

# Impact of Repeated Home Laundering on the Cyclic Deformation Performance of Elastane Knitted Sportswear Fabrics

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## Abstract

*After washing cycles, textiles having minimum deformation, maximum dimensional stability and the same performance of an unused product are major expectations of customers. This study examined the effects of washing cycles on the cyclic deformation of elastane knitted fabrics in detail. 12 knitted fabrics with two different linear densities of viscose yarn and three different polyamide/elastane gimped yarn of two different tightness levels (normal and tight) were used in the experiments. M&S P15A test method were used to evaluate the cyclic deformation of unwashed and washed fabrics (0, 5, 15 and 25 cycles) for four different recovery time periods (0 min, 2 min, 30 min and 24 h). Dimensional change, tightness factor and mass per unit area values were also examined in order to investigate the residual deformation of the fabrics after each washing stages. Consequently, it is determined that the fabrics having 21 tex viscose ground yarn and 78dtex20f elastane gimped yarn with higher setting show less residual extension (%). 5 and 15 washing cycles and a 30 min. recovery time are found significant for all repeated washings.*

**Key words:** *laundering, washing cycle, viscose yarn, elastane fiber, gimped yarn, knitted fabric, cyclic deformation.*

## ■ Introduction

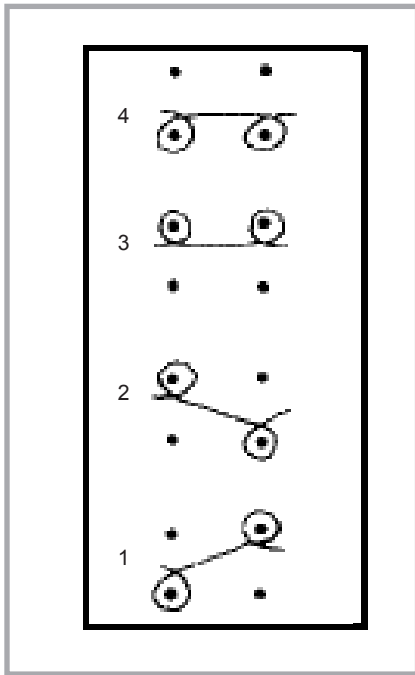
Due to the effects of fashion trends, sectoral development and growing consumer demands, a wide variety of textiles with new designs have been launched on the market. These textiles have been produced from different types of fabrics using many different types of fibers and yarns. As a consequence this condition has provided many different end-use applications for customers. Thus textiles have been affected by numerous important end-use processes such as environmental effects, use conditions, ironing, laundering, dry cleaning, drying conditions and sunlight. Laundering is one of the most important process in terms of the long-term use of garments while retaining the same performance and appearance.

Laundering involves some tough processes such as wetting mechanical agitation, hot water, chemical agents, wringing, and pressing [1]. After repeated launderings, the physical properties of textile change and garments show different deformation characteristics. The importance of this problem has been investigated by several researchers, who focused mainly on the tactile, mechanical and surface properties with respect to the laundering of fabrics [2-6]. There are also several studies dealing with the effects of washing chemicals, laundering conditions and drying variables on the dimensional stability of fabrics [7-10]. Different researchers have

focused their attention on the relation between fabric construction and laundering [11-13]. Some researchers have also studied the effect of repeated washings on permeability, swelling and some comfort properties of fabrics [14-16]. In addition, there are also a few researches on the effect of laundering on the elastic behaviour of fabrics [17-19].

Knitting from fibers with the added ingredient of elastane ensures ease of movement, bagging resistance and elastic recovery [20]. In this way, the elastic deformation and recovery of knitted fabrics and measurement of these properties are important in order to evaluate the performance of elastane-containing knitted fabrics. Analysis of dynamic elastic behavior would assist in improving sportswear properties by giving more pace, stamina and strength to the athlete [21].

In knitted fabrics, dimensional changes and physical deformations have occurred more after repeated laundering in comparison to woven fabrics. The loose structure and fewer contact points in a unit area of knitted fabrics are the reasoned for this. Considering the hardness of production of dimensional stable elastic fabric, this condition gets more complicated with the using of elastane yarns in the knitted structure. From this point of view, cyclic deformation is critical for these types of fabrics to challenge dimensional and shape changes, which are



**Figure 1.** Knitting fabric structure (Punto di Roma) of the test fabrics.

highly affected by washing processes, and thus should be taken into account in order to protect the original shape of garments. However, so far there have been few published works which investigated experimentally the effect of repeated home laundering processes on the cyclic deformation behaviour of knitted fabrics. This research examined the effects of washing cycles on the cyclic deformation of elastane knitted sportswear fabrics for different recovery times. Besides this, changes in some basic fabric structural properties during washing cycles were also investigated for the test fabrics.

## Materials and method

12 types of knitted fabrics with two different linear densities of viscose yarn – 21 tex (Ne 28) and 16 tex (Ne 36) (open-end rotor spun), three different polyamide/elastane gimped yarns (78dtex20f, 78dtex40f and 78dtex70f), and two different tightness levels (normal and tight) were fabricated for sportswear in a previous research [22]. The basic structural properties of the test fabrics are given in **Table 1**.

All the fabrics were knitted as four course Punto di Roma. This knitting type belongs to a group of structures that are reversible and have a tubular sequence of dial and cylinder knit only [23]. The fabric structure selected for this study is shown in **Figure 1**. The fabrics were produced on a Mayer & Cie circular knitting machine in 18 gauges of 36-inch diameter in the same machine settings. After the knitting process, unrolling and thermos-fixing were applied. Reactive dyestuff was used for the pad-batch dyeing process. The speed of the foulard was 40 m/min and the pH value of the dyeing bath was 11.5. After cold pad-batch dyeing, rinsing, neutralisation, drying and sanforization processes were applied, respectively. A cationic softener and fixing agent were used for the finishing process. The fabrics were batched for 16 hours at room temperature. The same dyeing and finishing routine was applied to all fabrics.

All measurements were performed at standard atmospheric conditions ( $20^{\circ} \pm 2^{\circ} \text{C}$  and  $65 \pm 2\% \text{RH}$ ) according to ASTM D1776. The experimental plan consisted of three main parts – the laun-

dering process, cyclic deformation tests of all unwashed and washed samples for different recovery times, and comparison of the basic structural parameters after laundering.

The fabric samples were tested as unwashed, and 5, 15 & 25 times washed according to the procedures given below. To examine the cyclic extension and recovery properties of the elastic knitted sportswear fabrics, the Marks & Spencer P15A test method was selected. This test method was chosen because it is a well-known and accepted testing method for residual deformation among companies in the textile market. Besides this, this test method is demanded from suppliers to evaluate the residual extension of elastomeric fabrics. After each washing cycle, test fabrics were exposed to cyclic deformation in both the wale and course directions to determine extension values (mm) and calculate residual extension values (%) for four different recovery times: 0 min, 2 min, 30 min and 24 h. Details were given in the laundering and cyclic test procedure part.

In order to make a clear evaluation of the residual deformation of the fabrics, the mass per unit area, tightness factor and dimensional change were also measured for every washing stage.

The tightness factor of the fabrics was determined using **Equation (1)** [23]:

$$\text{Tightness Factor} = \frac{\sqrt{\text{Tex}}}{\text{Loop Length } h \text{ (cm)}} \quad (1)$$

For each washing cycle, linear dimensional changes (%) were measured and

**Table 1.** Basic structural parameters of the test fabrics used in the experimental study. **Note:** \*f shows the number of the filaments in the yarn structure. \*\*CV, PA and EL denote viscose, polyamide and elastane, respectively.

Fabric code	Yarn linear density		Setting level	Setting(cm <sup>-1</sup> )		Raw material content ** CV/PA/EL, %	Mass per unit area, g/m <sup>2</sup>
	Viscose yarn	Gimped yarn* PA/EL		Wale	Course		
A1	21 tex (Ne 28)	78dtex40f (70/40denier)	Normal	28	28	72/20/8	343.9
A2			Tight	28	34	73/20/7	382.5
A3	21 tex (Ne 28)	78dtex70f (70/70denier)	Normal	28	29	67/24/9	362.0
A4			Tight	28	34	69/22/9	430.0
A5	16 tex (Ne 36)	78dtex40f (70/40denier)	Normal	29	28	70/24/6	324.0
A6			Tight	28	34	69/25/6	350.0
A7	16 tex (Ne 36)	78dtex70f (70/70denier)	Normal	28	28	62/26/12	354.8
A8			Tight	28	36	64/28/8	375.4
A9	21 tex (Ne 28)	78dtex20f (70/20denier)	Normal	28	26	68/24/8	313.7
A10			Tight	28	32	66/25/9	331.2
A11	16 tex (Ne 36)	78dtex20f (70/20denier)	Normal	28	28	62/30/8	287.6
A12			Tight	28	36	60/31/9	294.8

the change in the shape of samples was determined according to *Equation (2)*.

$$\text{Linear Dimensional Change (\%)} = \frac{L_0 - L_1}{L_0} \times 100 \quad (2)$$

Where  $L_0$  is the distance between a pair of marks on the fabric before washing and  $L_1$  – the distance between a pair of marks after washing.

The experimental plan for the investigation carried out with the cyclic deformation test of the fabrics is summarised in *Table 2*.

### Laundering procedure

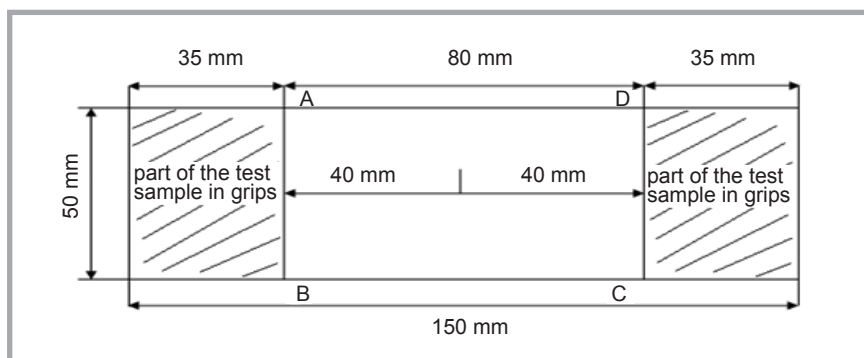
Fabric samples were marked and prepared according to ISO 3759, and then washed and dried according to ISO 6330. A home type, front loading washing machine was used at 40 °C (1h) using a non-phosphate ECE Detergent. All samples were dried by hanging in the middle part of the specimen fabric carefully. Before cyclic deformation tests, dimensional stability was also measured at each washing cycle. The cyclic deformation test procedure was repeated for unwashed (0), 5 washed, 15 washed and 25 washed fabric samples both in the wale and course directions.

### Cyclic deformation test procedure

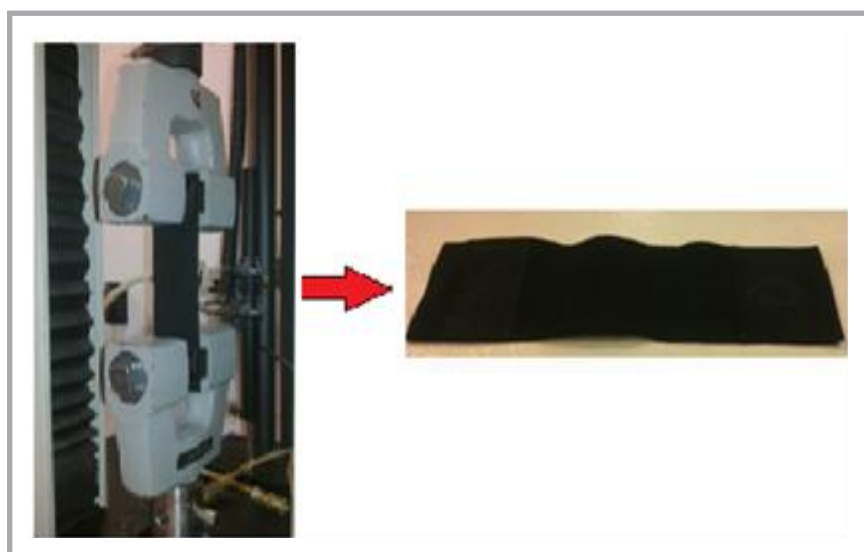
According to the procedures of the M&S P15 A test method, a universal tensile test machine (Instron 4411, ITW Test & Measurement, United Kingdom) was used with computer control, and 50 x 150 mm test samples (*Figure 2*) were extended at a fixed load (15 N) and test speed (500 mm/min) for two consecutive deformation cycles in both the wale and course direction (*Figure 3*). During two deformation cycles, maximum extension values were simultaneously recorded by the computer, and residual extension values (RE, %) were calculated for the allowed recovery time using *Equation (3)*.

$$RE(\%) = ((F_{lengt h} - I_{lengt h}) / I_{lengt h}) \times 100 \quad (3)$$

In *Equation (3)*, RE is the residual extension (%),  $F_{lengt h}$  the final (extended) length (mm), and  $I_{lengt h}$  is the initial length (mm). The initial length is always 80 mm. The final length is the measured length after the allowed recovery time completing the test. According to the original test procedure, a specified re-



*Figure 2. Dimensions of test samples for cyclic test.*



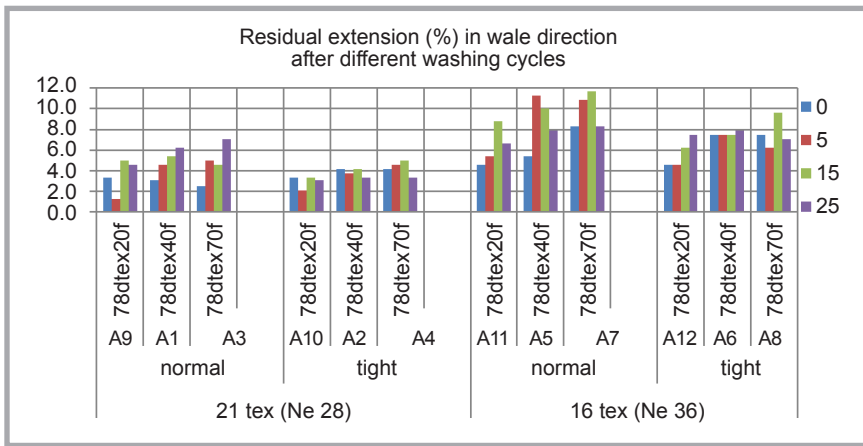
*Figure 3. Test sample during and after cyclic test.*

covery time of 2 minutes must be utilised. In this study, a principal recovery time of 2 minutes was used and four different recovery times (0 min, 2 min, 30 min and 24 h) were also examined to evaluate the impact of the recovery time on deformation values. Three repetitions were conducted in all directions for each case.

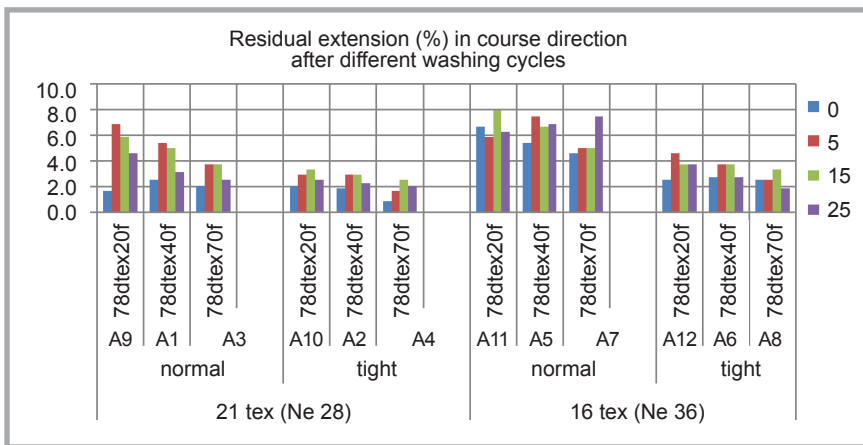
The effects of washing cycles on some basic fabric structural properties were also discussed. SPSS 22.0 Statistical Software was used for statistical analyses of the results. The significance of the parameters and type of material were tested by multivariate analysis of variance. ANOVA was used for analysis of variance with the Student Newman Keuls,

*Table 2. Summary of the experimental plan of the research.*

Number of test fabrics	Number of washing cycles	Parameter measured	Recovery time for residual extension	Parameter calculated for each case
12	0, 5, 15, 25	Wale extension at 1500cN load (Ewale, mm)	0 min, 2 min, 30 min, 24h	Residual extension in wale direction for different recovery times and washing cycles (REwale, %)
	0, 5, 15, 25	Course extension at 1500cN fixed load (Ecourse, mm)	0 min, 2 min, 30 min, 24h	Residual extension in course direction for different recovery times and washing cycles (REcourse, %)
<b>Properties evaluated</b>				
Effect of the number of washing cycles on residual extension				
Effect of the setting level on residual extension for different washing cycles				
Effect of the gimped yarn type on residual extension for different washing cycles				
Effect of the recovery time on residual extension for different washing cycles				
Correlations between residual extension values for different washing cycles				
Effect of washing cycles on some fabric physical properties				



**Figure 4.** Residual extension values (%) of elastane knitted fabrics in the wale direction after different washing cycles (allowed recovery time: 2 min).



**Figure 5.** Residual extension values (%) of elastane knitted fabrics in the course direction after different washing cycles (allowed recovery time: 2 min).

**Table 3.** Results of variance analysis on the residual extension values of elastane knitted fabrics.

Source	Dependent variable	21 tex (Ne 28)		16 tex (Ne 36)	
		F	Sig.	F	Sig.
Gimped yarn type	RE wale, %	18.387	0.000	145.785	0.000
	RE course, %	5.133	0.010	4.675	0.014
Course setting	RE wale, %	7.742	0.008	78.062	0.000
	RE course, %	30.104	0.000	175.110	0.000
Washing cycle	RE wale, %	8.290	0.000	45.134	0.000
	RE course, %	14.438	0.000	9.724	0.000

The values given in gray colour show significant values at a 95% confidence level  
RE: Residual Extension (%) for a 2 minute recovery time

SNK post hoc test to investigate significant differences between properties of the fabrics repetitive laundered.

## Results and discussion

In this study, the impacts of the number of washing cycles and recovery time on cyclic deformation values were examined in detail using 12 elastane knitted sportswear fabrics.

### Effect of washing cycles on residual extension after a cyclic test of elastane knitted fabrics

The effect of washing cycles on residual extension in the wale and course directions after the cyclic test can be seen in **Figure 4** and **Figure 5**, respectively. In these figures, residual extension values were calculated with a recovery time of 2 min. according to the M&S P15A test method.

In general, the effect of repeated washing cycles on the residual extension of the fabrics is gradual. This observation is in accordance with Lau et al. (2002), who found that the resilience values decreased by 10-20% after sixteen washing cycles [24]. As seen in **Figures 4** and **5**, the residual extension values of elastane knitted fabrics are very different for two different viscose yarn linear densities (21 tex and 16 tex). When setting levels are compared for every ground yarn linear density, it is clearly determined that elastane knitted fabrics with a higher setting show less residual extension after all washing cycles. The important point is that these situations are valid for all numbers of washing cycles, and the deformation tendency is similar in wale and course directions. When the number of filaments in PA/EL gimped yarn is examined, it can be seen that fabrics with 78dtex20f elastane gimped yarn show the lowest residual extension amongst the others, especially in the wale direction. The critical washing cycles in this research are determined to be 5 and 15 washing cycles for all test fabrics in the two different test directions.

Variance analysis results are presented in **Table 3**. Considering the effects of the parameters, it was determined that the number of filaments in gimped yarn, the course setting and washing cycle effects are statistically significant ( $p < 0.05$ ) at a 95% confidence level for all test fabrics.

Results of the SNK test applied for residual extension are given in **Table 3** with respect to the main effects. Results of the SNK post hoc test show that test results were generally divided into more groups for fabric with normal setting values. Lower residual extension values were obtained for 21 tex fabrics in comparison to 16 tex fabrics. As seen in **Table 4**, there is no statistically significant difference in residual extension values for 21 tex tight fabrics after different washing cycles. It can be said that the number of filaments in the gimped yarn structure is not important for such fabrics. The number of filaments in the gimped yarn structure is found non-significant in the course direction for many of the fabrics produced with 21 tex viscose yarns.

Higher residual extension values were obtained for 16 tex viscose fabrics in

comparison to 21 tex ones. Different washing cycle subsets show that the choice of gimped yarn is important for these fabrics, and different residual extension can be obtained after different numbers of washing cycles. If it is necessary to use 16 tex viscose yarns, it will be better to use a higher setting to prevent higher deformation in accordance with the results. The choice of the number of filaments in the gimped yarn structure can be made according to lower residual extension values; hence, 78dtex20f gimped yarn is possible when tight fabrics are produced. In this case, two different subsets are noted, and thus the results of fabrics washed 0, 5 and 25 times are significantly different those of the 15 washed ones. According to these results, it is observed that the highest and statistically significant values are obtained for elastane knitted fabrics washed 15 times.

When correlation coefficients were calculated between residual extension values of unwashed and washed fabrics, the coefficients were determined to be statistically significant, as given in **Table 5**. The highest and significant correlations were seen for elastane knitted fabrics washed between 5 and 15 times. Especially correlation coefficients for fabrics washed between 5 and 25 times is important ( $p < 0.05$ ).

Many textile producers can only test unwashed or a maximum of 5 times washed fabrics before sending consignments to customers due to time constraints, in general. The highest and significant correlations show that for most fabrics which have similar properties to those used in this study, cyclic deformation values of 5 times washed fabrics will be useful to correlate the results of fabrics washed 25 times.

**Table 4.** SNK post-hoc test results of residual extension values for washing cycles. **Note:** \* subsets not sharing the same group mean that they are significantly different from each other at a 95% confidence level, \*\* RE: Residual Extension (%) for a 2 minute recovery time.

Main effects			Washing cycle subsets for parameters*			
Viscose yarn	Setting level	Gimped yarn type	RE wale, %**		RE course, %**	
21 tex (Ne 28)	Normal	78dtex20f	0, 5		0, 5	
			15, 25		25	
					15	
		78dtex40f	0, 5, 15, 25		0, 25	
					5, 15	
	Tight	78dtex70f	0, 5, 15		0, 5, 15, 25	
			5, 15, 25			
16 tex (Ne 36)	Normal	78dtex20f	0		25, 5, 0, 15	
			5, 25			
			15			
		78dtex40f	0		0, 25	
			15, 25		5, 15	
			5, 15		5, 15	
	Tight	78dtex70f	0, 25		0, 5, 15, 25	
			5, 15			
Tight	78dtex20f	0, 5, 25		0, 5, 25		
		15		5, 25, 15		
	78dtex40f	0, 5, 15, 25		0, 5, 15, 25		
78dtex70f	0, 5, 25		0, 5, 15, 25			
	5, 25					
	15					

**Effect of recovery time on residual extension after the cyclic test of elastane knitted fabrics**

As another part of the research, residual extension values of test fabrics were calculated for different recovery times: 0 min, 2 min, 30 min and 24 hours after the test was completed. Residual extension values of unwashed fabrics in the wale and course directions for different recovery times are exhibited in **Figure 6** and **Figure 7**, respectively.

According to the residual extension results of unwashed fabrics in the wale direction, A7 test fabrics, which were produced from 16 tex viscose yarn and

78dtex70f polyamide/elastane gimped yarn with a normal tightness level, have the highest values for all recovery times. At the end of the cyclic tests, the residual extension values had varied between 3% (A3) and 10% (A7), while after a 24 h recovery time these values had varied between 0.83% (A9) and 6.25% (A7). As seen in **Figure 7**, the critical recovery time is 30 min for all test fabrics. After a 30 min recovery time, small changes can be found in the residual extension values. The fabrics made of 21 tex viscose ground yarns have generally lower residual extension values compared to fabrics produced from 16 tex viscose ones. When considering the effect of

**Table 5.** Correlation coefficients between residual extension values of unwashed and washed elastane knitted fabrics.

	Unwashed RE wale	Unwashed RE course	5 times washed RE wale	5 times washed RE course	15 times washed RE wale	15 times washed RE course	25 times washed RE wale	25 times washed RE course
Unwashed RE wale	1.000							
Unwashed RE course	0.469	1.000						
5 washed RE wale	0.897	0.612	1.000					
5 washed RE course	0.527	0.862	0.735	1.000				
15 washed RE wale	0.870	0.692	0.922	0.688	1.000			
15 washed RE course	0.160	0.814	0.294	0.618	0.471	1.000		
25 washed RE wale	0.770	0.560	0.905	0.668	0.853	0.306	1.000	
25 washed RE course	0.513	0.801	0.546	0.647	0.623	0.727	0.488	1.000

The values given in gray colour show significant values at a 95% confidence level  
RE: Residual Extension (%) for a 2 minute recovery time

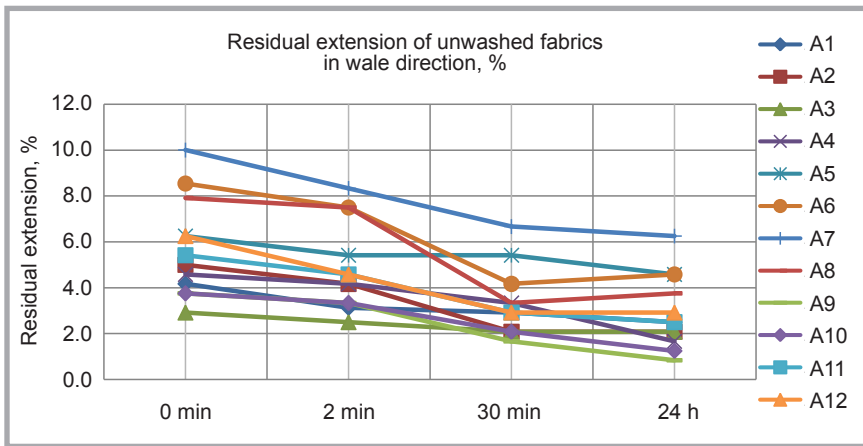


Figure 6. Residual extension values (%) of unwashed elastane knitted fabrics in the wale direction for different recovery times.

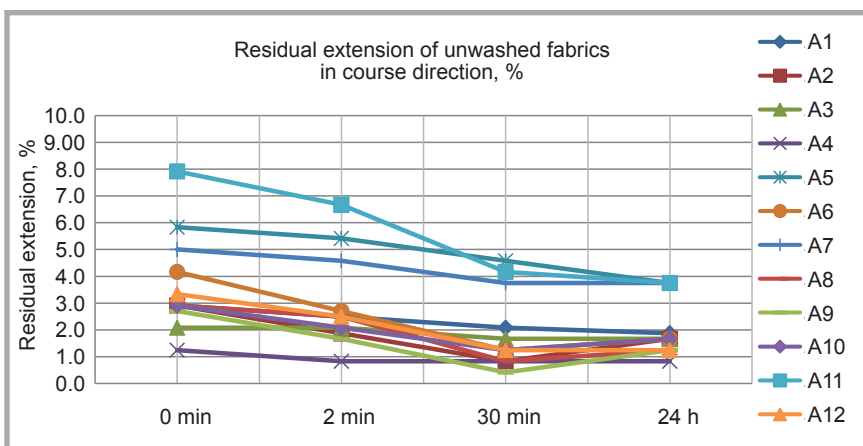


Figure 7. Residual extension values (%) of unwashed elastane knitted fabrics in the course direction for different recovery times.

the gimped yarn count, fabrics produced from 78dtex70f PA/EL gimped yarns have generally high cyclic deformation values, and those produced from 78dtex20f PA/EL gimped yarns have generally low. When examining the fabric tightness level, it is noticed that tight fabrics generally show less deformation than normal tightness level fabrics.

When the residual extension results of unwashed fabrics in the course direction were examined, it was observed that test fabrics A11, A5 and A7, which have 16 tex viscose ground yarn and a normal tightness level, distinct from others in their higher values for all recovery times. Similar to the wale direction samples, the critical recovery time is 30 min for all test fabrics, and after this time only small changes can be found in residual extension values. After a 24h recovery time, all fabrics show lower residual extension values than 4%.

The residual extension values for different recovery times of all test fabrics are given in Figure 8 and Figure 9 for 0 (unwashed), 5, 15 and 25 washing cycles. As seen in Figure 8, in the wale direction there is a significant difference between the residual extension values of fabrics 5 and 15 times washed when they were compared with the unwashed and other washing cycles. Besides, a decreasing

Table 6. Effect of recovery time on the residual extension values of elastane knitted fabrics.

Source	Dependent variable	21 tex (Ne 28)				16 tex (Ne 36)			
		Normal setting		Tight setting		Normal setting		Tight setting	
		F	Sig.	F	Sig.	F	Sig.	F	Sig.
Recovery time	Unwashed RE wale, %	5.626	0.005	15.937	0.000	15.733	0.000	52.757	0.000
	Unwashed RE course, %	2.750	0.065	4.070	0.018	7.100	0.001	19.433	0.000
	5 washed RE wale, %	2.333	0.099	7.778	0.001	44.326	0.000	22.590	0.000
	5 washed RE course, %	8.698	0.000	2.859	0.058	10.207	0.000	14.524	0.000
	15 washed RE wale, %	15.115	0.000	35.198	0.000	72.193	0.000	64.444	0.000
	15 washed RE course, %	46.436	0.000	17.573	0.000	23.953	0.000	12.213	0.000
	25 washed RE wale, %	16.252	0.000	13.968	0.000	37.508	0.000	50.198	0.000
	25 washed RE course, %	63.448	0.000	6.200	0.003	76.581	0.000	21.775	0.000

The values given in gray colour show significant values at 95% confidence level  
RE: Residual Extension (%)

Table 7. Effect of main factors on dimensional change (%) of elastane knitted fabrics.

Source	Dependent variable	21 tex (Ne 28)				16 tex (Ne 36)			
		Normal setting		Tight setting		Normal setting		Tight setting	
		F	Sig.	F	Sig.	F	Sig.	F	Sig.
Gimped yarn type	DC wale, %	31.542	0.000	45.343	0.000	3.520	0.051	5.691	0.012
	DC course, %	1.805	0.193	78.591	0.000	5.600	0.013	31.500	0.000
Washing cycle	DC wale, %	65.153	0.000	57.686	0.000	4.336	0.029	18.632	0.000
	DC course, %	1.026	0.378	31.818	0.000	0.800	0.465	0.500	0.615

The values given in grey colour show significant values at 95% confidence level  
DC: Dimensional change (%)

trend in residual extension values can be along with the increasing recovery time for all test fabrics. A minimum change in residual extension values was obtained for test fabric A10. Test fabrics A5 and A7 have the highest values for every washing cycle, and the decrements in their values are higher than those of the other fabrics for every stage. It is seen again that fabrics made of 16 tex viscose ground yarns have more residual extension than 21 tex viscose fabrics. The fabrics produced from 78dtex70f PA/EL and 78dtex20f PA/EL gimped yarns have the highest and lowest cyclic deformation values, respectively.

When residual extension values for different recovery times in the course direction were examined, it is observed that test fabrics A4 have generally low cyclic deformation values compared to the others for all recovery times. On the other hand, fabrics A5, A7 and A11 have high cyclic deformations, and after 5 washing cycles fabrics A9 also present high residual extension values. It is also important to obtain that in all washing cycles the highest recovery is found after 30 min recovery time for all fabrics. Similar to wale direction results, tight fabrics with thinner viscose ground yarn have generally low residual extension values. With regard to variance analysis (Table 6), it is observed that after different recovery times, the residual extension values of fabrics are significantly different from each other ( $p < 0.05$ ).

### Effect of washing cycles on selected physical properties of elastane knitted fabrics

In order to examine the effect of washing cycles on fabric properties, the mass per unit area, tightness factor and dimensional stability of the fabrics were measured after every washing cycle. In Figure 10 changes in mass per unit area values of the fabrics after 5, 15 and 25 washing cycles are presented.

As presented in Figure 10, increments in the washing cycles increase the mass per unit area values of the fabrics, where the highest increase was obtained after 5 washing cycles. This result is consistent with those of Solaiman et al. (2015), who observed an increase in fabric weight after some washing experiments [13]. This is valid for many of the test fabrics irrespective of the viscose yarn count. As described in the part below, shrinkage

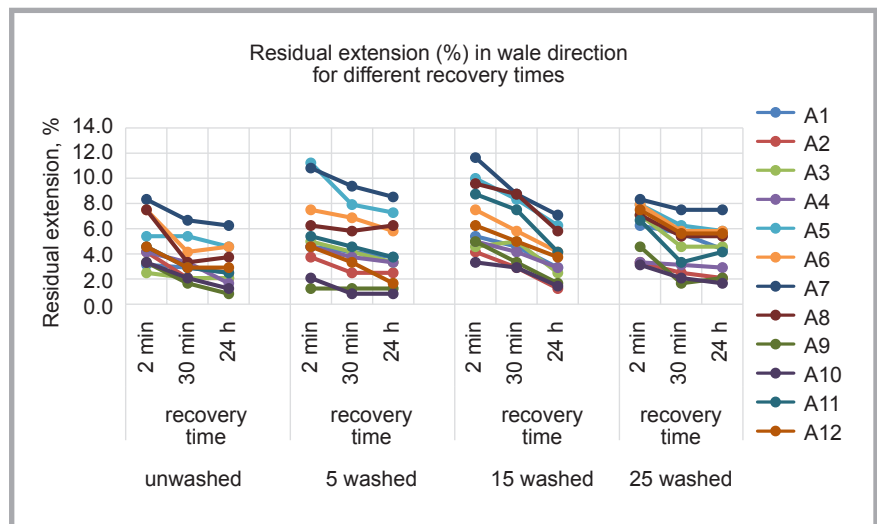


Figure 8. Residual extension values of elastane knitted fabrics in the wale direction for different recovery times and for 0 (unwashed), 5, 15 and 25 washing cycles.

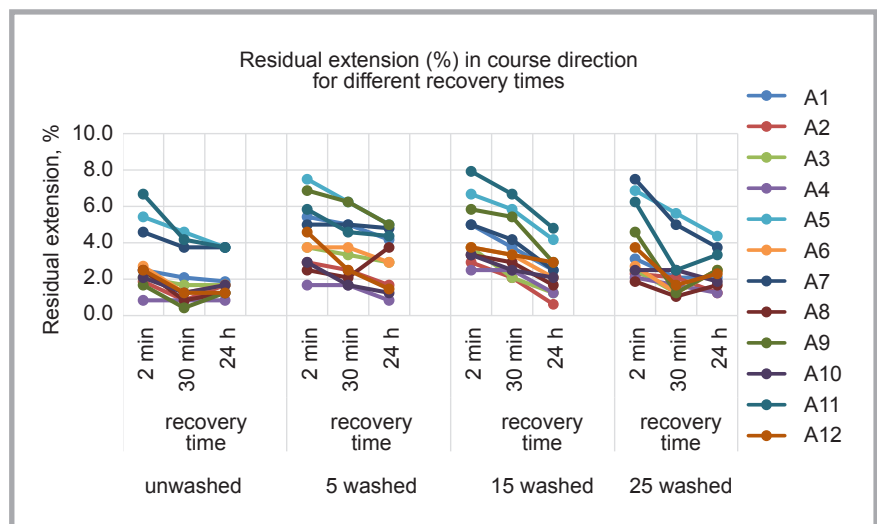


Figure 9. Residual extension values of elastane knitted fabrics in the course direction for different recovery times and for 0 (unwashed), 5, 15 and 25 washing cycles.

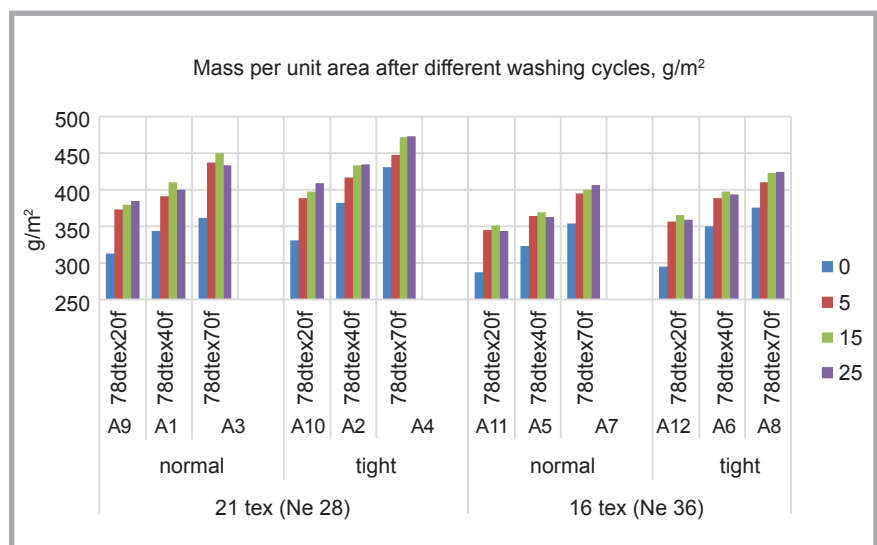


Figure 10. Mass per unit area values of elastane knitted fabrics after different washing cycles.

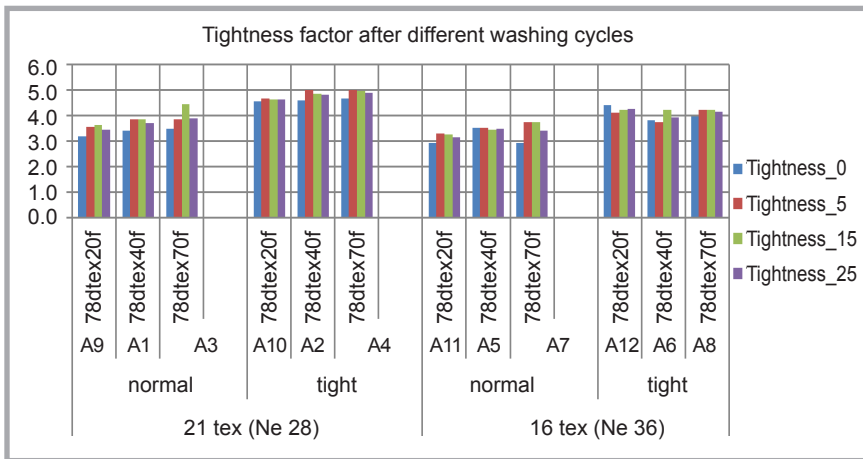


Figure 11. Tightness factor values of elastane knitted fabrics after different washing cycles.

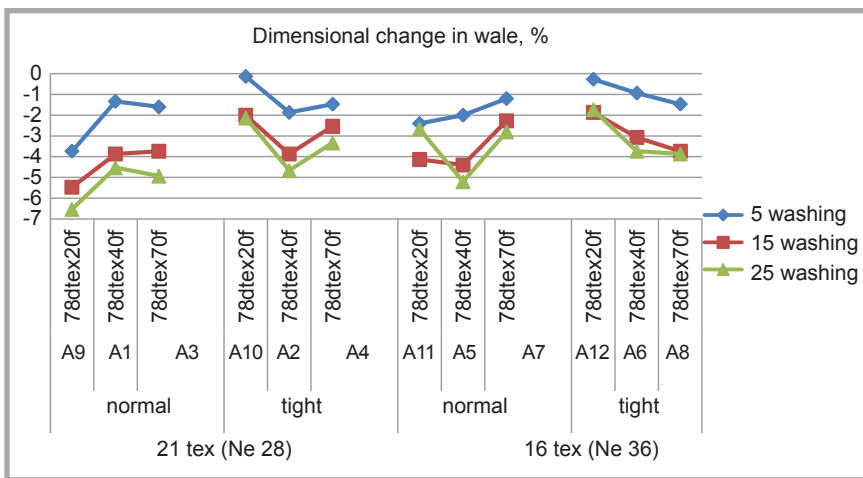


Figure 12. Dimensional change values in the wale direction of elastane knitted fabrics after different washing cycles.

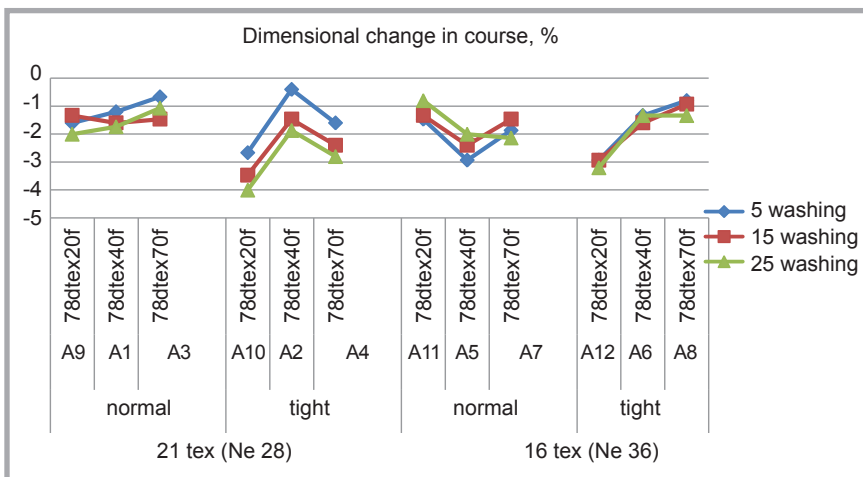


Figure 13. Dimensional change values in course direction of elastane knitted fabrics after different washing cycles.

was observed after washing cycles in all of the fabrics. Because of the shrinkage occurring after washing, the mass of the fabrics in the unit area increases. There is no systematic tendency for the difference (%) in fabric unit weight for the gimped

yarn type. For 25 washing cycles, slight decreases are observed for some fabrics, and it is thought that the breaking and moving away of fibers from the fabric structure may be the possible reason for this situation.

The effect of washing cycles on the tightness factors of elastane knitted fabrics are exhibited in Figure 11.

After 5 washing cycles, an increase in tightness factor values is observed in general. This result is in accordance with the other researchers [2, 3, 13, 25]. It can be said that after 25 washing cycles, tightness values of the fabrics show a diminishing tendency.

Dimensional changes in the wale and course directions after washing cycles are shown in Figure 12 and Figure 13, respectively. According to the dimensional change results, fabrics of a normal tightness level generally exhibit higher values compared to tight fabrics in the wale direction. As Herath and Kang (2009) remarked, under higher fabric tightness, stitches are densely packed and the structure has lesser structural space availability to shrink [25]. It is also seen in the wale direction that the percentage of the dimensional change of the fabrics increases with the increasing of the washing cycles from 0 to 25. This is also in agreement with the results of other researchers [4, 11].

In contrast to the results of the wale direction, tighter fabrics have more dimensional change values than normal ones in the course direction, particularly for 21 tex viscose fabrics. As shown in the course direction results, 16 tex viscose tight fabrics are the least affected by increasing the washing cycles, showing a similar tendency for all washing cycles.

The variance analysis result for dimensional change is given in Table 7. According to the variance analysis, the course setting is a more important parameter than the gimped yarn type. Besides, there is no significant relation between the dimensional change and residual extension properties of the fabrics at a 95% confidence level, which may be related to the elastane content of the fabrics.

## Conclusions

In this study, 12 knitted fabrics with two different base yarn linear densities (21 tex viscose and 16 tex viscose), two different settings (normal and tight) and three different polyamide/elastane gimped yarn (78dtex20f, 78dtex40f and 78dtex70f) were used, and the most effective washing cycle, the most appropriate linear densities of viscose and gimped



yarn, and the critical recovery time were examined.

It is determined that fabrics produced from 21 tex viscose ground yarns have less cyclic deformation than those produced from 16 tex viscose ground yarns after all repeated washings (0, 5, 15 and 25). When the setting levels are compared for the linear density of each viscose ground yarn, it is clearly seen that the fabrics of higher setting show lower residual extension for all washing cycles. When the effect of the number of filaments in the gimped yarn structure is examined, it is seen that fabrics of 78dtex20f elastane gimped yarn show the lowest residual extension compare to the others, especially in the wale direction. Besides this, high cyclic deformation values were generally observed for the fabrics produced from 78dtex70f PA/EL gimped yarns. It is understood that the choice of gimped yarn type is more important for 16 tex viscose fabrics than for 21 tex ones.

The critical washing cycles in this research seem to be 5 and 15 for all test fabrics in the two different test directions. Regarding residual extension values in relation to washing cycles, it is possible to claim that the effect of the washing cycles is not generally statistically significant for tight fabrics of 21 tex viscose yarns. For those fabrics, there is no difference as regards choosing the type of gimped elastane yarn. Considering the many parameters of the test fabrics, such as the ground yarn count, setting level, gimped yarn type and washing cycle, it is possible to reveal that the critical recovery time is 30 min for all test fabrics. After this recovery time, only small changes can be found in residual extension values. After a 24 h recovery time, all fabrics show lower residual extension values than 4%. According to the dimensional change results of the elastane knitted fabrics, shrinkage was observed after washing cycles in all of the fabric samples. Mass per unit area values of the elastane knitted fabrics increased considerably with the washing effect after 5 washing cycles, which continued after 15 washing cycles due to fabric shrinkage. But the values slightly decreased after 25 washing cycles, with the effect of fibers detaching from the yarn structure. According to the results for the tightness level of the elastane knitted fabrics, tighter fabrics showed less cyclic deformation compared to normal tightness level fabrics.

In conclusion, this paper presents an analysis and investigative study of elastane knitted fabrics which are widely used in the textile and apparel market with selected production parameters. It is hoped that the findings and evaluations from the study will provide useful knowledge and helpful information in the understanding and predicting of the usage performance of elastane knitted fabrics for researchers and engineers in the industry.



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