Effect of Laundering on Bending Properties of Plain-Knitted Fabrics

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Abstract
This work investigates the changes in bending properties in laundering of plain weft-knit silk fabrics, as compared with cotton and polyester. The effects of variations of linear density and stitch density of fabric samples on bending properties due to repeated laundering are examined. It is shown that both bending rigidity and hysteresis of the various yarns show different behaviour of the fibres in laundering. Silk is characterized by higher flexibility for bending in both principal directions than cotton and polyester, in laundering. Differences between technical face and technical back bending are also shown. Linear density of silk yarns affects bending rigidity more than cotton.

1. Introduction
Stability in fabrics is of an intrinsic nature, causing great concern to the manufacturer as well as the retailer and consumer. In recent years advancement and innovations in textiles have generated more interest into research areas like textile performance. Objective measurements of fabric mechanical properties have assumed greater importance in view of the fact that it is capable of reflecting the handle of fabrics. Bending properties have proven to be a powerful tool in the investigation of the properties of woven as well as knitted fabrics. Problems related to bending deformations of fabrics tend to differ, depending on the fabric structure. Within the same structure too, various fibre, yarn and fabric mechanisms may be responsible for the differences and the relative size of these may be determined [1]. Laundering is an indispensable aspect of fabric or garment care, therefore, it is essential to consider the performance in this respect.

In this study, therefore, the effect of laundering on the bending behaviour of knitted fabrics is investigated. Further, the bending rigidity and hysteresis of silk, cotton and polyester fabrics are compared.

2. Experimental

2.1. Yarn and knitting details
Plain fabrics were knitted from filament silk, combed, ring-spun and mercerised cotton and polyester yarns on a 6-gauge Brother KH-900 Paulie handknitting machine. Yarn and fabric parameters are shown in Table 1.

| Fibre code | Fibre content | Linear density (tex) | Twist (turns/inch) | Stitch density (stitch/inch) | Cover Factor | Thickness (mm) |
|------------|---------------|---------------------|-------------------|----------------------------|--------------|----------------|
| S1         | silk          | 118                 | 450               | 16                         | 10           | 1.44           |
| S2         | silk          | 118                 | 450               | 14                         | 9            | 1.63           |
| S3         | silk          | 256                 | 410               | 17                         | 8.5          | 2.22           |
| S4         | silk          | 256                 | 410               | 14                         | 8.5          | 15.23          |
| C1         | cotton        | 158                 | 390               | 17                         | 8            | 14.12          |
| C2         | cotton        | 158                 | 390               | 15                         | 8            | 13.94          |
| C3         | cotton        | 223                 | 230               | 14                         | 8.5          | 13.57          |
| C4         | cotton        | 223                 | 230               | 11                         | 8            | 12.44          |
| P1         | polyester     | 200                 | 320               | 15                         | 10           | 16.08          |
| P2         | polyester     | 200                 | 320               | 13                         | 8            | 14.59          |

2.2. Testing and Measurement
The knitted samples were dry-relaxed [2] by laying them free from constraints for 24 hours to condition in a standard atmosphere (65% ± 2% RH, 21 ± 1°C). Bending properties were measured according to the standard method stated below.

The samples were wet-relaxed by putting them in a water bath, containing a wetting agent, at 30°C for 12 hours, hydroextracted, tumble-dried at 60°C for 60 minutes and conditioned in the standard atmosphere, for 24 hours. Bending properties were measured.

For laundering [3], the samples were washed in a water bath containing 0.1% concentration of a neutral detergent, suitable for all the fibre-fabrics, at 35°C for 20 minutes using the handwashing cycle, rinsed twice at the same temperature, for 5 and 10 minutes respectively and hydroextracted centrifugally for 1 minute. They were tumble dried at 60°C for 60 minute, conditioned in the standard atmosphere and measured as mentioned above.

These laundering and measurement cycles were repeated...
ten times.

Bending rigidity $B$ and hysteresis $2HB$ were carried out on a KES Pure Bending Tester-FB2, between the curvatures of $K=-2.5$ and $2.5$ ($\text{cm}^{-1}$) with constant rate of curvature of $0.50$ ($\text{cm}^{-1}$)/sec. $B$ is obtained by the slope between $K=0.5$ and $1.5$ for $B_f$ and $K=-0.5$ and $-1.5$ for $B_b$ respectively. $2HB$ means twice the value of $HB$ and can be measured as the hysteresis width. $2HB$ is obtained by the mean value of hysteresis width in the range of $K=0.5$ to $1.5$ for $2HB_f$ and of $K=-0.5$ to $-1.5$ for $2HB_b$.

3. Results and Discussion

3.1. Effect of Laundering on Bending Rigidity

Figure 1 shows changes in bending rigidity with relaxation and laundering cycle. From this it can be seen that, in the dry-relaxed state (D), silk and cotton have approximately the same value of bending rigidity in the wale-way, while that of polyester is different and higher. Bending rigidity of silk decreases while that of cotton and polyester, generally increases after wet relaxation (W). After laundering L (after ten laundering cycles), there is not much change in rigidity with silk, while with the slackly knitted cotton and polyester, laundering affects rigidity considerably, especially in the wale direction.

As is expected, wale-way (bending moment applied about an axis parallel to the courses) bending rigidity is greater than course-way (bending moment applied about an axis parallel to the wales) rigidity in the dry-relaxed state. In their study on wool plain-knitted fabrics, Hamilton and Postle [5] noted that it is possible that the anisotropy of the plain-knitted structure may produce a different mechanism of bending, according to the direction of the axis about which the bending moment is applied whereas for plain-weaves fabrics, the differences are usually small. This is because for plain knits, if a single loop is considered, the bending moment applied parallel to the courses (wale-way) acts on two yarns, while the bending moment applied parallel to the wales (course-way) acts on a single yarn.

The effect of curvatures on wale-way and course-way rigidity are shown in Figure 2. It can be seen that with the wale-way technical face (+), bending rigidity is higher than that of the technical back (-), for all the fibre-fabrics types. On the other hand, the course-way back (-) bending rigidity is higher than that of the face (+), for all the fabric types.

Hamilton and Postle [5] pointed out that fabric bending rigidity for positive curvature in the wale-way was considerably greater than the corresponding value for negative curvature. They explained that examination of the plain-knitted structure shows that a very small positive curvature can cause jamming of adjacent courses at the back of the fabric. It therefore follows that for positive curvatures, in this direction, the increased resistance to bending is largely due to loop jamming in the length direction. In the wale-way negative curvature, there is no jamming in the plain-knitted structure. (Resistance to bending may arise principally from the bending and sliding of yarns and not from yarn compression or tension).

For bending moment applied about an axis parallel to the wales (course-way), the jamming in this case, occurs between adjacent wales for negative curvature bending. Hence, negative values are usually greater than positive values for a given fabric, as seen in Figure 2.

Our work agrees with the results of Hamilton and Postle's, which indicates that these behaviours are independent on fibre-fabric type. However, it can be
observed in Figure 2 that the difference in positive and negative bending rigidities for silk is not great as compared with cotton and polyester.

In Figure 3, the effect of linear density on bending rigidity is shown. (In the key of this figure, t means tight and s means slack; Tex 1 is for low tex and Tex 2 is for high tex). The results reveal that in both principal directions the bending rigidity is very sensitive to changes in linear density especially for silk in laundering. (It may be noted that data on high tex polyester yarns was unavailable). It has been shown ([5] and [6]) that bending rigidity increases with increasing linear density. In addition, it has also been shown [5] that the relaxation process has an influence on the effect of linear density. In our study, complete relaxation (ten laundering cycles) of silk still shows great sensitivity to variation in linear density, for the slackly knitted cotton.

3.2. Effect of Laundering on Bending Hysteresis

In Figure 4, change in bending hysteresis with relaxation process is shown for all the fabrics. Bending hysteresis for silk and polyester is affected considerably, upon wet relaxation, especially in the wale direction; the bending hysteresis decreases sharply. Cotton was not affected much by relaxation. The effect of laundering on bending hysteresis does not follow any particular pattern. As with the bending rigidity, it is revealed that generally, wale-way bending hysteresis is higher than that of the course-way. In both principal directions, polyester has the highest hysteresis.

Elder and Somashekar [1] have shown through their empirical studies on cotton that wale-way bending deformations are comparatively much higher than those of the course-way. Their work also shows that cotton, irrespective of the finishing treatments, has higher bending deformation values after wet-relaxation. Our results for cotton are consistent with theirs. However, with laundering, the bending hysteresis depends on the cover factor. For silk and polyester, laundering generally seems to decrease the bending hysteresis, but not so significantly. Phukan and Subramaniam [7] showed in their work which included polyester, that polyester displayed lower bending hysteresis.

In Figures 5, the dependence of bending hysteresis on linear density is shown. The fabrics knitted from yarns with higher linear density (Tex 2), has much higher bending hysteresis: In both directions, this phenomenon holds. Silk is very sensitive to the variation in linear density.

Fig. 4 Dependence of bending hysteresis on relaxation processes.

Fig. 5 Dependence of bending hysteresis on linear density.
4. Conclusions

With laundering, the bending rigidity and hysteresis of silk decreases. For cotton the bending rigidity increases while bending hysteresis decreases. Bending rigidity and hysteresis increase in the case of polyester. Laundering does not affect the bending properties of silk much after wet-relaxation, but affects cotton and polyester considerably. Cover factor also plays an important role in the determination of the value of the bending properties in cotton and polyester.

In the case of bending rigidity, cotton and polyester can be said to exhibit the same behaviour in laundering while silk shows different behaviour. On the other hand, silk and polyester have shown similar behaviour in bending hysteresis in laundering, which could mean that elastic behaviour is influenced by the yarn being a staple or filament while bending rigidity can be influenced by the fibre's natural resilience.

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