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EFFECTS OF REPEATED IRONING-LAUNDERING CYCLES ON COTTON, COTTON/ POLYESTER AND POLYESTER PLAIN FABRICS

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ABSTRACT

Textile products require laundering for a number of times throughout their wear life. Fabrics are mainly damaged by chemicals and mechanical distortions they are exposed during laundering which leads to the unpleasant appearance. Ironing is a process of smoothing out wrinkles by heat, pressure and friction, often with application of moisture or steam. The present contribution deals with the characterization of smoothness appearance, low-stress mechanical and dimensional properties of cotton, cotton/polyester and polyester plain fabrics after repeated cycles of laundering/ironing in comparison with repeated cycles of laundering. The results show that repeated ironing can preserve an appreciate smoothness appearance during wear life and also reduce the effects of successive launderings on low stresses mechanical properties.

KEYWORDS

Laundering/ ironing cycles; fabric smoothness appearance; low stress mechanical properties; dimensional stability.

1. INTRODUCTION

Laundering is a process that aims to remove soils and/or stains by treatment in an aqueous detergent solution or/and normally including rinsing, extracting and drying. This process usually changes the perception of the fabric handle significantly (Selvaraju et al., 2000). Easy wrinkling of a fabric leads to the unpleasant appearance of the clothes produced from that fabric. So, clothes must be ironed after the laundering process. Ironing is a process of smoothing out wrinkles and/or removing moisture by heat, pressure and friction, often with application of moisture or steam.
Little has been published on the effects of pressing and restorative ironing on aqueous laundered garments (Behery, 2005).
Particular attention has focused on the study of the effect of only repeated domestic laundering on knitted fabric properties without considering the effect of intermediary ironing between launderings.
As example, in their study, Mavruz and Oğulata (2009) 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 researchers 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 an another study, Önal and Candan (2003) examined the changes of dimensional properties of three different knitted fabrics consisting of cotton and cotton/polyester fibers blends, various densities and yarn types after applying numerous laundering and drying processes. The researchers

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indicated that the effects of fabric density, knitting type, yarn type and fiber blend on the dimensional characteristics of the fabric were significant.
Lau et al. (2002) stated that the application of wrinkle resistant finish on knitted shirting fabrics made of 100 % cotton kept shrinkage under control, improved crease resistance characteristics and decreased the side effects of the laundering process.
In their study, Quaynor et al. (2000) examined the effects of laundering temperature and repetitive laundering process on the dimensional stability of single jersey fabrics of cotton, silk and polyester fibers. They stated that fabric dimensional stability was affected by the fiber type and the fabric's structural parameters, rather than laundering parameters. Fabrics become more wrinkled with increasing temperature and repetitive laundering.
Erdem (2008) stated that the wrinkle resistance of viscose fabric was affected by the discontinuous laundering.
However, only the research work of Jiˇrí et al. (1997) has described the influence of ten repeated laundering/ironing cycles on the hand, shrinkage and surface roughness of cotton weave with two different treatments: sanforization and soft finishing. He stated that the influence of laundering/ironing cycles on the properties of cotton weaves is very complex and that it is dependent of the fabric's type and finishing.
Fabric aesthetic properties include the optimized handle of fabric, good appearance in the garment and good appearance in wear. Fabric properties like thickness, compressibility, bending properties, extensibility and dimensional stability are associated with fabric aesthetics (Hu, 2008).
Fabric assurance by simple testing (FAST system) is as useful set of instruments for light-weight wool fabrics (Ly et al., 1990). Its modules allow the prediction of fabric performance and the appearance during wear (Ly et al., 1988). The use of this system was not limited to wool fabrics, it was used by many researchers for natural and manmade fabrics (Shakyawara, 2015); (Giuffiths, 2002); (El-Gamal 2014); (Haghighat et al., 2012). In a previous research, Cheriaa et al. (2015) finds that compression, tensile and dimensional properties measured by FAST system are the most influenced fabric properties by steam ironing treatment.
The basic target of the present paper is to study plain weave fabrics behaviour after one, 5, 10 and 20 repeated cycles of laundering/ ironing. Results are compared to behaviours of the same selected weave fabrics subjected only to repeated launderings. So, this work is a comparative study between two consumer habits: "Laundering with or without ironing before wearing cloths", which are not studied yet. The novelty of this contribution is the evaluation based on smoothness appearance, on low stress mechanical properties and on dimensional changes. Three light-weights weave plain fabrics made from cotton, cotton/ polyester and polyester were selected for this study.

2. MATERIALS AND METHODS

2.1. Materials

This study was conducted on cotton, cotton/polyester and polyester plain weave fabrics. Basic characteristics of the selected fabrics are shown in table 1.

Table 1: Basic structural parameters of unwashed fabrics

Fabric code		F 1	F 2	F3
Composition		Cotton (100 %)	Polyester (100 %)	Cotton / Polyester (80% /20%)
Weave design (ISO 2959)		Plain	Plain	Plain
Density, cm^{-1} (ISO 7211-2)	warp	35	29	32
	weft	32	29	26
Area density, g/m^2 (ISO 3801)		138	124	137.5
Linear density, Tex (ISO 2060)	warp	19	22	19
	weft	20	17	20
Thickness, mm (ISO 5084)		0.322	0.3	0.326

The described fabrics are chosen with close mass values (light weight fabric <150 g/m^2), thickness and with the same weave type from the same industrial production. Plain weave is chosen because it's the weave type with the highest number of interlacing showing the worst resistance to wrinkles during wear and laundering compared to twill and satin because of the restriction of yarn slippage.

2.2. Methods

(60cm× 60cm) over-sewed specimens of each fabric have been processed on domestic laundering cycles and ironing/domestic laundering cycles.
The laundering/ironing cycle was realized by three successive operations:

(1) Washing and water extraction in washer-extractor machine "Electrolux Wascator Fom 71 MP-Lab".
(2) Flat drying in conditioned atmosphere.
(3) Steam ironing.

The washing method as stated in was adapted to simulate repeated home laundering practices for treating the fabric specimens with different laundering cycles: one, five, ten and twenty.
Washing cycle is described in table 2:

Table 2 : Description of the wash cycle

Main wash				Rinse 1		Rinse 2			Rinse 3	
Temperature °C	Load, kg	Bath level, cm	Time, min	Bath level, cm	Time, min	Bath level, cm	Time, min	Spin time, min	Bath level, cm	Time, min
40±3	2±0.1	10	15	13	3	13	3	1	13	2

After laundering, the specimens are conditioned according to ISO 139: 2005 for 24 h prior to further evaluation or ironing. The first part of fabric specimens were ironed, on one side, on a straight line profile, by a continuous movement, in the straight of grain of the fabric, until wrinkle removing, with a common steam hand iron (Macpi model 028, 2kg), carefully applied by the weight of iron itself. The sole plate temperature is about 150°C ± 3°C. The steam used is about 132°C.
After ironing, the specimens are conditioned according to ISO 139: 2005 for 24h. The other part of samples is kept as reference without ironing treatment.
Smoothness appearance was analyzed according to test method "AATCC 124-2009: Smoothness appearance of fabrics after repeated home laundering". This method is designed to evaluate the smoothness appearance of flat fabric specimens after repeated home laundering. Evaluation is performed using a standard lighting D65 and viewing area by rating the appearance of specimens in comparison with appropriate reference standards shown in figure 1.

SA.1	SA.2	SA.3	SA.3.5	SA.4	SA.5
Crumpled, creased, severely wrinkled appearance	Rumpled, obviously wrinkled appearance	Mussed, non pressed appearance	Fairly smooth, non pressed appearance	Smooth, finished appearance.	Very smooth, pressed, finished appearance.

Figure 1: AATCC 3-D smoothness appearance replicas disposed on a plan at 45° and taken under D65.
The FAST System [FAST-1, FAST-2 and FAST-3] was used to measure fabric mechanical properties: compression, bending and tensile.

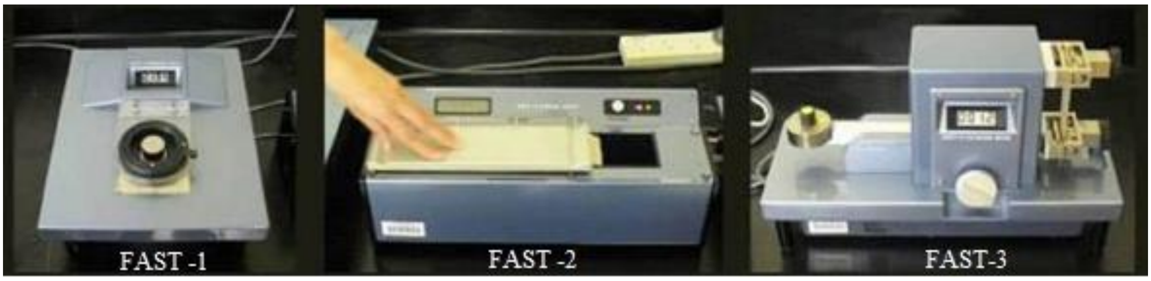


Figure 2: SIRO FAST Instruments

Using the FAST system, 16 parameters given in table 3 can be measured and calculated.

Table 3: Fabric properties measured and calculated from FAST system (Minazio P.G., 1995)

Instrument	Property	Symbol/Formula	U.M	Number of samples
FAST-1	Thickness at 2 gf/cm^2 (0,196 kPa)	T2	mm	5
	Thickness at 100 gf/cm^2 (9.81 kPa)	T100	mm	5
	Surface Thickness	ST=T2-T100	mm	
FAST-2	Bending Length in warp direction	C1	mm	3
	Bending Length in weft direction	C2	mm	3
	Bending Rigidity in warp direction	$B1 = w \times C_1^3 \times 9.807 \times 10^{-6}$	µN.m	
	Bending Rigidity in weft direction	$B2 = w \times C_2^3 \times 9.807 \times 10^{-6}$	µN.m	
	Weight (per unit area),	w	g/m²	3
FAST-3	Warp Extensibility at 5 gf/cm (4.9 N/m)	E5-1	%	3
	Weft Extensibility at 5 gf/cm (4.9 N/m)	E5-2	%	3
	Warp Extensibility at 20gf/cm (19.6 N/m)	E20-1	%	3
	Weft Extensibility at 20 gf/cm (19.6 N/m)	E20-2	%	3
	Warp Extensibility at 100 gf/cm (98.1 N/m)	E100-1	%	3
	Weft Extensibility at 100 gf/cm (98.1 N/m)	E100-2	%	3
	Bias Extensibility at 5 gf/cm (4.9 N/m)	EB5	%	6
	Shear rigidity	G=123/EB5	N/m	

Dimensional changes are evaluated according to ISO 3759: 2007: “Textile-preparation-marking-and measuring of fabric specimens and garments in test for determination of dimensional changes”. The dimensional changes in washed and ironed specimens were measured according to ISO 3759: 2007: Textiles- preparation, marking and measuring of fabric specimens and garments in tests for determination of dimensional change. One specimen of dimension 600 mm×600 mm was tested. Three pairs of reference points were made in each direction on the fabric keeping a distance of 350 mm apart, having placed not nearer than 35 mm to the edge. All specimens were then conditioned under a standard atmosphere and then measured. The percentage of change in dimension Y is calculated using the following formula:

$$Y\ (\%) = \frac{x(t) - x(0)}{x(0)} \times 100 \qquad (1)$$

Where x (0) is the original dimension and x (t) the dimension measured after treatment in mm.
All tests were carried out under standard conditions (65 ± 4% RH and 20 ± 2 °C).

3. RESULTS AND DISCUSSIONS

The present contribution aims to present a comparative analysis of smoothness appearance, physical (thickness, weight, bending properties, tensile “extension” and shear rigidity) and dimensional changes of light weighted plain woven fabrics subjected to repeated cycles of laundering and ironing/laundering. Different fabric compositions are studied: cotton, polyester and polyester cotton.

3.1. Smoothness appearance

Smoothness appearance is a visual impression of planarity of a specimen laundered and usually quantified by comparison with a set of reference standards according to AATCC test method. Although the 3-D smoothness appearance replicas were cast from woven fabrics, it is understood that these wrinkled surfaces do not duplicate all possibilities of fabric surfaces. So observer should mentally integrate degree and frequency of wrinkles in the specimens to determine a level of smoothness.

Table 4: Fabric smoothness appearance after repeated laundering and ironing/laundering

Fabric code	Treatment	1	5	10	15	20
F1	Laundering	SA.2	SA.2	SA.2	SA.2	SA.2
	Ironing/Laundering	SA.2	SA.2	SA3	SA.3.5	SA.3.5
F2	Laundering	SA.3.5	SA.3.5	SA.3.5	SA.3.5	SA.3.5
	Ironing/Laundering	SA.3.5	SA3.5	SA3.5	SA.4	SA.4
F3	Laundering	SA.3	SA3	SA.3	SA.2	SA.2
	Ironing/Laundering	SA.3	SA.3.5	SA3.5	SA.3.5	SA.3.5

- A change in the colour of the table cell shows a change in the smoothness appearance.

Table 4 illustrates the change of smoothness appearance under different cycles of laundering and ironing/laundering.

It can be noticed that although the three fabrics were carried under the same conditions of laundering, the smoothness appearance is significantly dependant on the fibre type. Cotton fabric has poor wrinkle recovery mainly due to attractive forces between fibres, such as Van der Waals forces and hydrogen bonds. Since these forces are relatively weak, they can be easily broken and rearranged by moisture and external stress (spinning, machine load). Once the stabilizing bonds are broken, the polymer chains are free to move and slippage occurs between them. New attractive forces form at a new location and tend to maintain the fibres in the shifted – bent or wrinkled – geometry. A bend or wrinkle, once formed, thus remains largely unchanged until external inputs – nothing else than the well-known ironing – convey adequate moisture, heat and mechanical energy to overcome the forced internal binding and remove wrinkles from the fabric (Bojan et al., 2014). Heat can disrupt hydrogen bonds, which can explain how ironing works. The weight of the iron flattens the fabric and the novel shape is then retained as the material cools. Ironing with steam is especially effective because the added water molecules serve as an internal lubricant, breaking hydrogen bonds and allowing cellulose molecules to slide past each other (Bojan et al., 2014). As heat is applied, the water evaporates, hydrogen bonds reform, and we have smoothened fabric. At least, smooth until it gets moist from perspiration.

Polyester has the smallest absorption ability because of the higher degree of crystalline zones in the polymer fibres. In addition, the glass transition temperature is about 85°C and it’s not reached by the laundering temperature (Wang et al., 2002). So, the fabric can resist to wrinkles.

It can be noticed from table 3 that ironing cycles changes the smoothness appearance mainly of cotton fabric. Cotton samples appearance pass from grade SA.1 to SA.2 in the first five cycles and to SA.3.5 in 20th cycles of ironing/laundering.

Polyester fabric was initially fairly smooth (SA.3.5), enhance of appearance is slightly from 3.5 to 4 after 15th cycles of ironing/laundering.

Fabric F3 made from a blend of polyester and cotton fibres shows a different behaviour compared to the first ones. A decrease in smoothness appearance is clear after 15 cycles of laundering. Difference in yarn characteristics made from a blend of cotton and polyester fibres compared to F1 or F2 made from 100% cotton or 100% polyester may show evidence of shrinkage, puckering and fuzzing of

yarns. However, a slight improving in the smoothness appearance of fabric F3 is also noted after the first five cycles of ironing/ laundering from SA.3 to SA.3.5.
So, for all selected fabrics, ironing removes wrinkles from fabrics after every laundering, but also contributes to improving the smoothness appearance and so the degrees of wrinkles of selected fabrics along wear life. Smoothness appearance is mainly noticed in 100% cotton fabric and with a lower degree in polyester fabric. This may reflect a property of weave a plain fabric structure which is “shape memory”, that is to say, the fabric response to repeated cycles of ironing/laundering is a remember of the flattened shape given by steam ironing.

3.2. Low stress mechanical properties

Fabric handle is related to basic mechanical properties; compression, bending, tensile and especially initial low stress regions of these properties (Mitsuo et al., 2006). The results of the measurements of different fabrics properties before and after various treatments are given below. We analyzed the data set for any possible trends or cause-effect relationships.

3.2.1. Compression properties

The mean values and the standard deviation of the FAST compression meter measurements of cotton, cotton/polyester and polyester fabrics are summarized in tables 5.

Table 5: Thickness T2, T100 and calculated surface thickness ST of fabrics F1, F2 and F3 during repeated laundering and ironing/ laundering cycles.

Fabric code	Property	Non treated	1		5		10		20	
			L	IL	L	IL	L	IL	L	IL
F1	T2	0.489 (1.8)	0.970 (3.4)	0.959 (5.1)	0.767 (6.1)	0.656 (4.8)	0.646 (2.4)	0.520 (3.4)	0.643 (4.8)	0.463 (5.04)
	T100	0.253 (1.06)	0.291 (2.5)	0.29 (2.9)	0.289 (2.3)	0.289 (2.3)	0.275 (3.0)	0.255 (1.6)	0.273 (2.7)	0.259 (3.1)
	ST	0.236	0.679	0.669	0.478	0.367	0.371	0.265	0.37	0.2406
F2	T2	0.271 (0.3)	0.281 (0.5)	0.281 (0.5)	0.286 (0.9)	0.284 (0.4)	0.286 (0.6)	0.275 (0.5)	0.287 (0.8)	0.272 (0.4)
	T100	0.246 (0.3)	0.253 (0.4)	0.254 (0.3)	0.258 (0.5)	0.265 (0.2)	0.255 (0.3)	0.25 (0.16)	0.256 (0.4)	0.251 (0.2)
	ST	0.025	0.029	0.028	0.028	0.019	0.0314	0.021	0.0362	0.0214
F3	T2	0.380 (2.1)	1.141 (4.8)	1.03 (4.2)	1.054 (6.3)	0.496 (3.7)	1.352 (5.07)	0.513 (3.2)	1.31 (5.7)	0.4962 (4.8)
	T100	0.217 (1.39)	0.249 (3.9)	0.254 (2.8)	0.248 (2.4)	0.224 (4.5)	0.259 (3.04)	0.225 (3.4)	0.257 (2.6)	0.22 (0.7)
	ST	0.162	0.891	0.776	0.806	0.272	1.093	0.288	1.053	0.2492

- (Standard deviation, %)
- L: designs Laundering cycle, I.L: designs Ironing /Laundering cycle

Compression may be defined as a decrease in intrinsic thickness with an appropriate increase in pressure. Surface thickness ST shows the roughness of fabric surface and structural stability of a surface layer. The fabric is considered to consist of an incompressible core and a compressible surface. It is reported that an increase in the surface thickness (less than 0.1 mm) can be perceived subjectively in fabric handle. For very thin and light-weight fabrics, a smaller increase in ST could produce a perceptible change in handle (Ly et al., 1991).
It is evident that when using a higher load during thickness testing, thickness is lower.
In the case of cotton fabric, the maximum increase in surface thickness ST is seen in the first five laundry cycles. It is determined that; the increase in thickness (compared to the untreated fabric) at

the end of 20^{th} laundry cycles is lower than the increase at the end of 5^{th} and 10^{th} cycles. In fact, in woven structures, during the first launderings, the yarns would interlace to a greater extent. After drying, the yarns could not recover to their original thickness due to the releasing of temporary tension. In addition to the shrinkage effect, the swelling factors could also lead to the change in thickness after laundering.
In the first ironing/ laundering cycles, the surface thickness of fabric F1 increased rapidly with the same degree of fabric only laundered and then decreased to approximately 0.2 mm when processed in 10 ironing/ laundering cycles, 0.2 mm corresponds to the surface thickness of a smooth surface (Fan, 2014). This may reflect that although ironing is a temporary setting process and its effects are normally eliminated with laundering, cotton fabric may keep the flattened shape surface after repeated ironing/laundering. This result is consistent with the improving of smoothness appearance after repeated laundering /ironing found in the previous paragraph.
For polyester fabric, thickness change is very small and the fabric stills maintain the same surface thickness along repeated laundering and laundering/ironing cycles. So, polyester fibres have the valuable characteristics of conferring minimum care properties on fabric containing it. So most polyester fabrics if washed correctly not require or at most only light ironing.
Polyester/cotton fabric allowed to be ironed between launderings show a greater decrease in surface thickness compared to the non ironed one. However, the fabric only laundered shows an increase in surface thickness with the increase of number of cycles. This result is consisting with the analysis of fabric smoothness appearance (table 4) which shows clear signs of damage after repeated laundering cycles from SA.3 to SA.2. The progressive increase in surface thickness can be explained by the fact that fabric based on low-shrinkage chemical fibres has lower shrinkage than pure cellulose fibres, so laundering produces shrinkage in different degrees in the same fabric which may explain the degradation of appearance and the sensory properties of the fabric.

3.2.2. Bending properties

Bending length is related to the ability of a fabric to drape and bending rigidity is related more to the quality of stiffness felt when the fabric is touched and handled.

Analyzing FAST-2 measurements made on fabric F1, it is possible to state that bending length increased as the number of laundering cycle's increases up to five cycles, and gradually decreased thereafter. The increases bending rigidity during the first launderings is related to yarn -to -yarn friction (Cronjè et al., 2013).
Starting from the considerations that the thickness of the cotton fabric decreases after 5^{th} repeated cycles and in a greater degree when ironing/laundering fabric samples, so lower bending rigidity are remarked (Yüksekkaya et al., 2008).
No significant change of bending properties of polyester fabric F2 was observed with ironing fabric inter launderings compared to bending properties of fabric samples only laundered.
Cotton polyester fabric i.e. fabric F3 doesn't show the same behaviour after repeated laundering when compared to 100 % cotton fabric (F1) and to 100 % polyester fabrics (F2). Bending length still maintains a steady value and then decreased between the 10^{th} and the 20^{th} cycle.
No significant change of bending properties of polyester/cotton fabric was observed with ironing fabric inter launderings compared to bending properties of fabric samples only laundered.

Table 6: Bending properties in warp and in weft directions of fabric F1 during repeated cycles of laundering and ironing/ laundering

Fabric F1	Non treated	1		5		10		20	
		L	I.L	L	I.L	L	I.L	L	I.l
C1	21 (0)	19.16 (1.5)	19.5 (2.56)	22.25 (1.58)	21.25 (1.66)	17.5 (0)	15.5 (3.22)	15.83 (4.82)	14.83 (1.94)
C2	21.3 (1.35)	21.5 (2.32)	22 (0)	23 (0)	20 (0)	17.5 (0)	16.16 (1.94)	18.33 (1.57)	16 (0)
w	138.46 (0.06)	145.56 (0.06)	144.8 (0.07)	153.3 (0.1)	153.1 (0.4)	154.5 (0.047)	154 (0.023)	154.7 (0.03)	153.7 (0.05)
B-1	12.5	10	10.52	16.56	14.41	8.12	5.5	6.02	4.98
B-2	13.1	14.19	15.12	18.29	12.015	8.12	6.43	9.34	6.17

Table 7: Bending properties in warp and in weft directions of fabric F2 during repeated cycles of laundering and ironing/ laundering

Fabric F2	Non treated	1		5		10		20	
		L	I.L	L	I.L	L	I.L	L	I.L
C1	17 (0)	16.3 (1.76)	16.5 (0)	16.03 (1.5)	16.47 (1.45)	15.9 (1.15)	16.05 (2.45)	15.87 (3.45)	15.75 (4.1)
C2	23.5 (0)	22 (0)	22.14 (1.5)	21.4 (1.81)	21.16 (1.36)	20.45 (1.12)	19.8 (2.4)	20.62 (2.46)	19.25 (1.78)
w	124.16 (0.07)	125.2 (0.5)	124.6 (0.02)	125.7 (0.6)	124.9 (0.01)	126.1 (0.02)	125.5 (0.07)	126.3 (0.08)	125.7 (0.04)
B-1	5.95	5.31	5.49	5.07	5.47	4.97	5.09	4.95	4.81
B-2	15.8	13.07	13.2	12.08	11.6	10.57	9.55	10.86	8.79

Table 8: Bending properties in warp and in weft directions of fabric F3 during repeated cycles of laundering and ironing/ laundering

Fabric F3	Non treated	1		5		10		20	
		L	I.L	L	I.L	L	I.L	L	I.L
C1	19.16 (1,5)	14.16 (2,03)	14.3 (2,014)	17 (0)	16 (0)	16.5 (3,03)	14.5 (0)	10.5 (0)	13.5 (0)
C2	25 (0)	20.16 (1,43)	20.5 (0)	20.75 (3,27)	20.75 (3,27)	22 (0)	23 (0)	16.75 (1,73)	17.16 (1,68)
w	137.5 (0.137)	144.2 (0.2)	144 (0.17)	150 (0.146)	149.3 (0.186	150.7 (0.148)	149.8 (0.123)	151.05 (0.145)	149.7 (0.125)
B-1	9.4	4.015	4.13	7.22	5.99	6.63	4.47	1.71	3.61
B-2	21	11.58	12.18	13.14	13.08	15.73	17.87	6.96	7.41

3.2.3. Extension properties

It is observed from tables 9, 10 and 11 that the extensibility of cotton, polyester, cotton/polyester fabrics samples increases with increased applied load but not at the same rate after the first laundering due to the relaxation of threads in the fabric.

Also, extensibility E100 is higher in warp direction (E100-1) compared to weft direction (E100-2) in the case of untreated fabrics, in fact, when a fabric is subjected to tension in one direction (warp or weft), the extension takes place in two main phases:

(1).The first phase is: decrimping or crimp removal in the direction of load.

(2).The second phase is the extension of the yarn, during which the fabric becomes stiffer, the stiffness depending mainly on the character of the yarn.

So, the more crimp there is in the warp or in the weft yarn, the more extensible is the fabric in this direction.
It is also clear that the percentage of extensibility was found to be low for the non treated polyester fabric because polyester fibres are of inherent poor elasticity property.
It is observed that the number of ironing/laundering cycles have not a significant effect on extension properties of polyester fabric compared to the same fabric only laundered (table 10).

Table 9: Extension properties of fabric F1 after repeated laundering and laundering/ ironing

Fabric F1	Non treated	1		5		10		20	
		L	I.L	L	I.L	L	I.L	L	I.L
E5-1	0.4 (0)	0.5 (0)	0.5 (0)	0.5 (0.05)	0.4 (0)	0.5 (0)	0.4 (0)	0.3 (0)	0.26 (0)
E5-2	0.3 (0)	0.4 (0)	0.4 (0)	0.4 (0)	0.4 (0)	0.5 (0)	0.4 (0)	0.4 (0)	0.5 (0)
E20-1	1.3 (1.9)	1.6 (6.25)	1.5 (0)	1.5 (0)	1.4 (7.14)	1.4 (7.14)	0.9 (2.85)	1 (0)	0.46 (1.94)
E20-2	0.5 (0)	1 (5.41)	1.1 (0)	1.2 (4.68)	1.2 (0)	1.2 (8.33)	1.1 (0)	1.1 (0)	1.1 (5.41)
E100-1	5 (2.27)	5.3 (5.4)	5.2 (4.8)	4.9 (4.47)	4.3 (2.64)	4.8 (2.53)	4.6 (2.55)	4 (0)	3.2 (3.125)
E100-2	1.3 (4.33)	2.9 (1.94)	2.95 (1.96)	2.45 (2.37)	2.1 (2.79)	2.9 (2.94)	2.7 (0)	2 (0)	1.5 (6.66)
EB5	0.7 (0.05)	1 (0.07)	1 (0.07)	1.3 (0.059)	1.1 (0.09)	1.2 (0.058)	1.1 (0.1)	2.8 (0.07)	2.2 (0)
G	175.5	123	123	94.9	111.8	102.5	111.8	43.9	55.9

Table 10: Extension properties of fabric F2 after repeated laundering and laundering/ ironing

Fabric F2	Non treated	1		5		10		20	
		L	I.L	L	I.L	L	I.L	L	I.L
E5-1	0.3 (0)	0.5 (4.1)	0.5 (10.8)	0.5 (0)	0.5 (0)	0.5 (0)	0.5 (0)	0.45 (5.6)	0.55 (5.78)
E5-2	0.1 (0)	0.2 (0)	0.25 (4.1)	0.2 (0)	0.2 (0)	0.25 (3.7)	0.2 (0)	0.15 (6.4)	0.15 (6.4)
E20-1	0.8 (0)	1 (0)	1.1 (9.09)	1 (3.7)	1.1 (9.09)	1 (10)	1.2 (0)	1.25 (4.68)	1.4 (0)
E20-2	0.2 (0)	0.3 (0)	0.32 (1.54)	0.3 (0)	0.3 (0)	0.3 (0)	0.3 (0)	0.25 3.7	0.3 (0)
E100-1	2.2 (0)	2.6 (2.19)	2.6 (2.19)	2.7 (3.3)	2.75 (0.09)	2.75 (0.09)	2.85 (1.85)	3.25 (6.43)	3.5 (0)
E100-2	0.4 (0)	0.7 (1.96)	0.75 (2.56)	0.7 (1.45)	0.6 (2.7)	0.75 (2.78)	0.65 (9.11)	0.65 (5.87)	0.75 (3.3)
EB5	2.58 (2.1)	2.98 (3.04)	2.85 (2.5)	2.74 (1.85)	2.7 (2.1)	2.8 (2.31)	2.9 (1.25)	4.75 (0.05)	3.5 (1.46)
G	47.61	41.22	43.15	44.89	45.55	43.92	42.4	25.9	35.14

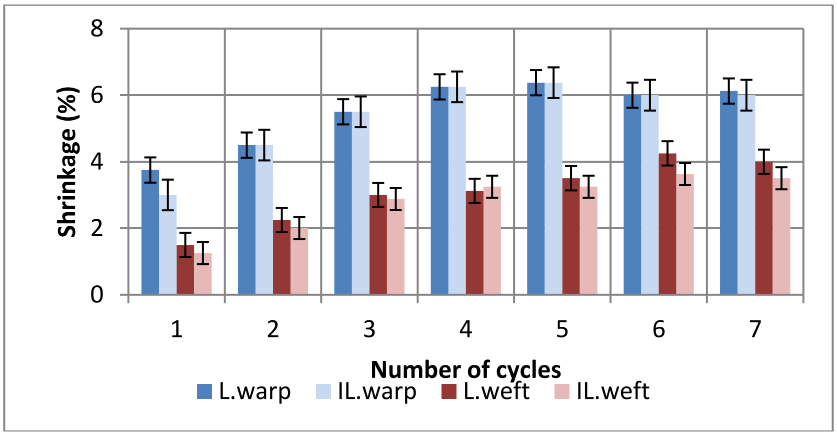
Table 11: Extension properties of fabric F3 after repeated laundering and laundering/ ironing

Fabric F3	Non treated	1		5		10		20	
		L	I.L	L	I.L	L	I.L	L	I.L
E5-1	0.1 (0)	0.1 (0)	0.1 (0)	1.1 (0)	0.7 (0)	1.2 (0)	0.6 (0)	1 (0)	0.75 (9.42)
E5-2	0.1 (0)	0.5 (0)	0.5 (7.98)	0.4 (0)	0.3 (10.45)	0.6 (0)	0.3 (12.12)	0.45 (13.32)	0.45 (13.32)
E20-1	0.3 (0)	0.85 (8.31)	0.8 (0)	2.3 (0)	1.2 (5,45)	2.7 (6,13)	1.5 (0)	2.5 (0)	1.75 (6,53)
E20-2	0.26 (3,87)	0.5 (3,7)	0.5 (0)	0.9 (0)	0.5 (4,87)	1.4 (0)	0.5 (0)	1.25 (9,11)	0.95 (5,97)
E100-1	1.06 (3,96)	3.6 (0)	3.6 (3,3)	5 (0)	3.2 (3,53)	6.2 (4,08)	3.9 (0)	5.2 (0)	4.05 (1,43)
E100-2	0.86 (5,46)	2.6 (0)	2.7 (0)	2.2 (0)	1.5 (0)	3.1 (3,3)	1.6 (2,78)	2.8 (1.94)	2.3 (4.87)
EB5	1 (2.1)	1.16 (3.8)	1.1 (0)	1.2 (4.78)	1.1 (5.89)	1.3 (4.78)	1.2 (0)	2.3 (6.9)	2.3 (0)
G	123	106	111.8	102.5	111.8	94.61	102.5	53.47	53.47

However, in the case of cotton fabric (table 9), extensibility of the samples maintains a steady value for the 10^{th} cycle of laundering and then decreases gradually.
The difference in the extension properties between the only laundered and ironed laundered fabric samples begin to be clear from the 5^{th} cycles. Less extension in each direction is noted in samples processed to ironing laundering cycles.
Polyester/cotton fabric shows a similar behaviour comparable to 100% cotton fabric in extension properties. In fact, firstly, an increase in extension is noted with the increase of laundering cycles and secondly, ironing leads to retain fabric extension properties.
Shear rigidity is a parameter providing a measure of the resistance to rotational movement of warp and weft threads within a fabric when subjected to low levels of shear deformation.
About 42 % drop in the shear rigidity value is observed in the cotton fabric after the first cycle of laundering and 68% drop after 20^{th} cycles of laundering.
The decrease in the shear rigidity value is about 13% in the polyester fabric after the first cycle of laundering and 45.5% after 20^{th} cycles.
The decrease in shear rigidity after laundering can be explained by the fact that: For cotton fabric, yarns swell under wet relaxation. When the fabric is dried the crimp remains, and the inter-yarn friction is reduced, producing a fabric with lower shear rigidity. For polyester, it may be also related to the decrease in inter-yarn friction, so the interlaced yarns can glide over each other more easily.
The fully relaxed structure, in which adhesion between fibres is largely prevented, would be expected to achieve constant shear rigidity after a few wash cycles (5-10 cycles). However, on further increasing the wash cycles, the shear rigidity values decrease.
In other hand, the multi laundering followed by ironing effects on the shear rigidity. The increased fibre-fibre contact resulting from ironing, restrict the relative movement of adjacent fibres and yarns and thereby increase rigidity (Selvaraju et al., 2000).
From table 11, it is well seen that shearing rigidity of fabric F3 decreases between the 10^{th} and the 20^{th} laundering cycle and that the decrease is lower when the fabric is subjected to laundering /ironing cycles.

3.3. Dimensional changes

After the specimens were subjected to repeated laundering and ironing/laundering practices, the benchmarks on the fabric specimens were measured so as to determine the percentage of shrinkage in the directions of warp and weft. Figures 3, 4 and 5 illustrate shrinkage of fabrics F1, F2 and F3 after repeated cycles of ironing/laundering and laundering.



- L: designs Laundering cycle /IL: designs ironing /laundering cycle

Figure 3: Shrinkage of fabric F1 after repeated laundering and ironing/laundering

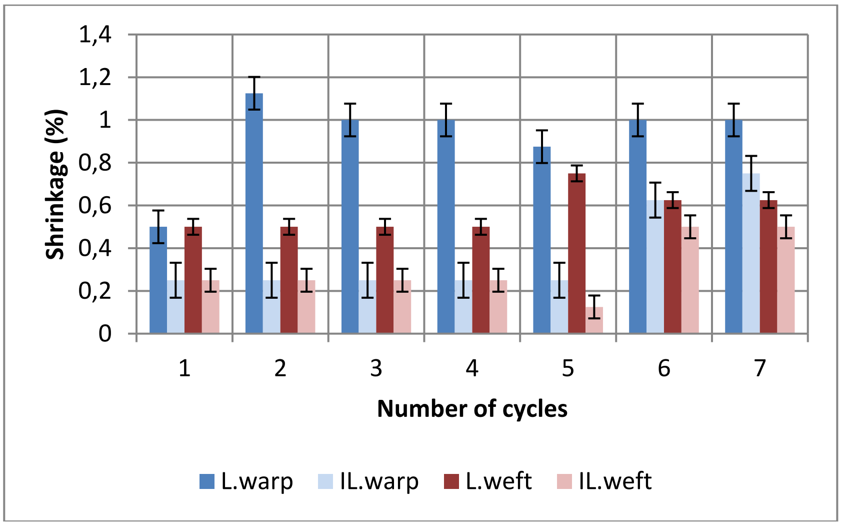


Figure 4: Shrinkage of fabric F2 after repeated laundering and ironing/laundering

It is notable that 5-10 wash cycles are required to attain the “fully relaxed” fabric dimensions either for cotton or cotton/polyester fabric. A slight progressive shrinkage may be noticeable; fabrics F1 and F3 continue to shrink slightly each time they are laundered.

Figure 3 shows that the shrinkage of the cotton fabric increases obviously during the first five cycles and then achieved a steady value after 10 laundering cycles. Shrinkage in polyester fabric increases slightly after 5 washes (figure 4). In fact, Polyester fabrics undergo a thermosetting cycle in industrial manufacturing to stabilize its dimensions. That’s why the addition of 20% polyester in a cotton fabric may allow a stability of dimensions before five laundering cycles.

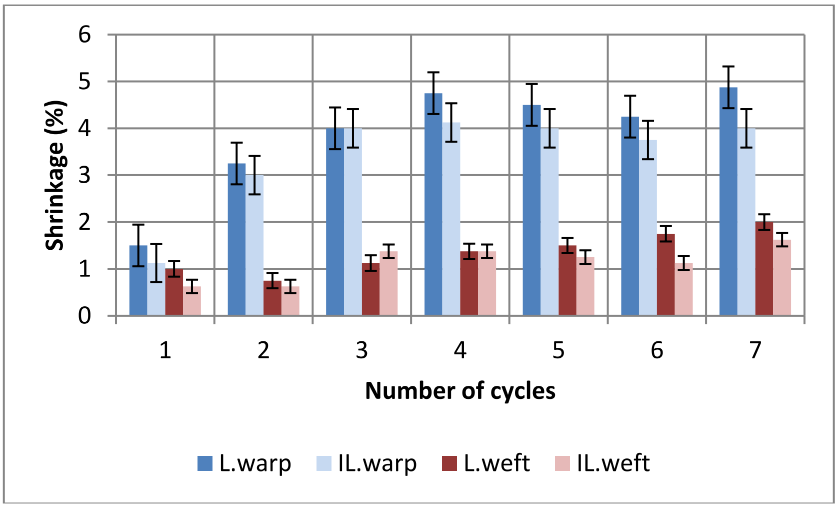


Figure 5: Shrinkage of fabric F3 after repeated laundering and ironing/laundering

Fabric shrinkage is greater in fabrics only laundered; this may be due to the fact that at every ironing cycle, by sliding the hot iron on the fabric, an extension is given to the fabric mainly in warp direction. That's why after laundering, the shrinkage may be different.

4. CONCLUSION

To sum up, in the present paper, the effect of repeated ironing/ laundering cycles on smoothness appearance, on low stress mechanical properties and on dimensional changes were investigated. Different behaviours are noticed when just laundering and when ironing/laundering fabrics from cotton, polyester and polyester/cotton fabrics. Ironing aims on removing wrinkles after laundering, but also on the conservation of an appreciated smoothness appearance of weave structure along wear life. The evaluation of low stress mechanical properties of plain weave fabrics under repeated cycles of ironing/laundering showed mainly a decreased thickness and surface thickness which indicated that compactness obtained by steam ironing is maintained through the subsequent cycles of laundering. Increased compactness in the fabrics successively ironed/laundered increases the yarn and fiber contacts, and so increases the frictional resistance to deformation. The influence of ironing /laundering on bending, extension and shear properties of light–weight weave plain fabrics from different compositions studied is complex. Cotton, polyester and cotton/polyester fabrics shrinkages were found slightly greater in fabrics only laundered.

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