Impact of lycra filament on extension and recovery characteristics of cotton knitted fabric

A Mukhopadhyay
Department of Textile Technology, National Institute of Technology, Jalandhar 144 011, India

I C Sharma & A Mohanty
Department of Textile Technology, The Technological Institute of Textile & Sciences, Bhiwani 127 021, India

Received 24 April 2002; accepted 24 September 2002

The effect of lycra filament and full relaxation finish on the extension at peak load, immediate recovery, delayed recovery, permanent set and resiliency of cotton-lycra blended knitted fabric has been studied. It is observed that for lycra blended fabric, the immediate recovery, extension and resiliency are higher but delayed recovery and permanent set are lower than those of 100% cotton fabric. Effect of full relaxation treatment is found to be useful in case of all-cotton fabric. On the application of external load, both lycra and non-lycra fabrics show higher extension at peak load along course direction than that along the other directions of fabric. However, the biased direction of 100% cotton fabric shows significantly higher immediate recovery and resiliency but lower delayed recovery and permanent set. In general, with repeated load cycles, the extension at peak load increases marginally but immediate recovery and resiliency change considerably during initial number of cycles. Laundering reduces the extension at peak load, immediate recovery and resiliency, whereas delayed recovery and permanent set become higher.

Keywords: Cotton fabric, Delayed recovery, Extension at peak load, Full relaxation, Immediate recovery, Lycra filament, Permanent set, Resiliency

1 Introduction

The yarn is subjected to tensile, bending, torsional and compressional strains during the process of knitting. Due to the elastic components of strain energy, the loops tend to change shape so as to reach minimum energy level. The shrinkage of knitted fabrics significantly increases with the introduction of home laundering and tumble drying. The deformation caused by the mechanical forces can be reduced by appropriate relaxation. The process occurs when the yarn is bent to stitch loops and the frictional forces at the binding points are brought to a minimum and are in equilibrium. The quality requirement of knitted fabrics becomes highly demanding in terms of appearance and performance. In response to the demand, the fabric producers were inspired to develop a rich source of materials using a variety of yarn with lycra for stretch and recovery.

The occurrence of elastic recovery is often evident during cyclic loading as well as stretch during body movement. It is important to observe the effect of lycra filament on the shape retention properties of knitted fabrics even after undergoing repeated wash and wear cycles. It may be noted that although the effects of laundering cycles on dimensional and mechanical properties of knitted fabrics have been studied by some research workers, no studies have been reported on lycra blended fabrics. Various types of shrink-resist and anti-shrink treatments have been described in literature. In mechanical processing, full relaxation treatment is meant for improving the performance of knitted fabrics, but its impact on lycra blended fabrics is not known. In the present work, the extent of influence of full relaxation treatment on the extension and recovery characteristics of knitted fabrics produced by lycra filament and cotton yarn has been examined.

2 Materials and Methods

2.1 Materials

Four different fabric samples were prepared from 19.7 tex (30's) yarns on a circular knitting machine of ninety feeders, 24 gauge and a needle bed of 30 inch diameter in identical condition. Lycra blended fabrics
were prepared using few feeders wherein lycra filaments (4% of the total weight of material) form the loop with cotton yarn alternatively with back plating. The samples thus prepared along with their codes are given below:

NLC - Non-lycra compacted fabrics
NLFR - Non-lycra full-relaxed fabrics
LC - Lycra compacted fabrics
LFR - Lycra full-relaxed fabrics

All the fabrics were processed in the industry using the sequence of scouring and compaction respectively. Additional full relaxation treatment was given to the NLFR and LFR fabrics before compaction in a relaxed dryer, known as horizontal dryer, at 160°C temperature and 4 m/min speed with 20% overfeed. All the fabrics were subjected to laundering process in a domestic twin-tub washing machine as per the ASTM standard using 0.5 g/L solution of non-ionic detergent Vaptex 1535 (96%). Four specimen were separately given 1, 6 and 15 laundering cycles and thus additional 12 specimens were prepared from 4 unlaunched samples. All the laundering cycles were carried out at normal temperature, which was followed by drying in the open space during daylight.

2.2 Methods

Fabric dimensional characteristics were measured and are given in Table 1. Fabric extension and recovery characteristic were measured on Instron tester (Model 4411) in tensile mode using the ASTM standards originally developed for measuring fibre recovery. The maximum load of 250 gf/cm with 12 mm/min crosshead speed was used on the fabric samples of 50 mm gauge length and 12 cm width.

The maximum extension, immediate recovery, delayed recovery, permanent set and resiliency were studied by plotting the jaw movement distance on x-axis and the applied load on y-axis (Fig. 1). The fabrics was subjected to 10 loading cycles and the following characteristics were studied at the interval of 1, 5 and 10 load cycles along wale, course and biased directions:

- Extension at peak load (%) = EH/(Gauge length) × 100
- Immediate recovery (%) = GH/EH × 100
- Delayed recovery (%) = FG/EH × 100
- Permanent set (%) = EF/EH × 100
- Resiliency (%) = W_2/W_1 × 100

where, W_1 is the area EIHE above x-axis; W_2, the area GIHG above x-axis; and E, F, G, H and I, the points shown in Fig. 1.

For the entire specimen, 15 tests were carried out at standard testing atmosphere.

![Fig. 1—Extension and recovery behaviour of fabric](image)

<table>
<thead>
<tr>
<th>Characteristic</th>
<th>Non-lycra compacted scouring 0°</th>
<th>Non-lycra fully relaxed 0°</th>
<th>Lycra compacted scouring 0°</th>
<th>Lycra fully relaxed 0°</th>
<th>Non-lycra compacted scouring 15°</th>
<th>Non-lycra fully relaxed 15°</th>
<th>Lycra compacted scouring 15°</th>
<th>Lycra fully relaxed 15°</th>
</tr>
</thead>
<tbody>
<tr>
<td>Wale's/inch</td>
<td>42.0 43.2 43.5 43.6</td>
<td>40.4 41.4 41.6 41.6</td>
<td>42.3 42.6 42.6 42.4</td>
<td>39.0 39.7 40.0 40.0</td>
<td>23.8 23.6 23.6 23.6</td>
<td>22.4 22.6 22.6 22.6</td>
<td>24.8 24.6 24.6 24.6</td>
<td>22.4 22.6 22.6 22.6</td>
</tr>
<tr>
<td>Courses/inch</td>
<td>53.9 54.5 55.2 55.5</td>
<td>60.8 61.0 61.6 61.8</td>
<td>59.3 62.0 62.9 64.7</td>
<td>71.4 72.9 74.1 74.8</td>
<td>23.8 23.6 23.6 23.6</td>
<td>22.4 22.6 22.6 22.6</td>
<td>24.8 24.6 24.6 24.6</td>
<td>22.4 22.6 22.6 22.6</td>
</tr>
<tr>
<td>Stitch density, stitches/inch</td>
<td>2264 2354 2401 2423</td>
<td>2456 2525 2563 2571</td>
<td>2508 2641 2679 2743</td>
<td>2746 2873 2964 2992</td>
<td>23.8 23.6 23.6 23.6</td>
<td>22.4 22.6 22.6 22.6</td>
<td>24.8 24.6 24.6 24.6</td>
<td>22.4 22.6 22.6 22.6</td>
</tr>
<tr>
<td>Stitch length, mm</td>
<td>2.33 2.37 2.38 2.37</td>
<td>2.40 2.39 2.42 2.42</td>
<td>2.73 2.66 2.60 2.59</td>
<td>2.65 2.62 2.64 2.58</td>
<td>23.8 23.6 23.6 23.6</td>
<td>22.4 22.6 22.6 22.6</td>
<td>24.8 24.6 24.6 24.6</td>
<td>22.4 22.6 22.6 22.6</td>
</tr>
<tr>
<td>Fabric weight, g/m²</td>
<td>174.8 180.8 180.9 180.6</td>
<td>198.1 215.2 226.4 228.2</td>
<td>194.1 207.9 209.8 211.9</td>
<td>224.0 234.2 236.5 236.4</td>
<td>23.8 23.6 23.6 23.6</td>
<td>22.4 22.6 22.6 22.6</td>
<td>24.8 24.6 24.6 24.6</td>
<td>22.4 22.6 22.6 22.6</td>
</tr>
<tr>
<td>Thickness, mm</td>
<td>0.55 0.54 0.54 0.55</td>
<td>0.60 0.62 0.58 0.55</td>
<td>0.65 0.67 0.67 0.67</td>
<td>0.71 0.74 0.72 0.74</td>
<td>23.8 23.6 23.6 23.6</td>
<td>22.4 22.6 22.6 22.6</td>
<td>24.8 24.6 24.6 24.6</td>
<td>22.4 22.6 22.6 22.6</td>
</tr>
</tbody>
</table>

* Laundering cycles
3 Results and Discussion

3.1 Effect of Direction of Loading on Fabrics before and after Laundering

3.1.1 Extension at Peak Load

It has been observed from Tables 2 - 5 and Fig. 2 that the extension at peak load is higher in course direction whereas it is lowest in wale direction and intermediate in biased direction (45° angle to wale or course). This is due to the higher loop extension in course direction as the forces are applied directly in the direction parallel to the axis of line of loop.

The extension of the fabric depends largely on the change in configuration of these initially circular loop

<table>
<thead>
<tr>
<th>Characteristic</th>
<th>Load cycles</th>
<th>Wale direction</th>
<th>Course direction</th>
<th>Biased direction</th>
</tr>
</thead>
<tbody>
<tr>
<td>Extension at peak load, %</td>
<td>1</td>
<td>23.30</td>
<td>22.31</td>
<td>22.68</td>
</tr>
<tr>
<td></td>
<td>5</td>
<td>24.41</td>
<td>23.75</td>
<td>23.91</td>
</tr>
<tr>
<td></td>
<td>10</td>
<td>24.84</td>
<td>24.07</td>
<td>24.17</td>
</tr>
<tr>
<td>Intermediate recovery, %</td>
<td>1</td>
<td>62.74</td>
<td>60.12</td>
<td>59.62</td>
</tr>
<tr>
<td></td>
<td>5</td>
<td>80.28</td>
<td>76.66</td>
<td>77.27</td>
</tr>
<tr>
<td></td>
<td>10</td>
<td>80.42</td>
<td>79.13</td>
<td>78.39</td>
</tr>
<tr>
<td>Delayed recovery, %</td>
<td>1</td>
<td>16.01</td>
<td>16.73</td>
<td>16.31</td>
</tr>
<tr>
<td></td>
<td>5</td>
<td>19.72</td>
<td>21.34</td>
<td>22.73</td>
</tr>
<tr>
<td></td>
<td>10</td>
<td>19.58</td>
<td>21.87</td>
<td>21.61</td>
</tr>
<tr>
<td>Permanent set, %</td>
<td>1</td>
<td>21.25</td>
<td>23.15</td>
<td>24.00</td>
</tr>
<tr>
<td></td>
<td>5</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td></td>
<td>10</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Resiliency, %</td>
<td>1</td>
<td>26.02</td>
<td>24.28</td>
<td>23.97</td>
</tr>
<tr>
<td></td>
<td>5</td>
<td>39.03</td>
<td>38.07</td>
<td>38.37</td>
</tr>
<tr>
<td></td>
<td>10</td>
<td>41.26</td>
<td>39.95</td>
<td>39.11</td>
</tr>
</tbody>
</table>

4 Laundering cycles
segments. These segments remain flat when external tension is applied in course direction. But, owing to the nature of loop interlocking, the yarn slippage could be expected to occur at an earlier stage for extension in the wale direction than that for extension in wale direction. In order to allow the occurrence of slippage, the net reaction force must always act in a direction normal to yarn axis, leading a greater extension at peak load in course direction.

It is further observed from Tables 2-5 that the extension at peak load decreases with the increase in laundering cycles in case of non-lycra fabrics while...
the trend is reversed in case of lycra blended fabrics in wale direction. In case of lycra blended fabric, there is a prominent increase in courses per unit length due to the laundering (Table 1) which results in greater extension along the wale direction. However, the increase in courses per unit length reduces the load per loop along the course direction, leading to a general reduction in extension at peak load due to the laundering.

3.1.2 Recovery Characteristics

It has been observed from Fig. 3 that with the change in direction of loading, the immediate recovery is maximum in biased direction in all the fabrics. However, the difference in values is more prominent in non-lycra fabrics. This is due to the presence of lycra in blended fabrics which improves the flexibility and shape retention properties of fabrics, irrespective to the direction of loading. Again on the application of load, the fabric behaviour in biased direction neither exhibits greater extension of loop as in course direction nor it shows a greater deformation of knit structure and yarn extension as in wale direction, leading to a greater recovery in biased direction. It is further observed that the immediate recovery decreases with the increase in laundering cycles. This may be due to the some amount of damage of fabrics by mechanical action of washing machine and action of detergent during laundering. Due to laundering, the hairiness of the cotton yarn becomes higher which may cause greater obstruction at crossover points of knitted fabrics during recovery.

Fig. 4 shows that the variation in delayed recovery with the direction of loading is very prominent in case of non-lycra cotton fabrics. The said value is lowest in biased direction. The delayed recovery is increased particularly during first cycle of laundering, and after subsequent laundering the changes become marginal.

It can be seen from Fig. 5 that the permanent set of fabric possesses a lowest value in biased direction. It also has the tendency to increase with the increase in laundering cycles and in certain fabrics the changes in permanent set become marginal after a particular number of laundering cycles.

It is observed from Fig. 6 that the resiliency increases from course to biased direction of loading. In general, the fabric resiliency decreases particularly during first cycle of laundering.
3.2 Effect of Load Cycles on Fabrics before and after Laundering

3.2.1 Extension at Peak Load

Tables 2-5 show that with the increase in load cycles, the extension at peak load increases marginally. This is due to the nature of extension and recovery behaviour of fabric which gradually stabilize with the increase in load cycle.

3.2.2 Recovery Characteristics

It is observed from Tables 2-5 that the immediate recovery sharply increases initially and thereafter changes become marginal in all the fabrics. As the permanent set approaches zero after initial number of load cycles, the internal reaction forces acting on the knitted fabric response immediately to the external force, leading to a greater immediate recovery after the release of load.

Tables 2-5 show that in general with the increase in load cycles, except in case of non-lycra compacted fabrics, the change in fabric delayed recovery along the wale and course directions is significant. During the initial cycles of loading, the change in total elastic recovery of fabric is therefore dominated by fabric immediate recovery.

It is again observed from Tables 2-5 that the permanent set approaches zero in fifth cycle of loading in all the fabrics before and after laundering. This is due to the change in loop configuration and loop interlocking points in plain knitted fabrics in case of first load cycle. The loops are unable to retain their shape as there is enough free space in between the loops before the load is applied. Therefore, the permanent set reduces drastically in second load cycle and approaches zero in fifth load cycle. Further, at first load cycle for a particular extension level as the yarn extends, the slippage between the fibres occurs up to a certain level and further slippage is prohibited with the increase in load cycle as the extension at peak load levels off, restricting the permanent set to zero.

Fabric tensile resiliency shows an increasing trend with the repeated load cycles; the changes however become marginal after the fifth load cycle.

3.3 Effect of Finishing Treatment on Fabrics before and after Laundering

3.3.1 Extension at Peak Load

It is observed from Tables 2-5 that the extension at peak load in the lycra blended fabrics is approximately three times higher than that of non-lycra fabrics in wale direction, whereas it is two times higher in course direction. This is due to the presence of lycra filaments in the fabric, assisting it to shrink in wale direction when comes off from the knitting machine. Subsequently, the courses per inch of the fabric increase, allowing more loops to contribute towards extension at peak load, particularly in wale direction. The lycra blended fabrics also have higher stitch length (Table 1), the impact of which is greater in course direction than that in wale direction, resulting in higher extension at peak load in former case. The above-mentioned increase in stitch length also results in higher extension at peak load in all the directions of loading.

It is again seen that except in course direction, the full-relaxed knitted fabrics possess higher extension than that of compacted fabrics. The higher extension of fabrics is due to the presence of higher number of courses per inch (Table 1), leading to the possibility of greater extension. Further, the fabric relaxation and setting treatment result in the reduction in magnitude of internal forces acting within the fabric. Consequently, the internal frictional restraints within the fabric are reduced. This effect is found to be very important in relation to the bending behaviour of fabrics, where inter-fibre frictional properties play an important role. Similar effect would be expected to occur within a yarn and would lead to a reduction in yarn bending rigidity after the decrease in initial tensile modulus, leading to higher extension at peak load in the fabrics.\textsuperscript{10,11} The above findings reflect the lack of course direction sensitivity due to the difference in relaxation dryer finishing technique.

The difference between the extension at peak load of full-relaxed and compacted fabrics is higher for lycra blended fabrics than that for non-lycra fabrics, particularly in wale and biased directions. The above findings are also valid for laundered fabrics at all the levels of loading cycle (Tables 2-5).
3.3.2 Recovery Characteristics

Tables 2-5 and Fig. 2 show that the immediate recovery value is considerably higher for lycra blended fabrics in all the directions of loading. This is due to the presence of lycra filament which possesses higher level of immediate recovery at repeated extension. Lycra helps in redistributing the segments of yarn between the contact points and relocation of these points closely after the unloading. Further, the higher stitch density in lycra blended fabric results in greater internal forces, leading to the higher immediate recovery of the fabrics.

The immediate recovery of full-relaxed non-lycra fabric is higher than that of compacted fabrics, particularly in wale and biased directions. However, the immediate recovery of lycra blended fabric shows insignificant difference between full-relaxed and compacted fabrics in all the directions of loading. The above findings indicate that the lycra filament nullifies the effect of relaxation dryer in case of immediate recovery. The findings mentioned above are also valid for repeated laundered fabrics at all levels of loading cycles, except for course-wise immediate recovery of non-lycra fabrics which tends to show the significant difference between compacted and full-relaxed fabrics after repeated laundering (Tables 2-5).

The difference in delayed recovery of knitted fabric due to the difference in finishing treatments is observed mainly in case of non-lycra fabrics in wale and biased directions (Fig. 4). It is further seen that at all levels of loading cycles the delayed recovery of non-lycra fabrics is higher than that of lycra blended fabrics in all the directions of loading before and after laundering (Tables 2-5). In case of lycra blended fabrics, the wale-wise delayed recovery shows marginal difference between compacted and full-relaxed fabrics after laundering.

Fig. 5 shows that the permanent set is higher in case of non-lycra cotton fabrics than that in case of lycra blended fabrics. This is due to the presence of lycra filament in lycra blended fabrics, which is fully recoverable when unloaded. Again, it can be seen that the difference in permanent set due to the difference in finishing technique is significant only in the wale direction of non-lycra cotton fabrics.

Fig. 6 shows that the resiliency is considerably higher for lycra blended fabrics in all the directions of loading. Particularly in non-lycra fabrics, the full-relaxed fabrics possess higher resiliency than that of the respective compacted fabrics along the wale direction. The above-mentioned findings on permanent set and resiliency are also valid for laundered fabrics at all levels of loading. But the difference in resiliency due to the difference in finishing becomes significant after laundering for all the fabrics (Tables 2-5).

4 Conclusions

4.1 Effect of direction of loading is very prominent on both lycra blended and non-lycra knitted fabrics. On the application of external load, the biased direction of fabrics shows better shape retention characteristics in terms of higher immediate recovery and resiliency and lower delayed recovery and permanent set. Higher extension at peak load is exhibited in coarse direction of fabric and than that in other directions of loading.

4.2 With the repeated load cycles, the extension at peak load increases marginally, the immediate recovery and resiliency change considerably, the delayed recovery changes up to a small extent, and the permanent set approaches zero during initial number of cycles.

4.3 Overall performance of lycra blended fabrics is better than that of non-lycra cotton fabrics as the immediate recovery, resiliency and extension at peak load are higher, whereas delayed recovery and permanent set are lower for lycra blended fabrics, irrespective of the direction of loading. Variations in the above characteristics are considerably higher with the change in direction of loading, particularly for non-lycra fabric.

4.4 Full relaxation treatment improves the recovery characteristics like immediate recovery and resiliency, particularly for non-lycra fabrics in the wale direction. The effect of full relaxation finish on the immediate recovery of lycra blended fabric is nullified by the lycra filament as the lycra imparts shape retention characteristics to the fabric. However, the above finish improves the extension at peak load for both lycra and non-lycra fabrics along wale and biased directions.

4.5 The changes in extension and recovery characteristics are prominent at initial laundering cycles and after that the changes become insignificant. In general, the laundering deteriorates the quality of fabrics as the immediate recovery and resiliency of fabric tend to reduce, whereas delayed recovery and permanent set become higher.

References
5 Turner J D, Text Proc, 3 (3) (1971)118