CHAPTER 4

INFLUENCE OF INDIVIDUAL FILAMENT FINENESS ON COMFORT CHARACTERISTICS OF MOISTURE MANAGEMENT FINISHED POLYESTER KNITTED FABRICS

4.1 INTRODUCTION

Filament fineness represents an essential and significant influencing factor on the wear comfort of a textile fabric. The lower fineness of micro-fibers proves to be physiologically advantageous, especially in wear situations where heavy and copious perspiration exists. In these circumstances, the micro-fiber textiles show better moisture transport and ensure better moisture control than the other construction parameters of comparative fineness above one denier in the micro-climate near the skin. The reason for the better physiological isolation of the micro-fiber textiles in these wear situations can be attributed to the higher absorption potential of the fiber surface occasioned by the fiber fineness as well as better capillary effect during the transport of liquid perspiration. Micro-polyester filament yarn is light weight and so fine that many fibers can be packed together very tightly. The space between yarns is porous enough to breathe and wick moisture away from body. In filament fabrics the water vapour transport depends on the fineness of the capillary.

Moisture management property is an important aspect of any fabric meant for apparel, which decides the comfort level of that fabric. Moisture management refers to the controlled movement of water vapor and perspiration from the surface of the skin to the atmosphere through the fabric.
This can be achieved through fabric construction or by adding a chemical finish to a fabric. The former technique involves creating capillaries by using denier differential with the help of microdenier and non-micro-denier fibers with hydrophobic or hydrophilic surfaces. The application of moisture management finish (MMF) to polyester knitted fabrics made from lower denier filament yarns has the double advantage of absorbing and evaporating the body sweat at a faster rate thereby making the wearer feel comfortable. Drying rate is indispensable for any fabric used for sportswear as the amount of sweat generated must be wicked and dried immediately such that the fabric has the potency to absorb more and more moisture from the skin, thereby making it dry.

It was observed that individual filament fineness and capillary pore size of yarns plays a major role in determining the moisture transmission characteristics of a fabric. Also the surface finishing imparted to fabrics influences wearer comfort.

### 4.2 METHODOLOGY

The influence of individual filament fineness on comfort characteristics of moisture management finished polyester knitted fabrics has been studied. Based on the study optimization of filament fineness has been identified to obtain maximum comfort level.

In order to study this effect five different knitted fabrics made from 150 denier polyester filament yarns containing 34, 48, 108,144, and 288 filaments were analyzed with respect to wetting, vertical wicking, transverse wicking, moisture vapor transfer and drying rate. All the test results have been analyzed using statistical tool at 95% confidence level and standard error has also been evaluated and represented in each figure.
Figure 4.1 Process Flow Chart for Application of Moisture Management Finish on Knitted Fabrics
In this study five different polyester continuous filament yarns of 150 denier were taken. It contained 34 filaments (4.4 denier per filament), 48 filaments (3.13 denier per filament), 108 filaments (1.39 denier per filament), 144 filaments (1.04 denier per filament), and 288 filaments (0.52 denier per filament) were selected. The polyester filament yarns were knitted on a circular knitting machine of 28 gauge with speed of 30 rpm to produce five different fabrics of single jersey structure containing 2.9mm stitch length.

4.3 FINISHING TREATMENT

The polyester knitted fabrics were hot washed and bleached. The five fabric samples were treated with a wetting agent consisting of a synergetic blend of ethoxylated alcohol (a fatty alcohol, ethylene oxide, and propylene oxide) at 2% concentration for half an hour at 60–70°C temperature and dried in a stentering machine at 140°C. These fabrics were treated for moisture management finish with a chemical combination of Amino Silicone Polyether Copolymer (ASPC) and Hydrophilic Polymer (HP) in the ratio of 1:2 with pH value of 5.5 at 60–70°C temperature. The samples were treated in the finishing bath and padded using a padding mangle. Then it was dried and cured in a stenter at 160–170°C and subjected to relaxation for 48 hours.

4.4 RESULTS AND DISCUSSION

In order to study the influence of individual filament fineness on comfort characteristics such as wetting, vertical wicking, transverse wicking, and moisture vapor transfer of moisture management finished polyester knitted fabrics, five different fabrics containing 150 denier polyester yarns were used and denoted as 34FF, 48FF, 108FF, 144FF and 288FF.
4.4.1 Geometrical Characteristics

The geometrical properties of MMF polyester fabrics were measured and the average value of 10 samples was given in Table 4.1.

Table 4.1 Fabric Geometrical Characteristics

<table>
<thead>
<tr>
<th>Sample</th>
<th>Wales per cm</th>
<th>Courses per cm</th>
<th>Stitch density (loops/cm²)</th>
<th>Areal density (grams/m²)</th>
<th>Stitch length (mm)</th>
<th>Thickness (mm)</th>
<th>Fabric Porosity (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>34FF</td>
<td>17.32</td>
<td>17.32</td>
<td>299.98</td>
<td>136.13</td>
<td>2.8</td>
<td>0.56</td>
<td>82.5</td>
</tr>
<tr>
<td>48FF</td>
<td>17.24</td>
<td>18.62</td>
<td>321.00</td>
<td>137.50</td>
<td>2.8</td>
<td>0.55</td>
<td>82</td>
</tr>
<tr>
<td>108FF</td>
<td>17.62</td>
<td>17.51</td>
<td>308.52</td>
<td>133.38</td>
<td>2.8</td>
<td>0.55</td>
<td>82.5</td>
</tr>
<tr>
<td>144FF</td>
<td>16.61</td>
<td>17.91</td>
<td>297.55</td>
<td>135.03</td>
<td>2.7</td>
<td>0.50</td>
<td>80.5</td>
</tr>
<tr>
<td>288FF</td>
<td>16.74</td>
<td>16.53</td>
<td>276.71</td>
<td>128.00</td>
<td>2.7</td>
<td>0.44</td>
<td>79.1</td>
</tr>
</tbody>
</table>

FF—Filaments fabric

There is no trend found between fiber fineness and the geometrical characteristics of the fabrics with respect to wales per centimeter, courses per centimeter, stitch density, and areal density. Effect of geometrical characteristics of the fabrics has insignificant effect at 95% confidence level. Fabric thickness value reduces by 2 to 21% with increase in filament fineness due to compactness of the finer filament yarn in the fabric. Also fabric porosity reduces by 2 to 4% for finer filament fabrics.

4.4.2 SEM Analysis

In order to study the surface structure of the microdenier polyester fabric, Scanning Electron Microscope (SEM) analysis of five different fabrics containing 150 denier polyester filament yarns was carried out and given in Figures 4.2(a) to 4.2(e).

It was clearly seen that fineness of the individual filaments increases with the increase in the number of filaments in the yarn. The shiny
appearance of the filaments is due to the moisture management finishing agents being affixed to the fabric.
4.4.3 Water Transmission Characteristics

The water transmission characteristics of MMF treated polyester fabrics were analysed and the average values were given in Table 4.2.

Table 4.2 Water Transmission Characteristics

<table>
<thead>
<tr>
<th>Samples</th>
<th>Sinking time (seconds)</th>
<th>Vertical wicking</th>
<th>Transverse wicking</th>
<th>Moisture vapor transmission (percentage)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Wicking height after 30 minutes (cm)</td>
<td>Water spreading area for 1ml of water(cm²)</td>
<td>Area covered to reach saturation (cm²)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Wales wise</td>
<td>Course wise</td>
<td></td>
</tr>
<tr>
<td>34FF</td>
<td>10.35</td>
<td>13.95</td>
<td>12.40</td>
<td>4.62</td>
</tr>
<tr>
<td>48FF</td>
<td>7.00</td>
<td>15.05</td>
<td>12.65</td>
<td>4.85</td>
</tr>
<tr>
<td>108FF</td>
<td>6.09</td>
<td>16.20</td>
<td>14.70</td>
<td>4.85</td>
</tr>
<tr>
<td>144FF</td>
<td>7.30</td>
<td>15.75</td>
<td>14.50</td>
<td>5.10</td>
</tr>
<tr>
<td>288FF</td>
<td>9.62</td>
<td>14.05</td>
<td>12.45</td>
<td>5.60</td>
</tr>
</tbody>
</table>

FF Filament fabrics

From Table 4.2 it is seen that 108 FF takes least time to sink in water. The wicking height in wale wise direction was more than in course wise direction for all five fabrics. In transverse wicking the water spreading area increases with increase in the number of filaments in the fabric. The moisture vapor transmission rate was higher for finer filament fabrics. The detailed explanation about the test results are given in subtopics 4.4.4 to 4.4.8.

4.4.4 Analysis of Wetting Characteristics

The ability of the fabric to sink completely in water were tested and included in Table 4.2.

From Figure 4.3 and Table 4.2, it is seen that 108 filaments fabric show quicker sinking time. As the number of filaments increases (144FF and 288FF) or decreases (34FF and 48FF) the time taken to sink the fabric is more.
The reason is when inter fiber space is too small or too large it will slow down the water entry. Among the selected fabrics, 108 filaments may be the optimum inter fiber-space that causes fastest entry of water into yarn pores. Effect of filament fineness on wetting behavior of fabrics is significant at 95% confidence level. (F calculated > F tabulated: p-value 6.24E-06).

![Figure 4.3 Wetting Characteristics of the Fabrics](image)

4.4.5 Analysis of Wicking Characteristics

The rate of water spreading by capillary action were tested for wicking rate and wicking height and given below.

4.4.5.1 Longitudinal Wicking Rate

The rate of water spreading by capillary action were tested for walewise and course wise direction and given in Figures 4.4 and 4.5.
Figure 4.4  Longitudinal Wicking Rate of the Fabrics – Wale Wise Direction

Figure 4.5  Longitudinal Wicking Rate of the Fabrics – Course Wise Direction
From Figures 4.4 and 4.5, the wicking height of all five fabrics in both wale and course wise direction were analyzed with respect to wicking time from 5 seconds to 5 minutes. The wicking height increases from 34 filaments fabric to 108 filaments fabric, and then it decreases for 144 filaments and 288 filaments fabric. The inter fiber space increases in yarn thereby increasing its surface area. This leads to increase in wicking rate. But, the wicking rate had gradually decreased for 144 filaments and 288 filaments even though more number of filaments were present. This may be due to the lower capillary pressure which slows down water entry due to very small pores that can be detrimental to quick wicking and also due to the lower fabric porosity which determines the surface area of the filaments. The wicking rate increases with time for all samples. This similar trend was seen in both wale wise and course wise direction.

Among the five fabrics, 108 filaments fabric shows 6% to 18% higher wicking rate than the other four fabrics. This may be the optimum capillary size that causes fastest entry of water into yarn pores. The fabric wicking rate in wale wise direction is 11–18% higher than in course wise direction for all samples and at all time intervals. The water moves longitudinally faster in vertical direction because knit loops lie one above the other and the loop leg orientation of the yarn is more in wale wise direction while in horizontal direction the loops are set side by side where the movement of the water follows the loop ie. first in horizontal direction and then in vertical direction intermittently. A similar trend was observed by Behera et al (2002). The increase in height of wicking in walewise direction is higher than course wise direction because of higher inter molecular forces of cohesion between water and wale-wise yarn. The effect of filament fineness on fabric wicking rate in wale wise and course wise directions are significant at 95% confidence level (Fcalculated>Ftabulated: t - wale wise=2.77E_07 and t - course wise=4.2E_07).
4.4.5.2 Wicking Height

The vertical wicking height reached after 30 minutes were tested and included in Table 4.2.

Figure 4.6 Wicking Height of the Fabrics (After 30 Minutes)

From Figure 4.6 and Table 4.2, it was observed that the wicking height of the fabric (after 30 minutes) have increased from 34 filaments fabric to 108 filaments fabric and then decreases for 144 filaments fabric and 288 filaments fabric The is due to the that the finer filaments fabrics have smaller pores and hence lower capillary pressure which slows down water entry. The same trend was found in both wale wise and course wise directions. Wicking height in wale wise direction was 10–16% higher than that of course wise direction for all five samples.
The results of wicking height (after 30 minutes) have shown the same trend as the wicking rate (from 5 seconds to 5 minutes). But it was clearly seen that wicking height increases at a faster rate up to 5 minutes and the speed of capillary flow slowed down after 5 minutes up to 30 minutes. It was observed that 75% of the total increasing wicking height is from 5 seconds to 5 minutes for all selected fabrics.

4.4.6 Analysis of Transverse Wicking Characteristics

The area covered by the spreading action of water for one drop and saturation method are given below.

4.4.6.1 Area of Water Spread for One Drop of Water

The area covered by the spreading action of one drop (1ml) of water were tested and included in Table 4.2.

From Figure 4.7 and Table 4.2 it is inferred that when the filament fineness (or the number of filaments) increases, the water spreading area also increases from 34 filament fabric to 288 filament fabric. The 288 filament fabric has 20% higher water spreading area than that of other selected fabrics. This may be due to the lower thickness and hence lower density of 288 filament fabric. With lower density the number of loops is also less per unit area. This aids in larger area spread when compared to other fabrics. This same trend was observed by Patil et al (2009). Transverse wicking is a unique phenomenon with respect to water transfer behavior of fabrics, since it has no directional effect. When the area spread was more the evaporation of the fabric was also more. Finer the filaments, larger was the area spread and quicker the moisture evaporation from the fabric surface.
4.4.6.2 Area of Water Spread and Time Taken to Reach Saturation

The area covered and time taken to reach saturation point were tested and included in Table 4.2.

From Figure 4.8 and Table 4.2, the water spreading area (to reach saturation) has increased from 34 filament fabric to 288 filament fabric by 31% though they differ in fabric geometry. Finer filaments in the fabric have higher surface tension which helps to hold the water droplet and transfer it in the lateral direction against gravitational force. When filament fineness was more, it showed higher water absorbency. This is due to more inter-fibre space due to which the water spreads well in parallel. This also indicates that finer the filaments, higher is the water holding capacity of the fabrics. The advantage of these assessments is that since transverse wicking being multi-directional, it eliminates the directional effect. When the time taken to reach saturation point is more correspondingly the area spread is also more.
4.4.7 Analysis of Moisture Vapour Transfer Behavior

The rate at which moisture vapour moves through a fabric were tested and shown in Table 4.2.

From Figure 4.9 and Table 4.2 it is seen that 34 filaments fabric and 48 filaments fabric shows 24%–31% lower moisture vapor transfer than that of 108 filaments fabric, 144 filaments fabric, and 288 filaments fabric with respect to height loss and weight loss. The finer denier fabrics such as 108 filaments fabric, 144 filaments fabric, and 288 filaments fabric gives higher moisture vapor transfer (MVT). This is due to the finer filaments in the yarn structure. Finer filaments have narrower capillaries and hence higher will be the transport of moisture. This similar trend was observed by Behra et al (2007a).
4.4.8 Analysis of Drying Characteristics

Drying rate indicates the ability of the fabric to evaporate the moisture present. Drying rates were expressed as average weight loss over initial water content per unit area.

Figure 4.9 MVT for Height and Weight Reduction of Water

Figure 4.10 Drying Rate of the Fabrics
From figure 4.10 it is seen that 108 Filaments, 144 filaments and 288 filament fabrics exhibit the quickest drying times. All the three fabrics take 8 minutes to dry and return to original weight. This indicates that finer the filaments, quicker was the drying time. Also from the graph it was seen that the initial drying rate was faster for the finer filaments constituting 108 filaments, 144 filaments and 288 filaments. This is due to the greater exposed surface area of these fabrics. The same trend was observed by Srinivasan et al (2007).

It is interesting to note that the 288 FF curve shows a slight deflection point at 6 minutes, corresponding to a lower slope. This indicates slower evaporation rate. In fact the higher slope upto 6 minutes represents the moisture release from the fabric. The lower slope after 6 minutes is gradual and this corresponds to the moisture release from the filaments. A similar trend was observed by Raul Fangueiro et al (2009). This is due to the fact that 288 filaments fabric has larger than optimum capillary size (pores) in its yarn, which slows down the moisture evaporation rate. But 108 filaments and 144 filaments fabric curves show a rapid and constant rate of evaporation till they reached dry fabric weight. 48 filaments and 34 filaments fabric takes 10 minutes and 12 minutes to return to original weight.

4.5 CONCLUSION

One of the objectives of this research work is to study the influence of individual filament fineness on comfort characteristics of MMF polyester knitted fabrics. In order to study the comfort characteristics of the fabrics wetting, vertical wicking and moisture vapor transfer were analyzed. A novel method has been introduced to measure the water spreading area on the fabric, in order to find out the transverse wicking behavior of the fabrics.
There is no trend found between filament fineness and the geometrical characteristics of the fabrics with respect to wales per centimeter, courses per centimeter, stitch density, and areal density. Fabric thickness value reduces by 2 to 21% with increase in filament fineness due to compactness of the finer filament yarn in the fabric.

Through SEM analysis it was clearly seen that fineness of the individual filaments increases with the increase in the number of filaments in the yarn. The shiny appearance of the filaments was due to the moisture management finishing agents being affixed to the fabric.

In the wetting test, it was observed that 108 filaments fabric exhibited quicker sinking time than the other four filament fabrics. As the number of filaments increases (144 FF and 288 FF) or decreases (34 FF and 48 FF) the time taken to sink the fabric was more.

In the longitudinal wicking rate, it was observed that the wicking height increases from 34 filaments fabric to 108 filaments fabric, and then it decreases for 144 filaments and 288 filaments fabric. Among the five fabrics, 108 filaments fabric shows 6% to 18% higher wicking rate than the other four fabrics. The fabric wicking rate in wale wise direction is 11 to 18% higher than in course wise direction for all samples and at all time intervals.

In the wicking test, it was observed that the wicking height of the fabric (after 30 minutes) have increased from 34 filaments fabric to 108 filaments fabric and then decreases for 144 filaments fabric and 288 filaments fabric. Wicking height in wale wise direction was 10–16% higher than that of course wise direction for all five fabrics. It was observed that 75% of the total increasing wicking height is from 5 seconds to 5 minutes for all selected fabrics.
In the transverse wicking test for one drop of water, the water spreading area increases from 34 filament fabric to 288 filament fabric. The 288 filament fabric has 20% higher water spreading area than that of other selected fabrics. In the saturation test, the water spreading area increased by 31% from 34 filament fabric to 288 filament fabric and correspondingly the time taken to reach saturation point also increased 2 times.

In the MVT test, 34 filaments and 48 filaments fabric showed 24% to 31% lower moisture vapor transfer than that of 108 filaments, 144 filaments and 288 filaments fabrics with respect to height loss and weight loss. The finer denier fabrics such as 108 filaments fabric, 144 filaments fabric, and 288 filaments fabric gives 20% higher moisture vapor transfer.

In the drying rate test it was observed that 108 filaments, 144 filaments and 288 filament fabrics exhibit the quickest drying times. All the three fabrics took 8 minutes to dry and return to original weight. 48 filaments and 34 filaments fabric had taken 10 minutes and 12 minutes to return to original weight respectively.

Comparing all selected fabrics, it was concluded that 108 filaments fabric had given the optimum level of comfort. The filament fineness and the number of filaments in the yarn play a vital role in determining the comfort characteristics of MMF microdenier polyester knitted fabric.