.

The open-end spun yarns of Ne 30/1 and 20/1 have been produced under the same conditions using the same fibres of 100% cotton. The Ne 30/1 and 20/1 contents the cotton fibres of the fibre length 28.72 mm, fiber uniformity ratio 44.7%, fibre micronaire value 4.60, fibre strength 23.23 g/tex, fibre elongation 10%, cotton brightness value Rd 63.57 and colour yellowness (+b) value 9.07 as the mean values all measured by HVI 900.

The yarn samples were spun in a rotor spinning machine (Rieter R1) which has a 32 mm rotor diameter and OB 20 type of opening roller. The yarn Ne 30/1 was produced at 7500 rpm openning roller speed and 95000 rpm rotor speed, whereas the yarn Ne 20/1 has a 7000 rpm openning roller speed and 90000 rpm rotor speed. For the finisher drawframe, Ne 0.100 sliver count was used with the same fibre properties.

Table 1. Yarn characteristics

	Ne 30/1	Ne 20/1
Hairiness Value	5.70	5.76
Uniformity (%)	12	13.5
CVm (%)	15.13	16.1
Thin Places (-50%),	26	24
Thick places (+50%)	76	80
Neps (+280)	13	19

The yarn variants were laboratory-tested by the use of Uster Tester 3 in order to assess such yarn quality parameters as the linear density, number of twist, unevenness of linear density, hairiness and number of faults. Table 1 gives the results.

3. METHODS

The fabrics, before and after the sanforizing application, were conditioned for 24h preliminary to testing and measurements at the standard relative humidity 65±2% and 20±2^{o}C temperature in accordance with the standard TS EN ISO 139 (6).

The wale and course densities were manually measured from the conditioned test specimens. For this, ten measurements from different parts of the fabrics were recorded, and then the mean density values per cm were taken into account for the study.

Similarly, the mean fabric weight per square-meter was determined in accordance with the standard TS EN ISO 12127 (7).

The dimensional stability in percent measured from both the length and width directions of the samples were determined in accordance with the TS 5720 EN ISO 6330 using a Wascator washing machine tester (8).

The spirality was only carried out on the fabrics after the sanforizing process by the use of Marks&Spencer Methods (9).

The bursting strength (KPa) tested, before and after the sanforizing process application on the conditioned fabric samples, using a James Heal TruBurst bursting strength tester were determined by the standard of TS 393 EN ISO 13938-2 (10).

The pilling properties of the samples, both before and after the sanforizing process, were tested in accordance with the TS EN ISO12945-2 using a Martindale pilling tester starting the cycles from 125 to 7000 rpm. In evaluation of the pilling tendency the scale 1 means very severe pilling, 2 severe pilling, 3 moderate pilling, 4 slight pilling and 5 means no pilling (11).

4. RESULTS AND DISCUSSIONS

Table 2 and 3 give the experimental data obtained according to the standard methods explained above for the single jersey fabrics produced using Ne 30/1 and Ne 20/1 respectively. In the necessary parts of the work, for shortening purpose, we used the BS for expressing 'Berfore Sanforizing Process', and the AS for 'After Sanforizing Process' regarding to the application of the sanforization process on the fabrics. Figures 1 to 5 illustrate the results. In the figures, in general, the horizontal axis is used to show the pre-adjusted weight (g/m^2), and accordingly the course density values (courses/cm) measured after knitting action of the yarns examined. Hence, the weight was systematicaly adjusted for Ne 30/1 between 90 and 140 (g/m^2) by setting the yarn loop length and the corresponding fabric density values measured have been found out varying from 12 to 22 (courses/cm). In the case of Ne 20/1, the weight on machine was ranged between 140 and 180 (g/m^2) by adjusting the yarn loop length, and accordingly the fabric density values measured have been found out from varying 14 to 22 (courses/cm). In evaluations of the results the investigated parameters have generally been connected to and explained on the base of setting values of the circular knitting machine and yarns used for this study. It is known that there is an inverse relationship between the yarn loop length fed from the machine and the fabric course density after knitting. In another way, the shorter the yarn loop length fed from the machine it is the higher the fabric course density after knitting. Here, all the comments refeering to the pre-adjusted weight (g/m^2) on machine may also be related to the measured fabric course density values (courses/cm) as well as the yarn loop length.

Table 2. Experimental data for the fabrics of Ne 30/1

Adjustment on the machine	Fabric course density after knitting	The course density (courses/cm)	The wale density (wales/cm)		Dimensional stability after the sanforizing process (%)		Measured weight (g/m^2)		Mean bursting strength (kPa)		Spirality after the sanforizing process (^{0})
(g/m^2)	(courses/cm)	AS	BS	AS	W	L	BS	AS	BS	AS	AS
90	12	16	11	13	-9,5	-12,1	102,1	128,2	396,3	382,5	11,7
100	14	17	11	13	-11,3	-11,8	106,9	129,1	398,7	392,5	10,4
110	16	17	11	12	-12,8	-10,9	112,3	136,1	429,6	400,3	8,9
120	18	17	11	14	-13,2	-10,5	125,4	143,4	444,4	456,8	7,9
130	20	21	12	13	-13,4	-6,7	136,8	157,5	445,8	449,3	7,1
140	22	23	12	16	-14,5	-5,5	147,6	171,4	489,5	509,2	4,8

BS: Before Sanforizing Process AS: After Sanforizing Process W: Widtwise Direction L: Lengthwise Direction

Table 3. Experimental data for the fabrics of Ne 20/1

Adjustment on the machine	Fabric course density after knitting	The course density (courses/cm)	The wale density (wales/cm)		Dimensional stability after the sanforizing process (%)		Measured weight (g/m^2)		Mean bursting strength (kPa)		Spirality after the sanforizing process (^{0})
(g/m^2)	(courses/ cm)	AS	BS	AS	W	L	BS	AS	BS	AS	AS
140	14	16	9	11	-9,1	-3,5	152	181,5	572,3	555,8	8,3
150	16	17	10	11	-11,1	-2	160,5	191,7	584,6	562,3	5,9
160	18	18	10	12	-13,6	-2,6	168,4	199,8	591,6	633,1	4,9
170	20	20	10	12	-16,9	-2	184,4	214,5	642,2	687,9	4,6
180	22	22	10	13	-19,8	-2,2	194,1	227	683	690	4,1

BS: Before Sanforizing Process AS: After Sanforizing Process W: Widtwise Direction L: Lengthwise Direction

4.1. Fabric weight, dimensional stability and other structural parameters

Figure 1 shows the measured weights, before and after the sanforizing process application, corresponding to the adjusted weight on the machine for the fabrics of Ne 30/1 and Ne 20/1 together with the linear equations approximated for the data obtained. In the equations, x is the pre-adjusted weight on machine for fabric production and y is the measured fabric weigth both in g/m^2.

It can be seen from the Figure 1 that there is a lineer relationship between the adjusted and measured weight values as expected. In the experimental work, the preadjusted weight on machine was systematically changed, and the fabric weight values before and after the sanforizing process, were measured. Because the calculation results from the regression equations are well fitted, these equations may be used to predict the weight before and/or after an application of sanforization process for the single jersey fabrics to be produced using a rotor spun yarn of Ne 30/1 and Ne 20/1.

The following expression has been constructed in order give a better understanding of the variation of the weight in the fabric before or after the application of the sanforizing process.

$$Vw = \frac{W_M - W_A}{W_A} \times 100 \quad (\%) \qquad (1)$$

Where;

Vw: Variation in the weight before or after the sanforizing process (%)

Wm: Measured value of the fabric weight before or after the sanforizing process (g/m^2)

W_A: Preadjusted value of the fabric weight on the machine (g/m^2)

The data in the Table 2 and 3 have been used to calculate the variations in the fabric weight using the expression (1). Hence, Figure 2 illustrates the results.

It is seen from Figure 2 that there is a deep point in the variation of the weight that the variation behaves differently i.e. This point for the fabric of Ne 30/1 before the sanforizing process, it is 110g/m^2 as the pre-adjusted weight or the corresponding fabric density value measured is 16 courses/cm, whereas, it is 120 g/m^2 or correspondingly 18 courses/cm after the sanforizing process. Similar observation can be seen for the fabrics of Ne 20/1 that they are 160 g/m^2 (18 courses/cm) both before and after the sanforizing process. Hence, it may be concluded that the variation in the weight is higher up to this point, then it settles on a certain level regarding to the pre-adjusted weight or the corresponding fabric course density value measured after knitting. This may be related to the structural properties of the knitted fabric in general or it is more special to single jersey fabrics.

The course change of fabrics produced from Ne 30/1 yarns, before sanforizing process measured between 12-22 courses/cm, after sanforizing process 16-23 courses/cm. The wale before sanforizing process 11-12 wales/cm, after sanforizing process 11-12 wales/cm. Whereas, the course change for the fabrics of Ne 20/1 yarns, before sanforizing process 14-22 courses/cm, after sanforizing process 16-22 courses/cm, the wale before sanforizing process 9-10 wales/cm, after sanforizing process 11-13 wales/cm as given in Table 2 and 3.

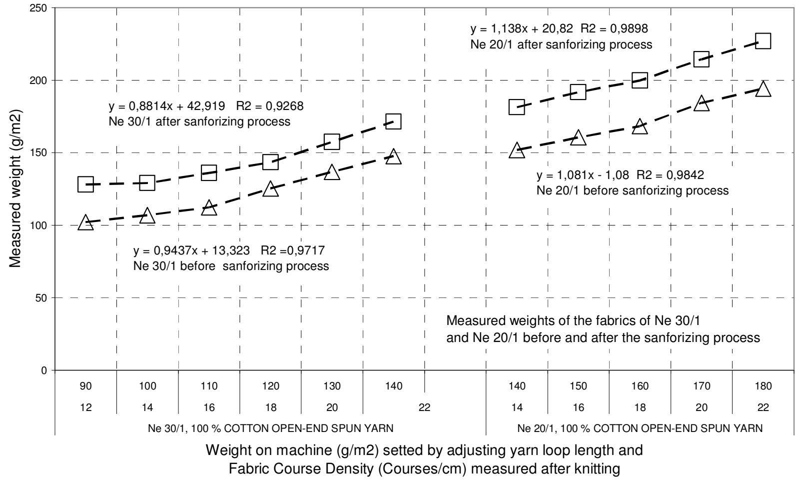

Figure 1. Measured weights for the fabrics of Ne 30/1 and Ne 20/1

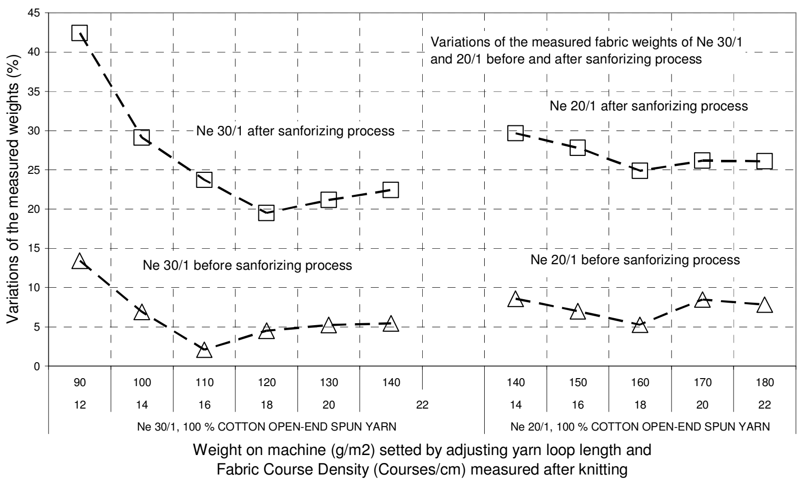

Figure 2. Variations of the measured weights of Ne 30/1and Ne 20/1

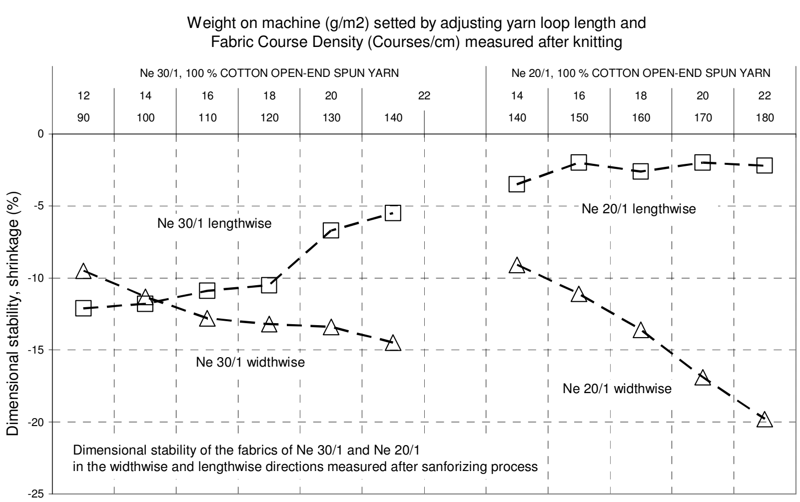

Figure 3. Dimensional stability for the fabrics of Ne 30/1 and Ne 20/1

Figure 3 shows the dimensional stability, meaning the shrinkage properties in per cent, for the fabrics measured both from the widthwise and lengthwise directions after washing process using a Wascator washing machine in accordance with the standard of TS 5720 EN ISO 6330 (8). It is clearly seen that the fabrics of Ne 30/1 shrink more on the widthwise direction by the increase of the weight determined by the setting yarn loop length, while they shrink less on the lengthwise direction. It is observed that there is an inverse relationship between the shrinkage of the length and width. On the other hand, again the fabrics of Ne 20/1 shrink more on the width for the increased fabric weight, while the shrinkage of the length is less changeable.

4.2. Spirality variation

Figure 4 shows the spirality for the fabrics of Ne 30/1 and Ne 20/1 measured only after the sanforization process using the Marks&Spencer Methods (9). Regression equations fitted for the data are also given with the figure. In the equations, x is the fabric pre-adjusted weight (g/m^2) and y is the spirality (degree). In general, the spirality decreases with the increase of the weight adjusted on machine. It is observed from the equations, the spirality functions well linearly for the fabrics of Ne 30/1 within the setting limits of the machine. However, the curve has been well-suited by a second-order polynomial regression for the fabrics of Ne 20/1. From this point of view, it is clearly seen that the fabric course density and yarn count play an important role for spirality behaviour of single jersey fabrics. However, the above comments of this study are only given to explain the connections between spirality and machine settings before and after knitting action. On the other hand, because the spirality has been measured after the sanforizing process, it has to be related to not only the yarn loop length and its shape mainly but also many of the other

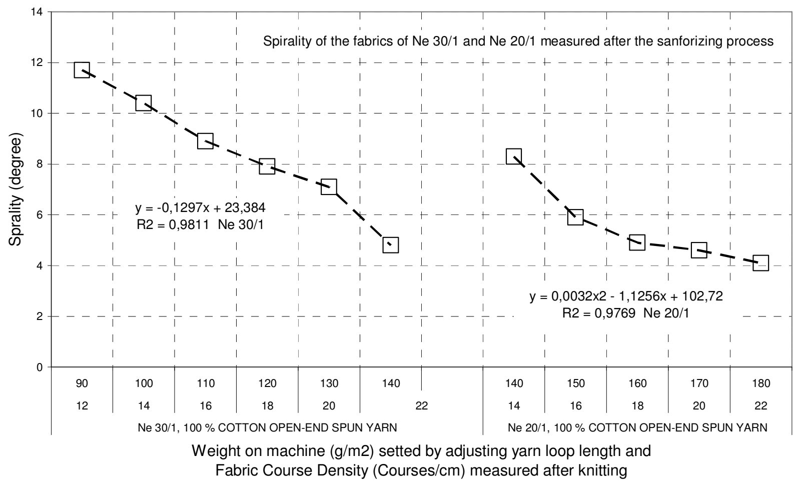

Figure 4. Spirality of the fabrics of Ne 30/1 and Ne 20/1

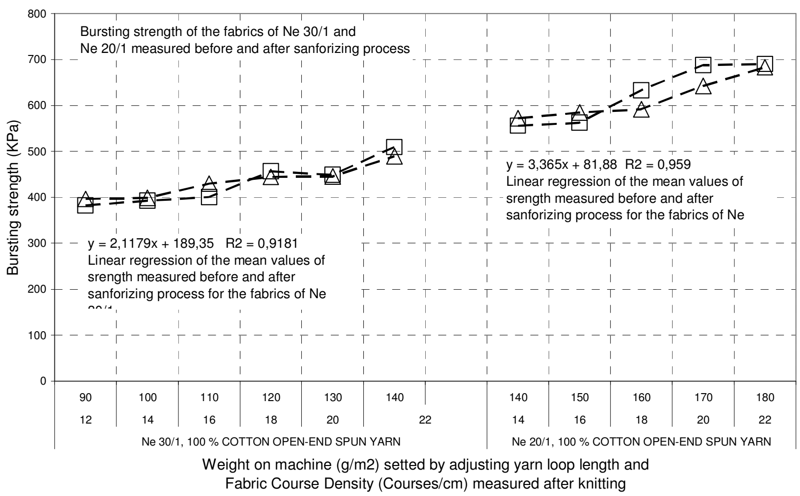

Figure 5. Bursting strength of the fabrics of Ne 30/1and Ne 20/1

factors such as the dimensional changes after sanforizing process, yarn characteristics, fabric patterns and types etc. In the future examinatios of our study, these factors will systematicaly be considered.

4.3. Bursting strength variation

Figure 5 shows the bursting strength for the fabrics of Ne 30/1 and Ne 20/1 tested, before and after the sanforizing process application on the conditioned fabric samples, using a James Heal TruBurst bursting strength tester and determined by the standard of TS 393 EN ISO 13938-2 (10). Linear regression equations are also given with the figure 5.

It is seen from the Figure 5 that the sanforization process has no significant effect on the strength. Therefore, the equations were fitted for mean values calculated by taking the average of the strength values obtained for the fabrics before and after the sanforizing process. In the equations, x is the fabric pre-adjusted weight (g/m^2) and y is the bursting strength (KPa). It is observed from the equations, the bursting strength functions well linearly both for the fabrics of Ne 30/1 and Ne 20/1 within the setting limits of the machine. Figure 5 illustrates that the increase of the weight or fabric course density inreases the fabric bursting strength. In this study, the yarns examined have been produced under the same conditions by the use of the same fibers. Though the yarn's strength testing results have not been given here in this paper, they had been tested and found out the the Ne 20/1 was stronger yarn than the Ne 30/1 in comparison. Hence, as shown from the Figure 5 that the yarn counts and their strengths are also important parameters determining the fabric strength. However, the data based on our experimental investigations for the subject would not be sufficient in order to give stronger evaluations and comments. Hence, all the other factors such as yarn, fabric and processing parameters in general will be considered in future examinations.

4.4. Pilling variation

The pilling properties of the samples, both before and after the sanforizing process, were tested in accordance with the TS EN ISO12945-2 using a Martindale pilling tester starting the cycles from 125 to 7000 rpm. In evaluation of the pilling tendency the scale 1 means very severe pilling, 2 severe pilling, 3 moderate pilling, 4 slight pilling and 5 means no pilling (11). Table 4 and 5 show the pilling properties for the fabrics of Ne 30/1 and Ne 20/1 before and after the sanforizing process. It is observed that the sonforization process has no significant effect on the pilling properties. There is no clear effect of the fabric weight on pilling; more or less the same pilling tendency is seen from the lower to the higher in fabric weights as given in the tables. On the other hand, the pilling cycles are of great important for the pilling tendency. The higher the pilling cycles it is the severe or very severe pilling for the fabrics. In general, the pilling properties are affected by not only the sanforizing process, fabric weight or density, and pilling cycles but also the fiber, yarn and fabric types and their structural parameters such as the fiber materials, yarn hairines, uniformity, and fabric pattern etc. are important factors de-

Table 4. Pilling properties of the fabrics of Ne 30/1

Adjustment on the machine	Fabric course density after knitting	125 cycles		500 cycles		1000 cycles		2000 cycles		5000 cycles		7000 cycles	
(g/m^2)	(courses/cm)	BS	AS	BS	AS	BS	AS	BS	AS	BS	AS	BS	AS
90	12	3-4	3	3	2-3	2	1-2	1-2	1-2	1-2	1	1-2	1
100	14	3-4	3-4	3	3	2	2-3	1-2	2	1-2	1-2	1-2	1-2
110	16	4	3-4	3-4	3	2-3	2-3	2	2	1-2	1-2	1-2	1-2
120	18	4	4	3-4	3-4	2-3	2-3	2	1-2	1-2	1-2	1-2	1-2
130	20	4	4-5	3	3-4	2-3	2-3	2	1-2	2	1-2	1-2	1-2
140	22	4-5	4-5	3-4	3-4	3	2-3	2-3	1-2	2	1-2	1-2	1-2

BS: Before Sanforizing Process AS: After Sanforizing Process

Table 5. Pilling properties of the fabrics of Ne 20/1

Adjustment on the machine	Fabric course density after knitting	125 cycles		500 cycles		1000 cycles		2000 cycles		5000 cycles		7000 cycles	
(g/m^2)	(courses/cm)	BS	AS	BS	AS	BS	AS	BS	AS	BS	AS	BS	AS
140	14	4-5	3-4	3-4	2-3	3	1-2	2	1-2	1-2	1-2	1-2	1
150	16	4-5	3-4	3-4	3	3	2-3	2	1-2	1-2	1-2	1-2	1-2
160	18	4	3-4	3-4	3	3	2-3	2-3	1-2	1-2	1-2	1-2	1
170	20	4	4-5	3-4	4	3	3-4	2-3	3	1-2	2-3	1-2	2
180	22	4	4-5	3-4	4	3	3-4	2-3	3	1-2	2-3	1-2	2

BS: Before Sanforizing Process AS: After Sanforizing Process

Table 6. Statistical significance analysis of the data for the fabrics of Ne30/1 and Ne 20/1

	Fabric pre-adjusted weight (FW)			Yarn count (YC)			FW x YC	Lack of fit
	F-V	P-V	C %	F-V	P-V	C %	C %	C %
FW $_{BS}$ (g/m2)	285.31	0.0001	98.94	2.69	0.1394	0.27	0.12	0.67
FW$_{AS}$ (g/m2)	128.57	0.0001	97.04	9.71	0.0143	1.62	0.34	0.99
CD $_{BS}$ (courses/cm)	6.37	0.0001	48.53	6.37	0.0001	51.47	-	-
CD$_{AS}$ (courses/cm)	41.65	0.0003	30.41	26.64	0.0013	55.56	0.25	13.78
WD $_{BS}$ (wales/cm)	9.99	0.0159	23.24	43.44	0.0003	67.11	0.061	9.58
WD$_{AS}$ (wales/cm)	9.35	0.0157	3.25	19.54	0.0022	68.64	-	28.10
SHR $_{W}$ (%)	198.58	0.0001	32.64	147.12	0.0001	34.79	29.53	3.04
SHR $_{L}$ (%)	68.39	0.0001	63.51	24.38	0.0017	19.76	8.93	7.80
SPR (degree)	100.81	0.0001	87.29	11.27	0.0121	8.11	1.06	3.54
BRST$_{BS}$ (KPa)	194.35>47.8	0.0001	91.69	24.96	0.0011	6.29	0.65	1.37
BRST$_{AS}$ (KPa)	66.22	0.0001	94.43	4.48	0.0720	2.41	1.06	2.09

termining pilling behaviour to be considered.

Yarns used in this experimental work have been produced under the same conditions using the same fibers. Except the yarn counts, the other quality parameters are almost identical as given in the material section. Hence, the effect of yarn parameters has not been examined in this paper, because it is thought that the solid statements would only be given by studying these parameters by systematical way on the subject.

5. STATISTICAL SIGNIFICANCE ANALYSIS

The experimental results have been statistically evaluated by using the Design Expert Analysis of Variance (ANOVA) software with F values of the significance level of α=0.05, with the intention of exploring whether there is any statistically significant difference between the variations obtained. We evaluated the results based on the F-ratio and the probability of the F-ratio (prob>F). The lower the probability of the F-ratio, it is the stronger the contribution of the variation and the more significant the variable.

Table 6 summerizes the statistical significance analysis for all the data obtained in the study except the pilling data which have been evaluated separetly. In the table, variables are the FW - pre-adjusted fabric weights on machine (g/m^2), YC - yarn count (Ne 30/1 and Ne 20/1), FW x YC - the interactions of these two parameters. Moreover, F-V is the F-Value, P-V is the P-Value and C % is the Contribution in per cent. BS means the Before Sanforizing Process, and AS is the After Sanforizing Process.

Abbreviations in Table 6: FW $_{BS}$ (g/m^2) - Fabric Weight Before Sanforizing Process, FW$_{AS}$ (g/m^2) - Fabric Weight After Sanforizing Process, CD $_{BS}$ (courses/cm) – Course Density Before Sanforizing Process, CD$_{AS}$ (courses/cm) – Course Density After Sanforizing Process, WD $_{BS}$

(wales/cm) – Wale Density Before Sanforizing Process, WD_{AS} (wales/cm) – Wale Density After Sanforizing Process, SHR_W (%) – Shrinkage in the Width, SHR_L (%) – Shrinkage in the Length, SPR (degree) – Spirality, $BRST_{BS}$ (KPa) – Bursting Strength Before Sanforizing Process, $BRST_{AS}$ (KPa) – Bursting Strength After Sanforizing Process.

The weight was systematicaly adjusted for Ne 30/1 between 90 and 140 (g/m^2) by setting the yarn loop length and the corresponding fabric density values measured have been found out varying from 12 to 22 (courses/cm). In the case of Ne 20/1, the weight on machine was ranged between 140 and 180 (g/m^2) by adjusting the yarn loop length, and accordingly the fabric density values measured have been found out from varying 14 to 22 (courses/cm). In evaluations of the results the investigated parameters have generally been connected to and explained on the base of setting values of the circular knitting machine and yarns used for this study. It is known that there is an inverse relationship between the yarn loop length fed from the machine and the fabric course density after knitting. In another way, the shorter the yarn loop length fed from the machine it is the higher the fabric course density after knitting. Here, all the comments refeering to the pre-adjusted weight (g/m^2) on machine may also be related to the measured fabric course density values (courses/cm) as well as the yarn loop length as explained in many parts of the paper.

The statistical analysis indicate that the fabric pre-adjusted weight have significant influence with % 97-98 contribution on the fabric weight values measured before and/or after the sanforizing process.

The contributions of fabric pre-adjusted weight and yarn count on the course density are in balance before the sanforizing process with the influence of both at around 50 %. However, after the sanforizing process, the yarn count is comparingly a major factor with the approximated contribution of 55 %, while the fabric pre-adjusted weight approximately contributes with 30 %. On the other hand, the yarn count is a major parameter on wale density with 67 % contribution, whereas the fabric pre-adjusted weight 23 % affecting the results before sanforizing process. After the sanforizing process, approximately the contribution of the pre-adjusted weight is 3 % as a minor factor and that of 68 % for the yarn count which becomes a major parameter.

The contributions of fabric pre-adjusted weight, yarn count and interaction of these two parameters for the shrinkage on the width are almost equally affecting with the contribution of each at around 30 %. However, the fabric pre-adjusted weight is comparingly a major factor with the approximated contribution of 63 %, while the yarn count approximately contributes with 19 % and the interaction is approximately 8 % as the minor factors on shrinkage of the length. These results of the analysis should be considered within the limited concept and data of our experimental examinations.

The fabric weight as major factor has a great influence on the spirality with the approximated contribution of 87 %. The yarn count becomes a minor factor with a contribution of around 8 %. However, as explained in results and discussions part of the paper, the comments are only given within the concept of this study to explain the connections between spirality and machine settings before knitting action. On the other hand, because the spirality has been measured after the sanforizing process, it has to be related to not only the yarn loop length and its shape mainly but also many of the other factors such as the dimensional changes after sanforizing process, yarn characteristics, fabric patterns and types etc. In the future examinatios of our study, these factors will systematicaly be considered.

The fabric weight with the contributions of over 90 % has been found as the major factor both before and after the sanforizing process for the bursting strength. On the other hand, the yarn count has been the minor factor with the contribution of less than 7 %. These results of the analysis should also be considered within the limited concept and data of our experimental examinations.

Table 7 gives the statistical significance analysis for the pilling data. The revolution cycles have been found as the major factor on pilling tendency approximately with the contributions of 69 % before the sanforizing process and 53 % after the sanforizing process. On the other hand, the fabric weight and yarn count have no significant influence on pilling properties. Hence, in this study, they are considered as the minor factors. However, this may not be absolutely proved because the interactions of these three parameters have not been given by the ANAVO testing and the lack of fit values seems to be important with the contribution of 27 % before the sanforizing process and 34 % after the sanforizing process approximately.

Table 7. Statistical significance analysis of the pilling data for the fabrics examied

	Fabric Weight			Yarn Count			Revolution Cycle			I	L
	F-V	P-V	C %	F-V	P-V	C %	F-V	P-V	C %	C %	C %
P_{BS}	3.71	0.0587	1.65	0.34	0.559	0.16	155.39	0.0001	69.4	-	27.8
P_{AS}	20.13	0.0001	11.05	7.09	0.0099	3.90	96.83	0.0001	53.20	-	34.07

I: Interaction = Fabric Weight x Yarn Count x Revolution Cycle   L: Lack of Fit

P_{BS}: Pilling Before Sanforizing Process P_{AS} : Pilling After Sanforizing Process

6. CONCLUSION

The followings give the outlines based on the experimental concept and data of this study as explained in detail in the main body of the paper.

There is a lineer relationship between the adjusted weight on machine and measured fabric weight values. But, there is a deep point in the variation of the weight that the variation behaves differently i.e. This point for the fabric of Ne 30/1 before the sanforizing process, it is 110g/m^2 as the pre-adjusted weight or the corresponding fabric density value measured is 16 courses/cm, whereas, it is 120 g/m^2 or correspondingly 18 courses/cm after the sanforizing process. Similar observation can be seen for the fabrics of Ne 20/1 that they are 160 g/m^2 (18 courses/cm) both before and after the sanforizing process. Hence, it may be concluded that the variation in the weight is higher up to this point, then it settles on a certain level regarding to the pre-adjusted weight or the corresponding fabric course density value measured after knitting. This may be related to the structural properties of the knitted fabric in general or it is more special to single jersey fabrics.

The fabrics of Ne 30/1 shrink more on the widthwise direction by the increase of the weight determined by the setting yarn loop length, while they shrink less on the lengthwise direction. It is observed that there is an inverse relationship between the shrinkage of the length and width. On the other hand, again the fabrics of Ne 20/1 shrink more on the width for the increased fabric weight, while the shrinkage of the length is less changeable.

In general, the spirality decreases with the increase of the weight adjusted on machine. It is observed from the equations, the spirality functions well linearly for the fabrics of Ne 30/1 within the setting limits of the machine. However, the curve has been well-suited by a second-order polynomial regression for the fabrics of Ne 20/1. From this point of view, it is clearly seen that the fabric course density and yarn count play an important role for spirality behaviour of single jersey fabrics. However, the above comments of this study are only given to explain the connections between spirality and machine settings before and after knitting action. On the other hand, because the spirality has been measured after the sanforizing process, it has to be related to not only the yarn loop length and its shape mainly but also many of the other factors such as the dimensional changes after sanforizing process, yarn characteristics, fabric patterns and types etc. In the future examinatios of our study, these factors will systematicaly be considered.

It was observed that the sanforization process has no significant effect on the strength. Therefore, the equations were fitted for mean values calculated by taking the average of the strength values obtained for the fabrics before and after the sanforizing process. In the equations, x is the fabric pre-adjusted weight (g/m^2) and y is the bursting strength (KPa). It is observed from the equations, the bursting strength functions well linearly both for the fabrics of Ne 30/1 and Ne 20/1 within the setting limits of the machine. Figure 5 illustrates that the increase of the weight or fabric course density inreases the fabric bursting strength. In this study, the yarns examined have been produced under the same conditions by the use of the same fibers. Though the yarn’s strength testing results have not been given here in this paper, they had been tested and found out the the Ne 20/1 was stronger yarn than the Ne 30/1 in comparison. Hence, as shown from the Figure 5 that the yarn counts and their strengths are also important parameters determining the fabric strength. However, the data based on our experimental investigations for the subject would not be sufficient in order to give stronger evaluations and comments. Hence, all the other factors such as yarn, fabric and processing parameters in general will be considered in future examinations.

It was observed that the sonforization process has no significant effect on the pilling properties. There is no clear effect of the fabric weight on pilling; more or less the same pilling tendency is seen from the lower to the higher in fabric weights as given in the tables. On the other hand, the pilling cycles are of great important for the pilling tendency. The higher the pilling cycles it is the severe or very severe pilling for the fabrics. In general, the pilling properties are affected by not only the sanforizing process, fabric weight or density, and pilling cycles but also the fiber, yarn and fabric types and their structural parameters such as the fiber materials, yarn hairines, uniformity, and fabric pattern etc. are important factors determining pilling behaviour to be considered. Except the counts, the other yarn quality parameters are almost identical as given in the material section. Hence, the effect of yarn parameters has not been examined in this paper, because it is thought that the solid statements would only be given by studying these parameters by systematical way on the subject. From the statistical analysis point of view, the revolution cycles have been found as the major factors on pilling tendency both before and after the sanforizing process.

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