(REFEREED RESEARCH)

EFFECTS OF LAUNDERING PROCESS ON ABRASION AND WRINKLE RESISTANCE OF COTTON PLAIN FABRIC

YIKAMA İŞLEMİNİN PAMUKLU BEZAYAĞI KUMAŞLARIN AŞINMA VE BURUŞMA MUKAVEMETLERİNE ETKİLERİ

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ABSTRACT

Textile products require laundering for a number of times throughout their service life. Textile products are damaged by the chemicals and the mechanical distortions they are exposed to during laundering. Dimensional change in fabrics is observed due to laundering process and this leads to deformation of clothes. This deformation tends to be greater when the selected laundering is not appropriate for the textile product. In this study, the effects of laundering parameters on abrasion and wrinkle resistance were investigated. The laundering parameters include duration, temperature and the number of repetitive laundering. According to the results, the increase of laundering duration, temperature and the number of repetitive laundering decreased the abrasion and wrinkle resistance of the fabrics. The effect of laundering duration on the abrasion and wrinkle resistance of fabrics was stronger than that of laundering temperature. The wrinkle resistance of the fabrics was more sensitive to repeated laundering than the abrasion resistance was. When the duration and temperature of the laundering were increased together, the decreases in the abrasion and the wrinkle resistance of fabric were substantial.

Key Words: Plain fabric, Abrasion resistance, Wrinkle resistance, Laundering duration, Laundering temperature, Repeated laundering.

ÖZET

Tekstil mamulleri kullanım ömürleri içinde defalarca kez yıkanmak zorundadırlar. Yıkama işlemi esnasında kullanılan kimyasal maddeler ve mekanik hareketler sonucu tekstil mamulleri zarar görebilmektedir. Yıkama işlemiyle kumaşlarda boyut değişimi gözlenmekte ve kumaşın görünümü bozulabilmektedir. Bu bozulma yıkama şartlarına riayet edilmemesi durumunda daha fazla olmaktadır. Bu çalışmada yıkama süresi, yıkama sıcaklığı ve yıkama tekrarı ile kumaş aşınma ve buruşma mukavemeti arasındaki ilişkiler incelenmiştir. Elde edilen sonuçlara göre genel olarak, yıkama süresi, sıcaklığı ve tekrarı arttıkça kumaş aşınma ve buruşma mukavemeti düşmektedir. Aşınma ve buruşma mukavemeti yıkama sıcaklığına göre yıkama süresinden daha fazla etkilemektedir. Yıkama tekrarı buruşma mukavemetini aşınma mukavemetine gore daha fazla etkilemektedir. Yıkama sıcaklığı ve zamanı beraber artırıldığı zaman kumaş aşınma ve buruşma mukavemetindeki düşüş yüzdesi en fazla olmaktadır.

Anahtar Kelimeler: Bezayağı kumaş, Aşınma mukavemeti, Buruşma mukavemeti, Yıkama süresi, Yıkama sıcaklığı, Yıkama tekrarı.

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1. INTRODUCTION

Even though laundering deteriorates fabric performance, it is required for many textile products. The purpose of the laundering process is to remove the impurities that are present on fabric. The laundering process may be useful only if it is done correctly (1). Fabrics are exposed to thermal and mechanical effects during the laundering process. As a result of these effects, changes are observed relating to some characteristics of the fabrics. In the laundering process, there are many factors affecting the quality of the process and product. Hardness of the water, amount and quality of the chemicals, laundering temperature and duration, drying temperature and type, and repetitive laundering affect the quality of the process and product. Unfortunately, especially the laundering durations and temperatures are unnecessarily raised in household usages.

Abrasion occurs due to the friction of the fabric with any surface. Abrasion is one of the most important reasons that make the textile products unusable. Because low abrasion resistance leads

to pilling on the fabric, appearance of the fabric gets worse. Easy wrinkling of a fabric leads to unpleasant appearance of the clothes produced from that fabric (2). Friction forces between the fabric and the water during laundering process are expected to increase fabric abrasion and wrinkles. Clothes must be ironed after the laundering process. It is a known fact that the laundering process increases fabric abrasion and wrinkle, but the effects of laundering duration, temperature and repetitive laundering on fabric abrasion and wrinkle are not yet well defined.

With this study, it was aimed to determine the effects of laundering duration, temperature and repetitive laundering on the abrasion and the wrinkle resistance of cotton plain fabrics. When the literature relating to the subject was examined, it was seen that some researchers investigated the effects of different parameters of laundering process on different properties of fabrics.

In their study, Mavruz and Oğulata (3) studied the effects of repetitive laundering on the dimensional change, bursting resistance and pilling performance of knitted fabrics which were treated with bio-polishing materials. The workers indicated that an increase in the number of repeated laundering decreased dimensional change, i.e., it provided a positive impact on the fabric due to the completion of relaxation. However, they determined that bursting resistance and pilling performance got worse.

In another study, Önal and Candan (4) examined the changes of dimensional properties of three different knitted fabrics consisting of cotton and cotton/polyester fibre blends, various densities and yarn types after applying numerous laundering and drying processes. The researchers indicated that the effects of fabric density, knitting type, yarn type and fibre blend on the dimensional characteristics of the fabric were significant.

Lau L. et al (5) stated that the application of wrinkle resistance finish on knitted shirting fabrics made of 100 % cotton kept shrinkage under control, improved crease resistance characteristics and decreased the side effects of laundering process.

In their study, Quaynor et al (6) examined the effects of laundering temperature and repetitive laundering on dimensional stability of single-jersey fabrics of cotton, silk and polyester fibres. They stated that fabric dimensional stability was affected by the fibre type and the fabric's structural parameters, rather than laundering parameters. Fabrics become more wrinkled with increasing temperature and repetitive laundering.

In a study conducted by Demirhan and Meriç (7), the effects of drying process by hanging and tumble-drying after laundering of weft knitted fabrics on dimensional changes of fabric were investigated. The researchers stated that different shrinkage ratios were obtained by different drying methods. The shrinkage ratios were reported to decrease with increasing rate of polyester in fabric structure in two and three-yarn fabrics.

Erdem İşmal (8) stated that the wrinkle resistance of viscose fabric was affected by the discontinuous (rope) washing.

2. MATERIAL AND METHOD

In this study, it was aimed to determine the effects of laundering temperature, laundering duration and repeated laundering on abrasion and wrinkle resistance of plain fabric. The selected material was 100 % cotton plain weave fabric. The fabric was made from ring carded spun yarns. The count, tenacity, evenness and hairiness of the warp and weft yarns were measured according to ASTM D 861-99, ASTM D 1423-02, ASTM D 1578-93, ASTM D 1425-96 and ASTM D 5647, respectively. The data of the warp and weft yarns were given in Table 1.

Table 1. Characteristics of the warp and weft yarns

Yarn	Count (Ne)	Twist (t/m)	Tensile Tenacity (cN/tex)	Evenness (% CV)	Hairiness (H)
Weft	20.04	719.0	20.40	13.13	5.65
Warp	20.07	831.5	20.75	12.98	5.37

Plain fabrics were produced on a 1996 model Toyoda Jat 600 weaving machine equipped with an electronic dobby. The number of yarns per cm, weight, abrasion resistance and wrinkle resistance of the fabric were measured according to the standards ASTM D 3775-03a, ASTM D 3776-96, ASTM D 4966 and ISO 2313, respectively. Laboratory climate conditions were as stated in ASTM D 1776-79. Table 2 shows the fabric characteristics.

Desizing and bleaching processes were applied to the fabric. Fabrics were impregnated with a solution containing 1g/L enzyme (the cellulase enzyme with a working pH of 4-6 and is soluble in water), 2 g/L non-ionic wetting agent, 2 g/L salt and 0.3 g/L $CaCl_2$ at 70°C for 4 hours, in order for desizing and then was rinsed with cold water. After that, scouring process was conducted by impregnating in a NaOH (5 %) solution at 95°C for 2 hours using pad-roll method. No finishing process other than desizing and scouring was applied to the fabrics. 9 different laundering processes were applied to the finished fabric using a home-type laundering machine. For the laundering process, a common detergent was used. This detergent contained less than 5% non-ionic active agent, polycarboxylate, phosphonate, soap, 5-15 % anionic active agent, oxygen-based bleach, 15-30 % phosphate and perfume. After the fabrics were washed with the detergent, they were dried in ambient air. The home-type laundering machine was selected to provide similarity to laundering process encountered in daily life. Data related to laundering processes are given in Table 3.

Table 2. Characteristics of the fabric

Reed Width	180 cm
Width of Raw Fabric	160 cm
Weight	165 g/m^2
Warp Density	24 ends/cm
Weft Density	23 picks/cm
Warp Yarn Number	3840
Warp Density on Reed	21.33 ends/cm
Number of Reed	70
Warp Tension	45 cN

Table 3. Laundering processes

Laundering #	Laundering Duration (minute)	Laundering Temperature (°C)
1	30	20
2		60
3		90
4	60	20
5		60
6		90
7	90	20
8		60
9		90

Laundering processes were classified according to the applied duration and temperature. The effect of the laundering duration on abrasion and wrinkle resistance of the fabric was examined in launderings # 1, 4 and 7. The effect of temperature on the abrasion and the wrinkle resistance of the fabric were investigated in launderings # 1, 2 and 3. As seen in Table 4, the effects of laundering duration and temperature on abrasion and wrinkle resistance of the fabric were examined separately for 3 groups. In order to examine the effects of repetitive laundering on abrasion and wrinkle resistance of fabric, each one of the 9 different laundering processes were repeated for 20 times. The abrasion and wrinkle resistances of fabric were

Table 4. Classification of laundering processes in terms of duration and temperature

Group Number	Laundering Duration			Laundering Temperature		
	Laundering #			Laundering #		
1	1	4	7	1	2	3
2	2	5	8	4	5	6
3	3	6	9	7	8	9

The abrasion resistance measurements were carried out with a Nu Martindale Abrasion and Pilling Tester. The abrasion resistance was measured in terms of cycle quantity until the warp and weft yarns broke. Greater numbers of cycles correspond to better abrasion resistance. Wrinkle recovery angles were measured by using a Crease Recovery Angle Tester. During wrinkle resistance testing, the totals of recovery angles in face to face and back to back positions in weft and warp directions were calculated and reported as the total recovery angle. Higher wrinkle resistance values lead to greater recovery angles. The relationships between laundering parameters and abrasion and wrinkle resistance of fabrics were examined in terms of correlation coefficients and percentage decreases in the characteristics of the fabric.

3. RESULTS AND DISCUSSION

The abrasion and wrinkle resistances of the fabrics were measured. The results of these measurements were given in Table 5.

Table 5. Abrasion and wrinkle resistances of fabrics with repeated laundering

Laundering #	Number of Repeated Laundering	Abrasion Resistance		Wrinkle Resistance			
		Number of Cycles	Percentage Decrease After Repeated Laundering	Warp (Total Recovery Angle, deg)	Percentage Decrease After Repeated Laundering	Weft (Total Recovery Angle, deg)	Percentage Decrease After Repeated Laundering
1	1	19800	-	130	-	155	-
	10	19300	2.5	122	6.2	148	4.5
	20	17650	**8.5**	100	**22**	120	18.9
2	1	18900	-	110	-	140	-
	10	18350	2.4	100	9.1	128	8.6
	20	17980	2.0	78	**22**	104	18.8
3	1	18020	-	100	-	126	-
	10	17820	1.1	90	10	118	6.3
	20	16800	5.7	72	20	105	11.0
4	1	18300	-	105	-	132	-
	10	17950	1..9	92	12.4	128	3.0
	20	17000	5.3	72	21.8	110	14.1
5	1	17400	-	94	-	128	-
	10	17100	1.7	80	15.6	119	7.0
	20	16900	1.2	60	25	103	13.4
6	1	17050	-	90	-	116	-
	10	16740	1.8	86	4.4	116	0.0
	20	16100	3.8	68	20.1	98	15.6
7	1	17950	-	68	-	100	-
	10	16990	5.3	60	11.8	98	2.0
	20	16800	1.1	53	11.7	82	16.3
8	1	16950	-	60	-	95	-
	10	16280	4.0	48	20	85	10.5
	20	15960	2.0	40	16.7	80	5.9
9	1	14020	-	52	-	75	-
	10	13460	4.0	40	15.4	72	4.0
	20	12550	6.8	37	7.5	50	**30.6**

3.1. The relationship between laundering duration and abrasion resistance of fabric

The effects of laundering duration and temperature parameters were evaluated based on the results of the first launderings as shown in Table 6. The correlation coefficients and percentage decreases in abrasion resistance were given in Table 6.

A significant negative relationship at the 0.01 significance level was obtained between the laundering duration and the abrasion resistance of the fabric. As the laundering duration increased, the abrasion resistance of the fabric decreased. Maximum decrease in the abrasion resistance was experienced between the launderings # 6 and 9, with a value of 17.8 %. That is, the maximum decrease in the abrasion resistance was observed when the laundering duration was increased from 60 minutes to 90 minutes for a laundering temperature of 90°C.

3.2. The relationship between laundering temperature and abrasion resistance of fabric

The correlation coefficients and the percentage decreases in abrasion resistance were given in Table 7.

Between the laundering temperature and the abrasion resistance of the fabric, a significant negative relationship at the 0.01 significance level was obtained. With increasing laundering temperature, the abrasion resistance of the fabric decreased. When the decreases of percentage in the abrasion resistance were investigated, it was seen that the maximum decrease occurred between launderings # 8 and 9, with a value of 17.3 %. Namely, the maximum decrease in the abrasion resistance occurred when the laundering temperature was increased from 60°C to 90°C for a laundering duration of 90 minutes.

The total percentage decrease in abrasion resistance due to the laundering duration was obtained as 43.6, whereas that decrease due to the laundering temperature was found as 39. Hence, abrasion resistance performance of the fabric was found to be more sensitive to laundering duration compared to laundering temperature.

3.3. The relationship between laundering duration and wrinkle resistance of fabric

The correlation coefficients and the percentage decreases in warp wrinkle resistance recovery angle WRA and weft WRA were given in Table 8.

Table 6. Correlation coefficients and percentage decreases in abrasion resistance in terms of laundering duration

	1st Group			2nd Group			3rd Group		
Laundering #	1	4	7	2	5	8	3	6	9
Temperature (oC)	20			60			90		
Duration (minute)	30	60	90	30	60	90	30	60	90
Abrasion Resistance (cycle)	19800	18300	17950	18900	17400	16950	18020	17050	14020
Percentage Decrease of Abrasion Resistance (%)	-	7.5	2.4	-	7.9	2.6	-	5.4	17.8
Correlation Coefficient (Duration - Abrasion Resistance)	-0.941*			-0.955*			-0.959*		

* Statistically significant at the 0.01 significance level

Table 7. Correlation coefficients and percentage decreases in abrasion resistance in terms of laundering temperature

	1st Group			2nd Group			3rd Group		
Laundering #	1	2	3	4	5	6	7	8	9
Duration (minute)	30			60			90		
Temperature (°C)	20	60	90	20	60	90	20	60	90
Abrasion Resistance(cycle)	19800	18900	18020	18300	17400	17050	17950	16950	14020
Percentage Decrease of Abrasion Resistance (%)	-	4.5	4.7	-	4.9	2.0	-	5.6	17.3
Correlation Coefficient (Temperature-Abrasion Resistance)	-0.997*			-0.986*			-0.936*		

Table 8. Correlation coefficients and percentage decreases in WRA in terms of laundering duration

		1st Group			2nd Group			3rd Group		
Laundering #		1	4	7	2	5	8	3	6	9
Temperature (°C)		20			60			90		
Duration (minute)		30	60	90	30	60	90	30	60	90
Total Wrinkle Recovery Angle, deg (WRA)	Warp	130	105	68	110	94	60	100	90	52
	Weft	155	132	100	140	128	95	126	116	75
Warp WRA Percentage Decrease (%)		-	19.2	35.2	-	14.5	36.1	-	10	42.2
Weft WRA Percentage Decrease (%)		-	14.8	24.2	-	8.6	25.8	-	7.9	35.3
Correlation Coefficient (Duration -Warp WRA)		-0.994*			-0.979*			-0.948*		
Correlation Coefficient (Duration - Weft WRA)		-0.996*			-0.966*			-0.944*		

Between the laundering duration and the wrinkle resistance of the fabric, a negative relationship was found at the 0.01 significance level. As the laundering duration increased, wrinkle resistance of fabric decreased. The maximum percentage in the wrinkle resistance occurs between launderings # 6 and 9, with a value of 42.2 %. In other words, the maximum decrease in the wrinkle resistance was observed when the laundering duration was increased from 60 minutes to 90 minutes for a laundering temperature of 90^{o}C.

3.4. The relationship between laundering temperature and wrinkle resistance of fabric

The correlation coefficients and the percentage decreases in warp WRA and weft WRA were given in Table 9.

A significant negative relationship at the 0.01 significance level was detected between the laundering temperature and the wrinkle resistance of the fabric. As laundering temperature increased, the wrinkle resistance of the fabric decreased. As the decreases of percentage in the wrinkle resistance were investigated, it was seen that the maximum decrease occurs between launderings # 1 and 2 for the warp WRA and launderings # 8 and 9 for the weft WRA. The total percentage decrease in the wrinkle resistance due to the laundering duration was obtained as 273.4, whereas that due to the laundering temperature was found as 119.5. Consequently, it can be said that the wrinkle resistance was more sensitive to the laundering duration compared to the laundering temperature.

3.5. The relationships between repeated laundering and abrasion and wrinkle resistances of fabric

For the 9 launderings given in Table 5, correlation coefficients between number of repeated laundering with abrasion and wrinkle resistances of fabric were separately calculated and the results were given in Table 10.

Table 9. Correlation coefficients and percentage decreases in WRA in terms of laundering temperature

		Group 1			Group 2			Group 3		
Laundering #		1	2	3	4	5	6	7	8	9
Duration (minute)		30			60			90		
Temperature (Co)		20	60	90	20	60	90	20	60	90
Total Wrinkle Recovery Angle, deg (WRA)	Warp	130	110	100	105	94	90	68	60	52
	Weft	155	140	126	132	128	116	100	95	75
Warp WRA Percentage Decrease (%)		-	15.3	9.1	-	10.5	4.3	-	11.8	13.3
Weft WRA Percentage Decrease (%)		-	9.7	10	-	3.0	6.3	-	5.0	21.1
Correlation Coefficient (Temperature – Warp Wrinkle Resistance)		-0.994*			-0.986*			-0.997*		
Correlation Coefficient (Temperature – Weft Wrinkle Resistance)		-0.998*			-0.938*			-0.915*		

Table 10. Correlation coefficients between numbers of repeated laundering with abrasion and wrinkle resistances of fabric

Laundering Number	1	2	3	4	5	6	7	8	9
Correlation Coefficients Between Repeated Laundering and Abrasion Resistance	-0,964*	-0,990*	-0,943*	-0,974*	-0,989*	-0,986*	-0,921*	-0,973*	-0,994*
Correlation Coefficients Between Repeated Laundering and Warp Wrinkle Resistance	-0,973*	-0,983*	-0,991*	-0,993*	-0,997*	-0,949*	-0,997*	-0,989*	-0,935*
Correlation Coefficients Between Repeated Laundering and Weft Wrinkle Resistance	-0,954*	-0,987*	-0,994*	-0,949*	-0,992*	-0,880*	-0,924*	-0,976*	-0,928*

A significant negative relationship at the 0.01 significance level was detected between the repeated laundering with the abrasion and the wrinkle resistances of the fabric. Namely, when the number of launderings increased, the abrasion and the wrinkle resistances of the fabric decreased. The decreases of percentage due to repeated laundering was investigated. As shown in Table 5, the maximum decrease was observed between 10th and 20th cycles of the laundering # 1 for abrasion resistance and warp WRA, and that for weft WRA was observed between the 10th and the 20th cycles of the laundering # 9.

4. CONCLUSIONS

In this study, the effects of laundering duration, laundering temperature and repetitive laundering on abrasion and wrinkle resistance of cotton plain fabrics were examined. 9 different laundering processes with different temperature and duration combinations of 20, 60 and 90 ^{o}C and 30, 60 and 90 minutes were applied to cotton plain weave fabrics. The fabrics were dried in ambient air following laundering. After that, abrasion and wrinkle resistance performances of the

fabric were measured. The effects of laundering parameters on abrasion and wrinkle resistance behaviours of the fabrics were examined in terms of correlation coefficients and decreases of percentage in these characteristics of the fabrics. A statistically significant negative relationship at the 0.01 significance level was obtained between laundering parameters and abrasion and wrinkle resistance of fabric.

As the duration, temperature and the number of laundering cycles were increased, the abrasion and wrinkle resistances of the fabric decreased. The maximum decrease in the abrasion resistance with respect to laundering duration was observed when the laundering duration was increased from 60 minutes to 90 minutes for a laundering temperature of 90^{o}C. On the other hand, the maximum decrease in the abrasion resistance in terms of laundering temperature was observed when the laundering temperature was increased from 60^{o}C to 90^{o}C for a constant laundering duration of 90 minutes. The maximum decrease in the wrinkle resistance was observed when the laundering duration was increased from 60 minutes to 90 minutes when the laundering temperature was kept at 90^{o}C. While the maximum decrease in the wrinkle resistance in warp direction was observed when the laundering temperature was increased from 20^{o}C to 60^{o}C for a laundering duration of 30 minutes that in weft direction occurred when the laundering temperature was increased from 60^{o}C to 90^{o}C for a constant laundering duration of 90 minutes. Consequently it can be said that, the fabrics which were laundered at higher temperatures for a longer durations tended to wrinkle and abrade more. In their study, Mavruz and Oğulata (3) have also found that repeated laundering in knitted fabrics to reduce pilling performance.

On the other hand, the total percentage decrease in abrasion resistance due to laundering duration was obtained as 43.6, whereas that decrease due to the laundering temperature was found as 39. In addition to this, the total percentage decrease in the wrinkle resistance due to the laundering duration and temperature was obtained as 273.4 and 119.5, respectively. As a result the abrasion and wrinkle resistance of the fabric were affected by laundering duration more severely than by the laundering temperature.

The total percentage decrease in abrasion resistance and wrinkle resistance due to repetitive laundering was obtained as 8.5 and 30.6, respectively. Therefore the wrinkle resistance of the fabric was affected more severely by repetitive laundering than the abrasion resistance was. When the duration and temperature of the laundering increased together, the percentage decrease of abrasion and wrinkle resistance of fabric was substantial. So, one should refrain from increasing the laundering duration and temperature together.

Fabrics are laundered repetitively in order to maintain hygiene during their use. Laundering process is a high-cost process due to water and detergent use. And, other factors that increase the cost are the duration and the temperature of the laundering process. Besides increasing the cost, duration and temperature have negative effects on textile products. These undesirable effects, namely, shrinkage, deformation, abrasion and wrinkling are critical for performance of the fabrics. Because of the great amount of water consumption and waste water generation in laundering, it is a process with a major environmental impact. Therefore, laundering parameters should be carefully investigated.

This study was conducted on cotton plain weave fabrics. More beneficial and reliable information might be obtained by making similar studies for other natural and synthetic fibres with common use, comparing these results obtained and systematically changing the concentration as well as the duration and the temperature of the laundering processes.

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