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Visual Evaluation of the Surface of Tencel/Cotton Blend Fabrics in Production and Cleaning Processes

Abstract
This study focusses on the visual evaluation of the surface of Tencel/cotton blend fabrics throughout production and cleaning processes. The results showed that pilling increased with consecutive laundering and dry-cleaning processes. Entanglements were mostly observed during the tangling of fibrils on the laundered fabrics, while pills were formed by fibre entanglements in/on the dry-cleaned ones. More fibrils were observed on the abraded parts of fabric samples taken from the initial laundering cycles. No clear difference was observed between the broken fibre ends and surface appearance of the laundered and dry-cleaned fabrics. The crease recovery capability of the laundered fabrics appeared to be slightly below that of the finished fabric, while dry-cleaned fabrics had slightly better crease recovery properties than the laundered ones.

Key words: *Tencel, cotton, fabrics, fibrillation, pilling, laundering, dry-cleaning.*

Introduction

Natural and synthetic cellulose fibres are essential for the day-to-day functioning of the textile industry. Thanks to their features, these fibres give clothing and apparels the highest comfort: softness, fang, strength, good look and functionality [1 - 4]. Cellulose fibres are included in the group of high comfort fibres. Lyocell is established as the generic name for cellulose fibres regenerated by means of the NMMO process. The reason for its recent appearance on the market is that Lyocell fibre (Tencel of Courtaulds, Lenzing-Lyocell of Lenzing AG) has the advantage of being used in a less contaminant spinning process than the one for conventional viscose. Like all cellulose fibres, Lyocell fibre absorbs water perfectly and gives hygienic properties to textile products. These fibres are widely used in the apparel industry, also in blends with synthetic fibres. They can be successfully used in the production of underwear and apparels. They can also be used in technical textiles, nonwovens and foils. Standard Lyocell fibres, in comparison with other cellulose fibres (viscose), have a higher breaking strength, either wet or dry. Also, enormous differences exist between Lyocell and cotton in both thermal transmission and vapour permeability [5]. Lyocell fibres absorb more moisture at 20 °C/65% r.h. The vapour permeability of knitted fabrics from Lyocell is about 8.5% higher, and at the same time the heat transmission is about 62% lower than that of knitted fabrics from cotton, which is 10% heavier than Lyocell knitted fabrics.

Lyocell fibres are distinguished by their specific ability to fibrillate in a wet state under the impact of external mechanical effects [6, 7]. Fibrillation means the detachment of fibrils along the fabric surface of individual fibres swollen in water, which is caused by mechanical stress. Textile fabrics made of lyocell staple fibres undergo controlled fibrillation and defibrillation by specific finishing processes. Novel extraordinary surface effects will result, which are called peach skin, silk touch, denim or used look effects.

Various researches were conducted on fabrics containing Lyocell fibres. Ibbett and Hsieh [2] studied the effect of liquid swelling on the structural rearrangement of lyocell twill fabrics by using a variety of techniques. Frydrych, Dziworska and Matusiak [8] used different kinds of cellulose yarns as warp and weft in fabrics of plain weave structure, with different weft density, and presented the results of the breaking force and strain of fabrics in weft and warp directions before and after finishing [8]. They determined the influence of fabric finishing, weft density, and raw material on the elongation at break value. Dziworska et al. [9] found that fabrics with Lyocell and Tencel fibre wefts were characterised by greater crease resistance in comparison with fabrics with cotton and viscose wefts. It was noted that fabrics with Tencel and Lyocell fibre wefts showed better air permeability in comparison with fabrics with cotton and viscose wefts. Morgado et al. [6] found that cellulases first attack the cellulose microfibrils on the surface of the fabric because they are more externally exposed than the cellulose of the original fabric structure and have the same characteristics in terms of molecular weight, polydispersity and crystallinity index as the base fabric. Cellulases proved to be thorough surface finishing agents since they only change the fibre surface, not the crystallinity.

Table 1. *Properties of weft and warp yarns.*

Properties. unit	Weft yarn	Warp yarn
Evenness. CV%	8.7	10.8
Actual yarn count, Tex	60.3	23.2
Count, CV%	2.2	0.5
Tenacity, cN/tex	18.51	16.83
Tenacity, CV%	6.14	8.65
Elongation, %	8.99	7.00
Elongation, CV%	6.03	8.59
Twist/meter (Z twist)	452.7	944.8
Twist, CV%	2.5	5.2

Materials and methods

Within the scope of this work, 65/35% Tencel/cotton fabric was woven with a weave construction of 3/1 twill (268 g/m^2 weight, 47 ends/cm, 21 picks/cm) under industrial conditions. 59 tex and 23 tex open-end rotor spun yarns were used as weft and warp threads, respectively. The fabric samples were tested to determine their cloth thickness, pilling, abrasion and crease recovery properties in accordance with the standards BS 2544, ISO 12945-2, BS 5690 and BS EN 22313:1992, respectively. Properties of the yarns are given in ***Table 1*** (see page 39).

Woven gray fabrics were subjected to desizing and bleaching. Afterwards, test samples underwent primary fibrillation, enzymatic, dying and secondary fibrillation processes.

Finished fabrics were subjected to repeated laundering and dry-cleaning cycles. Laundering took place in a domestic type laundering machine at 40 °C, and the laundered fabrics were then tumble dried at 60 °C. Dry cleaning was performed under laboratory conditions, and these fabrics were subsequently dried by laying them on a flat surface.

This study was initiated to observe the impact of primary fibrillation, enzymatic, secondary fibrillation and dying processes on the surface characteristics of Tencel blended fabrics. The reaction of fabrics to laundering and dry-cleaning as well as their appearance after cleaning treatments also depends on the properties of the fibres employed. Taking this situation into consideration, the aim was to study the variations in the surface characteristics after cleaning. The formation of pills and the contribution of fibrils to the pilling process during the production and cleaning stages were investigated in detail, and scanning electron microscopy was used to study the various stages of pill development. SEM analysis was also conducted in order to study the damage caused to the fibres during abrasion, and the form of the fibre breaks was discussed. Besides this, the thickness and crease recovery properties of the fabrics were also examined and evaluated.

The data obtained were evaluated using a univariate ANOVA test. For this purpose an SPSS 13 software package was employed.

Tested properties of the fabrics are given in ***Table 2***. The following notations were used in ***Table 2*** for the fabrics:
GF: gray fabric
PF: fabric taken after primary fibrillation
ET: fabric taken after enzyme treatment
FF: fabric taken after secondary fibrillation and the dying process (finished fabric)
1L, 2L, 3L, 4L, 10L: Fabrics taken after first, second, third, forth and tenth laundering cycles
1DC, 2DC, 3DC, 4DC, 10DC: Fabrics taken after first, second, third, forth and tenth dry cleaning cycles.

Results and discussion

Pilling

Visual evaluation of the samples revealed that the pilling of fabrics after enzyme treatment was better than that of the one which underwent the primary fibrillation process. In addition, the FF samples displayed a similar surface appearance to the ET samples in terms of pilling. It was also observed that the pilling grades of the laundered fabric samples excelled those of the dry-cleaned ones, which means the dry-cleaned fabrics seemed to have more pills on their surface. As expected, pilling increased with consecutive laundering and dry-cleaning processes.

SEM analysis was conducted in order to examine the surface characteristics of the fabrics and the structure of the pills. When the pills were more closely examined, fibrillation was observed on Tencel fibres, and the effect of fibrillation on the formation of pills was also sought.

SEM micrographs seen in ***Figures 1***, ***2*** and ***3*** showed that the FF sample was more fibrillated than the PF and ET samples, and for the latter two samples PF was the most fibrillated one. Pill entanglements on the PF fabric samples were composed of long fibrils. The presence of long fibrils on the PF samples was expected since this is a process that forms fibrils. It was also observed that Tencel fibrils on the ET samples seemed to be lying on the fabric rather than being actually attached to the fibres. On the other hand, secondary fibrillation and dying processes applied to the fabrics might be the reason for the higher fibrillation tendency of the FF samples.

When the relation between fibril and pill formation was investigated, it was observed that the tendency of the fibres to form fibrils seemed to have some effect on the formation of pills. The form of the pills that existed on the ET and FF fabrics were also different. Fibrils on the FF samples seemed to become a part of the pill structure rather than just loosely wrapping around it (***Figure 4***), as was also in the case of the ET samples. Pills on the PF samples also differed from those of the ET and FF samples, and they resembled a fringe rather than a pill form due to their long fibrils (***Figure 5***).

Microscopic studies also revealed that entanglements were more often observed than the tangling of the fibrils on the laundered fabrics, while pills were formed by fibre entanglements in the dry-cleaned ones (***Figures 6 - 7***). These differences in pilling may be caused by the different impacts of laundering and dry-cleaning processes on the fabrics. For domestic type laundering machines, the ratio of water/fabric is at a level to permit fabric-to-fabric or fabric-to-machine surface friction. Due to this mechanical interaction, there is a tendency to pill formation, and pill fall- off might be high during the laundering process. On the other hand, the chemicals and solvents used dur-

Table 2. *Tested properties of the fabrics.*

Properties, unit		Test samples													
		GF	PF	ET	FF	1L	2L	3L	4L	10L	1DC	2DC	3DC	4DC	10DC
Pilling		3/4	3/4	4/5	4/5	4/5	4/5	4	4	3/4	3/4	3/4	3	2/3	2/3
Weight loss of fabrics after abrasion, %		7.3	8.1	9.7	9.7	8.2	8.2	8.1	6.0	8.1	8.0	7.6	9.5	6.8	7.4
Thickness loss of fabrics after abrasion, %		11.2	11.6	6.3	11.9	7.0	6.9	6.4	4.3	6.7	11.3	8.8	8.8	6.4	5.9
Crease recovery in weft direction, deg	Face-to-face	81	95	105	127	113	113	104	108	104	124	123	125	128	131
	Back-to-back	70	94	84	114	101	106	96	100	95	111	115	116	113	110
Crease recovery in warp direction, deg	Face-to-face	36	68	71	97	88	83	81	78	72	95	94	89	97	96
	Back-to-back	92	87	93	122	114	101	101	106	93	114	116	119	127	123

ing dry-cleaning might have rendered the fabrics more sensitive to friction in the next processes while it is not inherent in the process itself and might have caused the fibres to loose most of their oil content. As a result of this, the pilling tendency might have increased after the dry-cleaning process. This phenomenon might be the reason for the presence of entangled fibrils (rather than fibres), in pills on the laundered fabrics, while in the case of the dry-cleaned ones, it is quite the opposite. These effects became more obvious with each laundering and dry-cleaning cycle and caused pilling to increase.

Abrasion

It was observed that all test samples abraded after 12,000-14,000 rubs. Examination of abraded regions of the fabrics under SEM yielded the following results:

It can be said that, in the abraded regions of the PF fabrics, there were not as many fibrils as expected. It is probable that long fibrils present on the PF samples were easily removed from the surface of the fabric under the effect of abrasive forces.

It is possible to say that abraded regions of the ET fabrics were also free of fibrils, which might be considered as a sign that enzyme treatment was realised successfully, as well as the fibril removal effect of the abrasive forces.

On abraded FF samples, fibres with long fibrils were observed. It has been already mentioned that, after pilling tests the FF samples were fibrillated more than the other fabric samples . This situation can also be considered true after abrasion tests. Abrasive forces might have removed some of the fibrils that were formed after secondary fibrillation and might have extended the length of some (***Figure 8***).

It is also possible to say that more fibrils were observed on the abraded parts of fabric samples taken from the initial laundering cycles. On the other hand, fewer fibrils were present on the abraded parts of the sample taken after the tenth laundering. No clear difference was observed between the broken fibre ends and surface appearance of the laundered and dry-cleaned fabrics (***Figures 9*** and ***10***).

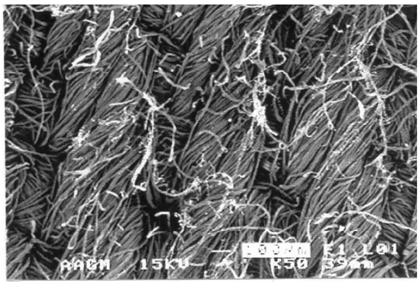

Figure 1. *Appearance of primary fibrillated fabric sample.*

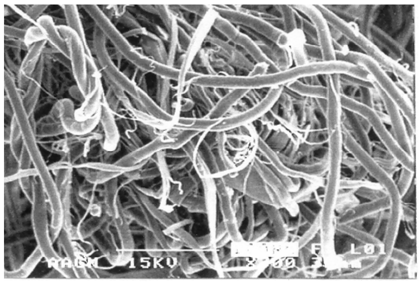

Figure 2. *Appearance of enzyme treated fabric sample.*

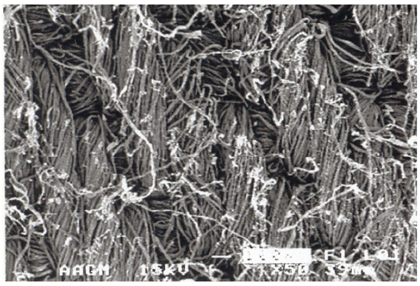

Figure 3. *Appearance of a finished fabric sample.*

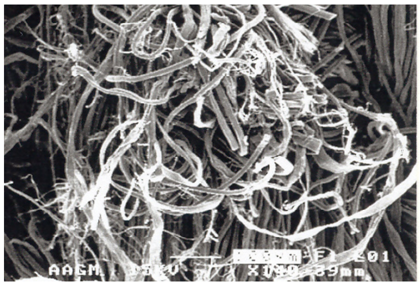

Figure 4. *An example of a pill structure on finished fabric sample.*

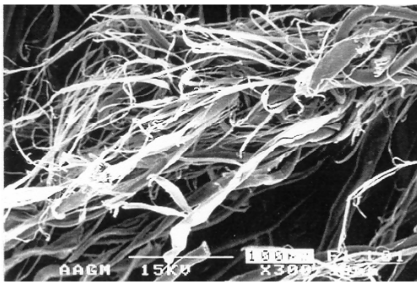

Figure 5. *An example of a pill structure on a primary fibrillated fabric sample.*

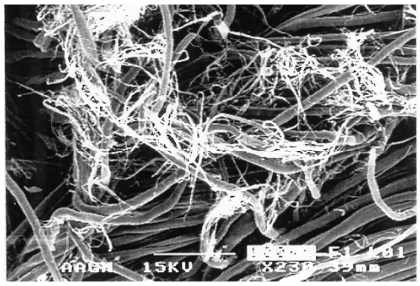

Figure 6. *An example of the appearance of pills on a laundered fabric sample.*

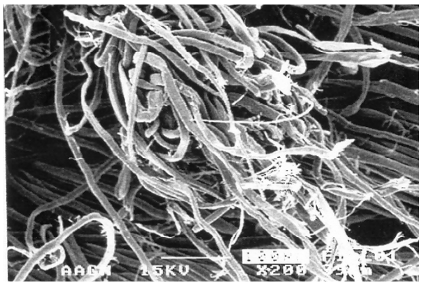

Figure 7. *An example of the appearance of pills on dry-cleaned fabrics.*

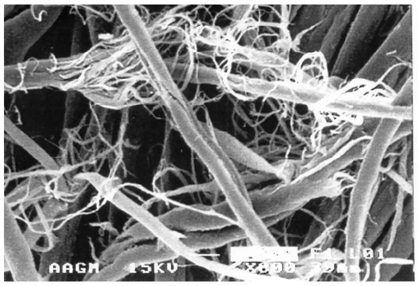

Figure 8. *Fibrils on FF samples after secondary fibrillation.*

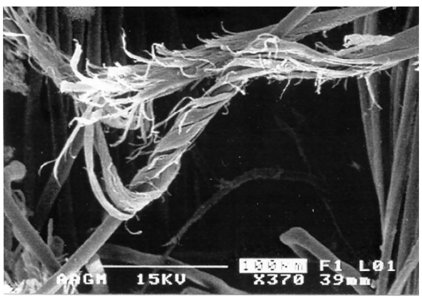

Figure 9. *A broken fibre end on laundered fabrics.*

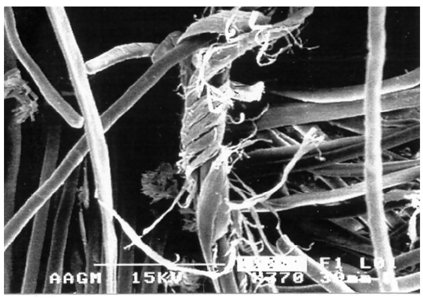

Figure 10. *A broken fibre end on dry-cleaned fabrics.*

It is important to note that, after the abrasion test, almost all of the broken fibre ends observed were cotton. It was concluded that cotton fibres broke before Tencel fibres during the abrasion tests. The breakage of cotton fibres might have made it difficult for the Tencel fibres to be held in the fabric structure, and they might have been removed from the fabric without being broken when subjected to abrasive forces. The breakage of cotton fibres was mostly in the multiple splitting form.

Analysis of data obtained from abrasion tests, using the univariate analysis of variance method at a 95% confidence interval, indicated that the treatments applied to the fabric was the most statistically significant main factor affecting the abrasion behaviour of the fabrics, whereas other categorical variables, namely laundering and dry-cleaning processes, did not have a significant effect on the behaviour.

When the abrasion of the samples was evaluated according to the percentage of weight loss at the end of the abrasion period, the results obtained revealed that the weight loss of the gray fabric was the lowest, which might be due to the presence of a sizing agent on the fabric, as well as to the fact that the fabric had yet not undergone any treatment processes. The weight loss of the ET sample was greater than that of the one which underwent primary fibrillation. Enzyme treatment was adopted in order to remove long fibrils formed during primary fibrillation. This process might have weakened the connection of fibrils to the fibres; these fibrils were probably removed during the abrasion tests, thus resulting in a higher weight loss than the one observed for fibrillated fabrics.

The presence of fibrils on the finished fabric, which causes a "peach-skin" effect, might also have resulted in the other/second highest weight loss of this fabric, which can occur during abrasion. Therefore, it is feasible to expect that it might be easier for the fibrils to be removed from the surface.

The weight loss of the laundered and dry-cleaned fabrics was slightly lower than that of the finished fabric, since some fibres and/or fibrils might have been removed from the surface of the fabrics during these cleaning processes before abrasion.

It is possible to say that progressing laundering cycles had no virtual influence on the weight loss of fabrics, while no stable trend was observed in the weight loss of dry-cleaned fabrics after abrasion. A reduction in the thickness of the fabrics after abrasion, when calculated as a percentage of their initial thickness, displayed almost parallel behaviour to the percentage of weight loss during abrasion. Namely, any change in the thickness of the laundered fabrics after abrasion remained constant, whereas thickness change in the dry-cleaned fabrics decreased. All this may be caused by possible differences in the intensity of each step of the cleaning processes as well as in the different nature of laundering and dry-cleaning. Further detailed studies are required to build upon this result.

However, it is worth mentioning that the weight loss and thickness of the laundered and dry-cleaned fabrics after abrasion differed significantly from that of the FF fabrics at a 95% significance level. It is possible to mention that it was the first step of the cleaning process (either laundering or dry-cleaning) which predominantly affected the thickness and weight loss of the fabrics .

Crease recovery

Univariate analysis of variance results made it clear that the effects of production stages are statistically significant for the crease recovery of the fabrics at a 95% confidence interval. From the results obtained it can be said that, during the production stages, the creasing tendency of the fabrics declined as the sizing agent was removed, and after the fabrics had been treated with various chemicals. It can also be concluded that the crease recovery capability of the laundered fabrics was slightly below that of the finished fabrics, while it is not possible to state the same for the dry-cleaned fabrics. It is also possible to say that the dry-cleaned fabrics had/developed slightly better crease recovery properties than the laundered ones. Although this may appear to contradict the pilling results, the mechanical behaviour of the fabric, which was influenced by the detergent in the molecular basis, may be responsible for this. It should also be considered that the complexity, intensiveness and direction of the forces applied to the fabric samples were totally different in pilling and crease recovery tests. Although it was thought that the loosening or tightening of the fabric structure after laundering could had an impact on the result obtained, no difference was found in the warp and weft densities of the samples. The disposal of water from the fabrics by centrifuging in domestic type laundering machines might have also increased the creasing tendency of the fabrics.

Univariate analysis of variance results indicated that the other categorical variables, namely laundering and dry-cleaning processes, did not have a significant effect on the behaviour, and repeated laundering and dry-cleaning processes did not seem to have a considerable effect on crease recovery.

Summary and conclusions

The scope of this study was to investigate changes on the surface of Tencel/cotton blend fabrics throughout production and cleaning processes. Both the pilling, abrasion, thickness and crease recovery properties of the fabrics taken from each production stage and after cleaning processes were studied. The conclusions below given can be derived from the results obtained:

The pilling of fabrics after enzyme treatment was better than that of the one which underwent the primary fibrillation process. In addition, the FF samples displayed a similar surface appearance to the ET samples in terms of pilling. It was also observed that the pilling grades of the laundered fabric samples exceeded those of the dry-cleaned ones. As expected, pilling increased with consecutive laundering and dry-cleaning processes. Entanglements were mostly observed during the tangling of fibrils on the laundered fabrics, while pills were formed by fibre entanglements on the dry-cleaned ones.

When abrasion test results were considered, it was observed that the weight loss of the ET and FF samples were greater than that of the one which underwent primary fibrillation. It is possible to say that extending laundering cycles had virtually no influence on the weight loss of the fabrics, while no stable trend was observed in the weight loss of the dry-cleaned fabrics after abrasion. A reduction in the thickness of the fabrics after abrasion displayed almost parallel behaviour to the percentage of weight loss during abrasion. More fibrils were observed on the abraded parts of the fabric samples taken from the initial laundering cycles. No clear difference was observed between the broken fibre ends and surface appearance of the laundered and dry-cleaned fabrics.

The creasing tendency of the fabrics taken from each production stage declined. The crease recovery capability of the laundered fabrics appeared to be slightly below than that of the finished fabric. It is also possible to say that the dry-cleaned fabrics had slightly better crease recovery properties than the laundered ones. Repeated laundering and dry-cleaning processes did not seem to have a considerable effect on the crease recovery.

As a final conclusion it can be said that laundering and dry-cleaning processes have different impacts on the surface characteristics of Tencel/cotton blended fabrics in terms of pilling, abrasion and crease recovery. Dry-cleaning agents seem to have a stronger negative effect on the fabric surface rather than within the structure, while it is not the case for laundering.

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