Comfort aspects of finished polyester-cotton and polyester-viscose ring and MJS yarn fabrics

G K Tyagi, G Krishna, S Bhattacharya & P Kumar

The Technological Institute of Textile & Sciences, Bhiwani 127 021, India

Received 25 February 2008; revised received and accepted 26 June 2008

The influence of different experimental conditions on the thermal comfort behavior of polyester-viscose and polyester-cotton ring and MJS yarn fabrics has been studied. The results show that the yarn structure and the fibre cross-sectional shape have a large influence on improving the thermal comfort of woven fabrics. The fabrics made from MJS yarns perform better than those of the ring yarn fabrics in respect of absorbency, air and water vapour permeabilities and thermal insulation. Incorporation of non-circular polyester fibre in the mix further improves these characteristics. The chemical finishing treatment also induces noticeable changes in the thermal comfort characteristics of fabric, though the magnitudes of changes are different for different ring and MJS yarn fabrics, depending upon processing parameters used. The finished fabrics provide enhanced thermal insulation, more absorbency and lesser air and water vapour transport than the corresponding grey fabrics regardless of the yarn type. Moreover, polyester-viscose fabrics are more promising than the polyester-cotton fabrics for comfort applications expect thermal insulation.

**Keywords**: Circular polyester fibre, MJS yarn, Ring-spun yarn, Thermal insulation, Trilobal polyester fibre, Wickability

1 Introduction

Although in the recent past, the textile industry had increasingly focused its attention on higher machine productivity and lower production costs, the current trend within the industry is towards improved wear comfort. Numerous reports have indicated that most of the queries received by the technologists from the consumers are related in one way or another, to the comfort aspects of the substrates and consequently common intentions are heading in the direction of further improvement. The thermal comfort of clothing made from natural and synthetic fibres, as determined by the movement of heat, moisture and air, involves a complex combination of properties, both subjective and physical. Lower thermal resistance results in discomfort for the wearer because excessive heat may be dissipated rapidly by vaporization of the body water. A garment that permits free access of liquid (water) can become uncomfortable in wet weather, when the reverse movement of exterior water towards the skin is experienced. Finally, fabrics with low moisture transmission fail to quickly remove the water generated at the body surface as perspiration. This is especially true for Shirting fabric, in which a combination of high thickness and high density can result in inadequate moisture transmission, which is often a cause of discomfort. There is good correlation between moisture transmission and air permeability of woven fabrics. These relationships appear to result from the co-dependence of these properties on the geometrical features of the fabric structures and outside weather conditions. There have been several studies on the relationship between the structure of woven fabrics and their properties. Literature concerning the comfort characteristics of woven fabrics has mainly focused on the ring and rotor yarn fabrics, and little is known about the handle characteristics of jet-spun yarn fabrics. However, since no one seems to have actually assessed the extent to which fibre cross-sectional shape influences thermal comfort characteristics of jet-spun yarn fabrics, it seems worthwhile to do so now because fibre cross-sectional shape determines the size and geometry of capillary spaces between fibres and consequently the wicking rate. Exploring relationship between fibre cross-sections and objectively measured thermal comfort characteristics of finished polyester-viscose and polyester-cotton ring and MJS yarn fabrics is the focus of this investigation.

\( ^a \) To whom all the correspondence should be addressed.

E-mail: drgktyagi@rediffmail.com
2 Materials and Methods

2.1 Preparation of Fabric Samples

The yarns used in this study were made from blends of polyester, viscose, and cotton fibres on ring and air-jet spinning machines. The specifications of polyester, viscose, and cotton fibres are given in Table 1. For blending polyester and viscose fibres, each of the two components was hand opened and sandwiched well to produce a homogenous blend. However, for polyester-cotton yarns, the cotton was first combed and then mixed with polyester in opening room. Two different types of polyester fibres, viz. circular and trilobal, were used. The conversion to drawn sliver was carried out by using a MMC carding machine and a Lakshmi Rieters’ draw frame DO/2S. Three drawing passages were given to card slivers, the linear density of finisher sliver being adjusted to 2.93 dtex. The drawn slivers were spun into yarns on Murata air-jet spinners (802 MJS). The machine parameters used to produce these yarns were: spinning speed 200 m/min, feed ratio 0.98, first nozzle pressure 2.5 kg/cm$^2$, second nozzle jet pressure 4.5 kg/cm$^2$, and condenser width 4 mm. For ring spinning, the drawn slivers were converted into suitable rove using OKK roving frame. Equivalent ring yarns were spun on Lakshmi Rieters’ ring frame G5/1 using a spindle speed of 14000 rpm.

Experimental ring and MJS yarns were separately used to produce plain woven fabrics on a Texmaco shuttle loom. The construction of the twelve sets of fabrics was kept constant at 28 ends/cm and 28 picks/cm (i.e., 71 ends/inch×71 picks/inch) for single 16.8 tex yarns. For a given set of fabric, the warp used was the same as filling yarn. The details of the fabrics are given in Table 2.

2.2 Finishing Treatment

The fabrics were desized in 0.5 gpl non-ionic detergent (Wet Aid NI) at boiling temperature for 30 min and rinsed in hot water for 5 min. After desizing, the polyester-viscose fabrics were scoured using 2gpl sodium carbonate and 0.5 gpl non-ionic detergents (Wet Aid NI) at 60 °C for 90 min and rinsed in hot water for 5 min. The polyester-cotton fabrics, on the other hand, were immersed in a solution containing 2 gpl sodium hydroxide and 1% non-ionic detergent (Wet Aid NI) at 100 °C for 90 min. After the treatment, the samples were thoroughly washed with cold and hot water for 15 min each to remove adhered chemicals completely from the fabrics, neutralized with acetic acid (2 gpl), washed thoroughly and dried at 90 °C. All fabrics were later subjected to finishing treatment. The typical finish formulation used was: Cerapern K (amino based softener), 10 gpl; CAN (amino based softener), 8 gpl; Sarasoft BTM (amino based softener), 5gpl; and acetic acid, 2gpl.

2.3 Tests

2.3.1 Yarn Properties

All the yarns were tested for flexural rigidity on weighted ring yarn stiffness tester by ring loop method. The yarn diameter was measured by Leica Q500 MC at 100 randomly selected places along the length of the yarn. A sufficient length of yarn was covered to take care of any variation.

2.3.2 Fabric Properties

2.3.2.1 Air Permeability

Air permeability tests were conducted on Prolific air permeability tester according to ASTM standard D737-96. The conditioned test specimen was centrally

<table>
<thead>
<tr>
<th>Fibre</th>
<th>Fibre profile</th>
<th>Length (mm)</th>
<th>Linear density (dtex)</th>
<th>Tenacity (cN/tex)</th>
<th>Breaking extension (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Polyester</td>
<td>Circular</td>
<td>44</td>
<td>2.22</td>
<td>45.02</td>
<td>29.20</td>
</tr>
<tr>
<td>Polyester</td>
<td>Trilobal</td>
<td>22.2</td>
<td>40.61</td>
<td>30.00</td>
<td></td>
</tr>
<tr>
<td>Viscose</td>
<td>-</td>
<td>44</td>
<td>1.66</td>
<td>24.24</td>
<td>18.25</td>
</tr>
<tr>
<td>Cotton</td>
<td>-</td>
<td>35°</td>
<td>1.52 (3.9)°</td>
<td>30.52</td>
<td>6.30</td>
</tr>
</tbody>
</table>

Table 1 — Specifications of polyester, viscose rayon and cotton fibres

<table>
<thead>
<tr>
<th>Ref. no.</th>
<th>Fibre composition</th>
<th>Fibre profile</th>
<th>Yarn type</th>
<th>Yarn characteristics</th>
</tr>
</thead>
<tbody>
<tr>
<td>S&lt;sub&gt;1&lt;/sub&gt;</td>
<td>48:52 P/C</td>
<td>Circular</td>
<td>Ring</td>
<td>Diam.× 10&lt;sup&gt;3&lt;/sup&gt; cm</td>
</tr>
<tr>
<td>S&lt;sub&gt;1&lt;/sub&gt;</td>
<td>48:52 P/C</td>
<td>Circular</td>
<td>Ring</td>
<td>16.98</td>
</tr>
<tr>
<td>S&lt;sub&gt;2&lt;/sub&gt;</td>
<td>48:52 P/C</td>
<td>Trilobal</td>
<td>Ring</td>
<td>17.08</td>
</tr>
<tr>
<td>S&lt;sub&gt;3&lt;/sub&gt;</td>
<td>65:35 P/C</td>
<td>Circular</td>
<td>Ring</td>
<td>17.22</td>
</tr>
<tr>
<td>S&lt;sub&gt;4&lt;/sub&gt;</td>
<td>65:35 P/C</td>
<td>Trilobal</td>
<td>Ring</td>
<td>17.66</td>
</tr>
<tr>
<td>S&lt;sub&gt;5&lt;/sub&gt;</td>
<td>48:52 P/V</td>
<td>Circular</td>
<td>Ring</td>
<td>16.64</td>
</tr>
<tr>
<td>S&lt;sub&gt;6&lt;/sub&gt;</td>
<td>48:52 P/V</td>
<td>Trilobal</td>
<td>Ring</td>
<td>16.91</td>
</tr>
<tr>
<td>S&lt;sub&gt;7&lt;/sub&gt;</td>
<td>65:35 P/V</td>
<td>Circular</td>
<td>Ring</td>
<td>16.82</td>
</tr>
<tr>
<td>S&lt;sub&gt;8&lt;/sub&gt;</td>
<td>65:35 P/V</td>
<td>Trilobal</td>
<td>Ring</td>
<td>17.45</td>
</tr>
<tr>
<td>S&lt;sub&gt;9&lt;/sub&gt;</td>
<td>48:52 P/V</td>
<td>Circular</td>
<td>MJS</td>
<td>15.70</td>
</tr>
<tr>
<td>S&lt;sub&gt;10&lt;/sub&gt;</td>
<td>48:52 P/V</td>
<td>Trilobal</td>
<td>MJS</td>
<td>15.99</td>
</tr>
<tr>
<td>S&lt;sub&gt;11&lt;/sub&gt;</td>
<td>65:35 P/V</td>
<td>Circular</td>
<td>MJS</td>
<td>16.188</td>
</tr>
<tr>
<td>S&lt;sub&gt;12&lt;/sub&gt;</td>
<td>65:35 P/V</td>
<td>Trilobal</td>
<td>MJS</td>
<td>16.40</td>
</tr>
</tbody>
</table>

Table 2 — Specifications of fabric samples

<sup>a</sup>Yarn linear density, 16.8 tex. P/C – Polyester/cotton and P/V – Polyester/viscose.
placed between adapter disc and the lower grip and sufficient tension was applied on the fabric to eliminate wrinkles. Adequate holding pressure was applied so as to prevent slippage of the fabric and also to eliminate the leakage of air through the gripping faces. The power supply to the equipment and vacuum pump was switched-on and the flow adjusting valve was slowly opened and adjusted to increase the air-flow till the desired pressure drop was obtained on the manometer. Recorded air-flow was divided by the exposed area of the test specimen. Exposed area of test specimen was 10 cm$^2$ under the pressure drop of 10 mm of water column. As the air permeability of single layer fabric was not measurable due to its high porosity, all the fabric samples were doubled before measuring the air permeability. Oxtoby suggests that for fabrics with an open structure, several layers may be superimposed in order to give a value that is measurable and shows that the product of the air-flow and the number of layers is approximately constant.

2.3.2.2 Water Vapour Transmission

Water vapour permeability of fabrics was determined by means of the Permetest tester. The instrument measures the heat flow caused by the evaporation of water passing through the tested specimen. The fabric sample was spread on the measuring head and thereafter water was injected on the measuring head. Evaporation took place under standard atmospheric conditions of 65% RH and 20°C temperature. As the heat lost from the wet measuring head depends upon the permeability characteristics of the fabric, the output voltage with a fabric would be different as compared to the bare measuring head. The relative water vapour permeability is given by the following expression:

$$\text{Relative water vapour permeability} (\%) = \left[ \frac{U_1}{U_2} \right] \times 100$$

where $U_1$ and $U_2$ are the output voltage with and without fabric on the measuring head.

2.3.2.3 Wickability

The wickability of fabrics was determined by Inplane wicking tester based on horizontal wicking of water through fabric, and was estimated by measuring the weight of water through it with time. The fabric sample of specific size (16 cm × 16 cm) was placed on a glass plate connected to a glass siphon tube. Water reaches the plate through this glass tube due to siphonic action from a beaker, placed on a measuring balance. As water wicked through the fabric, the change in the weight of water was measured by the balance interfaced with a computer. The duration of the test was 5 min for all fabric samples.

2.3.2.4 Thermal Insulation

Thermal insulation of the fabric was measured on SASMIRA thermal conductivity tester based on guarded hot plate method. The test specimen was placed between the heated lower plate and an insulated top plate. The time taken by the hot plate to cool down from 50°C to 49°C was measured and corresponding ‘Clo’ value determined from graph. The ‘Clo’ value was converted to the more frequently used ‘Tog’ value using the following formula:

$$\text{Tog} = 0.645 \times \text{Clo}$$

2.3.2.5 Fabric Total Absorbency

Total absorbency, which measures the water holding capacity of the fabric, was determined by using 0.2% soap solution. A sample of size 20 cm × 20 cm was dipped in the solution for 5 min and then hung vertically to allow any extra water to drop down. It was then weighed and the percentage gain in weight of the fabric sample was taken as a measure of the total absorbency of the fabric. Fabrics were conditioned in a standard atmosphere for 24 h before all the tests were carried out.

3 Results and Discussion

The influence of experimental factors, viz. fibre cross-section, fibre mix, polyester content, yarn type and finishing treatment, on the thermal comfort characteristics was assessed with the help of ANOVA analysis (Table 3). The confidence level used was 99%.

3.1 Air Permeability

One of the comfort measures that greatly affects the wearer is air permeability. A material that is permeable to air is likely to be permeable to water, but very often may result in physical or psychological discomfort in the wearer. Figure 1 shows air permeability results for various woven fabrics. Expectedly, the polyester-viscose MJS yarn fabrics possess appreciably higher air permeability than the ring-spun yarn fabrics, and it has different values for different fibre-mix. However, for all fibre-mix, the air permeability decreases significantly with the increase in polyester content due to increased yarn diameter. The permeability measurements show a marked
dependence on the profile of the polyester fibre used. It is clearly visible in Fig. 1 that virtually all the data for air permeability relative to fibre profile lie in a wide range, and the fabrics containing trilobal polyester fibre generally exhibit higher air permeability. However, there is a signified decrease in air permeability on finishing. The effect could conceivably be due to the reduction in inter-yarn space and pore size in the fabric as a result of finishing. Nevertheless, polyester-viscose fabrics are more permeable than their polyester-cotton counterparts, and the differences are statistically significant at 99% level.

### 3.2 Thermal Insulation

Thermal insulation is an important measure for analyzing the effect of the material properties on heat transfer. Figure 2 compares the thermal insulation results of different fabric structures before and after finishing treatment. In any event, the thermal insulation of ring yarn fabrics is not inferior to the MJS yarn fabrics. The results for variance analyses indicate that the profile of polyester fibre used has a significant impact on the thermal insulation of fabric. For both types of structures, the thermal resistances of trilobal polyester blended fabrics are higher than those of circular polyester blended ones as the former involve greater amount of trapped air in the substrate. Amongst polyester-cotton and polyester-viscose fabrics, the higher thermal insulation of the former is likely due to the higher thickness of polyester-cotton fabrics. The presence of convolutions in the cotton fibre, which, in turn, influence the amount of air entrapped also improve insulation. One might expect increased conductivity due to increase in the amount of heat transfer. Figure 2 shows that increasing cotton content lowers the thermal insulation on account of its higher moisture content. Increased polyester content has little effect on the thermal insulation of polyester-viscose fabrics. The behavior of the grey polyester-viscose and polyester-cotton fabrics subjected to finishing treatment, on the other hand, shows a masking effect of thermal insulation, which improves in an unexplainable way. Insulation measurements differ significantly for grey and finished fabrics regardless of yarn structure.

### 3.3 Water Vapour Transmission

Figure 3 shows the water vapour permeability of the experimental fabrics. The data reveal that the fabrics made from polyester-viscose MJS yarns
exhibit higher water vapour permeability. This is explained by the observation that these yarns produce a less hairy and more compact structure which provides greater inter-yarn spaces. On the other hand, the water vapour permeability of both types of fabrics tends to decrease on finishing. The greater thicknesses together with the lesser porosity of the finished fabrics are thought to have contributed more strongly to the decreased water vapour transmission. The analysis of variance demonstrates that the changes in water vapor permeability caused by chemical finishing are significantly influenced by the fibre profile and the composition of the mix, at a confidence level of 99%. This is particularly evident for the fabrics produced with non-circular polyester fibre and polyester-minority mix. Furthermore, the polyester-cotton fabrics are relatively less water vapour permeable than the polyester-viscose fabrics, as expected.

3.4 Wickability

Wickability is also an important factor in determining the comfort of clothing for active wear. High wickability facilitates quick drying and fast cooling in hot environments. The wickability results relative to different processing parameters are given in Fig.4. Invariably, ring-spun yarn fabrics exhibit much higher wickability than the MJS yarn fabrics under identical conditions. The high wickability of the ring yarn fabric is believed to result from the small, uniformly distributed and inter connected pores and channels, which facilitates fast liquid transport. The wickability data of the fabrics made from a trilobal polyester fibre are quite close to those made with a polyester fibre of round cross-section, indicating that the fibre cross-sectional shape does not have much influence on the liquid transport in the fabric. Surprisingly, however, the wickability measurements
do not significantly differ for the grey and finished fabrics, and thus are not finish-dependent, although for all experimental combinations, the finished fabrics yield slightly higher wickability than the corresponding grey fabrics. The higher wickability is due to the decrease in contact angles and increased pore volumes. Moreover, the wickability always remains higher for polyester-viscose fabrics as compared to polyester-cotton fabrics and it increases slightly as the polyester content is decreased from 65% to 48%. The higher hydrophilicity of the viscose component of fibre-mix, which governs liquid transport through capillary interstices in yarns, is obviously the contributing factor for higher wickability.

3.5 Absorbency

Generally, the difference in packing densities of ring and MJS yarns results in different absorbency values of these fabric structures (Fig. 5). The data also reveal that with the increase in the polyester content in the fibre mix, absorbency is reduced and the values of absorbency for polyester-viscose fabrics are slightly higher than those for polyester-cotton fabrics of similar type in respect of yarn structure and blend composition. In quantitative terms, the 48:52 polyester-viscose MJS yarn fabrics exhibit the higher absorbency, whereas 65:35 polyester-cotton ring yarn fabrics have the lowest absorbency. The absorbency decreases in the order: polyester-viscose MJS yarn fabric > polyester-viscose ring yarn fabric > polyester-cotton ring yarn fabric. As already stated, the differences in the moisture regains of the constituent fibres would account for the variation in total absorbency. The results of variance analyses indicate that the fibre cross-sectional shape and the finishing treatment have a significant effect on the absorbency of the woven polyester-viscose and polyester-cotton fabrics. In effect, the values of absorbency are measurably higher for trilobal

Fig. 4—Influence of fibre cross-sectional shape on wickability [(1) 48:52 P/C ring yarn, (2) 65:35 P/C ring yarn, (3) 48:52 P/V ring yarn, (4) 65:35 P/V ring yarn, (5) 48:52 P/V MJS yarn, and (6) 65:35 P/V MJS yarn]

Fig. 5—Influence of fibre cross-sectional shape on absorbency [(1) 48:52 P/C ring yarn, (2) 65:35 P/C ring yarn, (3) 48:52 P/V ring yarn, (4) 65:35 P/V ring yarn, (5) 48:52 P/V MJS yarn, and (6) 65:35 P/V MJS yarn]
polyester blended fabrics than those of circular polyester blended ones, presumably due to the higher absorbency of the former\(^1\). The response of absorbency of the grey fabric differs from that of the finished fabric and depends on fibre composition and yarn structural features. Very remarkably, for both polyester-viscose and polyester-cotton fabrics, absorbency increases dramatically on finishing regardless of the yarn structures. The chemical finishing appears to flatten the yarn and fabric floats, and it seems likely that the increased thickness of the structure may have reflected the difference in response of various fabrics to absorbency changed. Moreover, the absorbency indices are considerably lower for polyester-cotton fabrics than for polyester-viscose fabrics, as expected.

4 Conclusions

4.1 Fibre profile, composition of fibre-mix and yarn structure are prime factors in controlling comfort characteristics of woven fabrics. Invariably, MJS yarn fabrics display higher absorbency and higher air and water vapor permeabilities than the ring-spun yarn fabrics. Polyester-cotton mix with higher polyester content and circular polyester or combination of these factors may limit these characteristics. For all experimental combinations, the finished fabrics are less air and water permeable, but more absorbent than the corresponding grey fabrics.

4.2 The MJS yarn fabrics provide markedly low wickability than ring-spun yarn fabrics, which, however, increases with the decrease in polyester content. Finishing treatment does not enhance the wickability of either type of fabrics. Moreover, the fabrics made with polyester-viscose mix exhibit a greater ability than the polyester-cotton fabrics to transport water.

4.3 The thermal insulation data of the fabrics made from MJS yarn are quite close to those made with a ring-spun yarn. Interestingly, however, there is a large margin for improvement of MJS yarn fabric’s thermal insulation. The most important insulation limiting factor is fibre cross-sectional shape, and a trilobal fibre has a potential for a substantial improvement in thermal insulation. The fabric’s thermal insulation also increases on finishing, and with increased polyester content. Nevertheless polyester-cotton fabrics exhibit higher thermal insulation as compared to polyester-viscose fabrics regardless of processing conditions used.

Industrial Importance: Comfort is an important aspect in today’s terms as both consumer and industry are focusing more on the comfort aspect of clothing materials. Accordingly, a proper selection of fibre and yarn engineering should lead to realization of specific comfort properties of the fabric in a much economic and scientific way. Additionally, finishing treatments also play a vital role in this regard. This study provides a valuable insight into fibre selection and yarn engineering so as to achieve comfort properties specific to end use requirement.

References