CHAPTER 8

INFLUENCE OF MOISTURE MANAGEMENT FINISH ON THERMAL COMFORT CHARACTERISTICS OF KNITTED FABRICS MADE FROM DIFFERENT YARNS

8.1 INTRODUCTION

From the result obtained in chapter 7 it is established that moisture management finished (MMF) Microdenier polyester fabrics exhibited better results than other four fabrics with regards to comfort characteristics. But all the tests done till now were to find the suitability of the fabric for water transmission characteristics. To know the level of performance of microdenier polyester fabric among other fabrics made from commercially available yarns for heat transfer characteristics, it become necessary to analyze the thermal comfort characteristics.

Thermal protection of clothing is essential function in most of the environmental conditions in various parts on the earth. The general clothing assemblies approximately covers around 90% of a human body. Therefore, the thermal transmission characteristics of clothing are extremely important, as our body responds to the external thermal environment through clothing. The thermal barrier between the human body and the environment formed by the clothing ensemble and entrapped still air influence the heat and mass transmission from human body to the environment or vice versa in the form of heat and moisture (both liquid and vapour) transfer processes. In fact
the heat and moisture transfer processes are normally coupled under transient situations. The heat loss from the body and the feeling of individual comfort in a given environment is much affected by the clothing worn.

The thermal transmission behaviour of textile fabrics is also influenced, to a great extent, by fibre arrangement within yarns. The packing density of staple yarns varies widely depending on the fibre arrangement. Irrespective of the production techniques, textile fabrics are porous materials consisting of a solid matrix with an interconnected void and the thermal transmission characteristics depend primarily on the porosity of fabrics. So, it is obvious that the parameters which affect the fabric porosity also affect its thermal transmission behaviour.

As far as the geometrical characteristics of textile fabrics are concerned the fabric thickness has the most significant influence on thermal behaviour, explaining more than 90% of the phenomenon. This is due to the fact that the increase in thickness of fabric affects the fabric porosity due to the corresponding increase of volume. The thermal insulation characteristics of textile assemblies depend on the randomness of fibre arrangement in fabrics. Fibre arrangement as well as fabric thickness determines fabric insulation. Yarn structural parameters influence the thermal transmission characteristics of fabrics due to presence of air pockets within the yarn body (Apurba Das and Alagirusamy 2010).

8.2 METHODOLOGY

The influence of moisture management finish on thermal comfort characteristics of knitted fabrics made from five different yarns has been studied, to know the level of performance of micro-denier polyester knitted fabrics among the selected materials.
Five different types of yarns namely Microdenier polyester (M1), spun polyester (M2), polyester/cotton blend yarn (M3), filament polyester (M4) and 100% cotton (M5) was used for the study. All the yarns were of the same count or denier (i.e.) spun polyester, polyester/cotton and cotton were 35 \text{ s Ne} count, whereas Microdenier polyester (containing 108 filaments) and filament polyester (containing 34 filaments) were of 150 denier average fineness.

The selected yarns were knitted on the circular knitting machine of 28 gauge to produce five different fabrics of single jersey plain structure containing 2.9 mm stitch length. The MMF treatment has been given as described in chapter 7.2.1. Thermal characteristics such as thermal conductivity, thermal resistance, thermal absorbtivity, relative water vapour permeability and water vapour resistance were tested. 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 8.1 Process Flow Chart for Application of Moisture Management Finish on Knitted Fabrics

- Microdenier polyester yarn
- Spun polyester yarn
- Polyester / Cotton yarn
- Filament polyester yarn
- Cotton yarn

Development of five knitted fabrics
Single jersey structures with 2.9mm stitch length

Preparatory wet processing for the above fabrics
(Scouring/ Hot wash / Bleaching)

Application of wetting agent to the fabrics
Application of Moisture Management Finish

Dispersion containing Hydrophilic Polysiloxane and Hydrophilic Polyester with pH=5.5 and Temp=60-70°C

Fabrics subjected to testing for:
- Geometrical characteristics
- Thermal conductivity
- Thermal absorptivity
- Dry thermal resistance
- Wet thermal resistance
- Relative water vapour permeability
- Water vapour resistance
8.3 RESULTS AND DISCUSSION

The influence of moisture management finish on thermal comfort characteristics such as thermal conductivity, thermal resistance, thermal absorptivity, relative water vapor permeability and water vapor resistance were tested.

8.3.1 Geometrical Characteristics

The geometrical properties of five different knitted fabrics were measured and the average value of ten samples was given in Table 8.1.

<table>
<thead>
<tr>
<th>Material Type</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>
</tr>
</thead>
<tbody>
<tr>
<td>Microdenier Polyester</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Un Treated</td>
<td>16.93</td>
<td>16.81</td>
<td>284.59</td>
<td>126</td>
<td>2.9</td>
<td>0.51</td>
</tr>
<tr>
<td>Treated</td>
<td>17.85</td>
<td>17.71</td>
<td>316.12</td>
<td>135.5</td>
<td>2.7</td>
<td>0.56</td>
</tr>
<tr>
<td>Spun Polyester</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Un Treated</td>
<td>16.53</td>
<td>14.96</td>
<td>247.28</td>
<td>106</td>
<td>2.9</td>
<td>0.44</td>
</tr>
<tr>
<td>Treated</td>
<td>17.32</td>
<td>15.74</td>
<td>272.61</td>
<td>113</td>
<td>2.8</td>
<td>0.45</td>
</tr>
<tr>
<td>Polyester/Cotton</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Un Treated</td>
<td>16.28</td>
<td>15.02</td>
<td>244.52</td>
<td>100</td>
<td>2.9</td>
<td>0.41</td>
</tr>
<tr>
<td>Treated</td>
<td>17.13</td>
<td>15.56</td>
<td>266.54</td>
<td>110.5</td>
<td>2.8</td>
<td>0.43</td>
</tr>
<tr>
<td>Filament Polyester</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Un Treated</td>
<td>16.91</td>
<td>16.53</td>
<td>279.52</td>
<td>121</td>
<td>2.9</td>
<td>0.5</td>
</tr>
<tr>
<td>Treated</td>
<td>17.82</td>
<td>17.36</td>
<td>309.35</td>
<td>130.5</td>
<td>2.7</td>
<td>0.55</td>
</tr>
<tr>
<td>100% cotton</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Un Treated</td>
<td>16.89</td>
<td>16.45</td>
<td>277.84</td>
<td>122</td>
<td>2.9</td>
<td>0.44</td>
</tr>
<tr>
<td>Treated</td>
<td>17.66</td>
<td>17.28</td>
<td>305.16</td>
<td>126</td>
<td>2.8</td>
<td>0.45</td>
</tr>
</tbody>
</table>

The wale and course density of the fabrics were increased after MMF was applied. This area shrinkage due to finishing treatment affects the areal density of the fabrics. Microdenier polyester and filament polyester fabrics exhibits higher areal density and thickness than the other three fabrics. After MMF there is an increase of 7% in areal density and 9% in thickness for both fabrics. Spun polyester and polyester/cotton show 6% and 9% increase in areal density while the increase in thickness is 2% and 4% respectively.
Cotton exhibits a marginal 3% increase in areal density and 2% increase in thickness values. The application of MMF has reduced the loop length for all five fabrics thereby showing an increase of 8.5% in stitch density.

8.3.2 Thermal Characteristics

Thermal Characteristics of untreated and MMF treated fabrics were analyzed and the average values were given in Table 8.2.

Table 8.2 Thermal Characteristics

<table>
<thead>
<tr>
<th>Material Type</th>
<th>Co-efficient of thermal conductivity W/m K</th>
<th>Thermal Absorptivity W/m² K/m²</th>
<th>Dry thermal resistance (Transient state) m² K/W</th>
<th>Wet thermal resistance (Isothermal state) (Ret) m² K/W</th>
<th>Relative water vapour permeability (%)</th>
<th>Water vapour resistance (Ret) Pa m²/W</th>
</tr>
</thead>
<tbody>
<tr>
<td>Microdenier polyester</td>
<td>Un Treated 0.039 101.9 0.0186 0.0119 72.48 2.59</td>
<td>Treated 0.0423 113.8 0.0181 0.0110 74.06 2.07</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>spun polyester</td>
<td>Un Treated 0.035 77.02 0.0243 0.0244 64.28 3.26</td>
<td>Treated 0.0357 84.54 0.0218 0.0206 65.2 2.49</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>polyester/cotton blend</td>
<td>Un Treated 0.035 78.10 0.0243 0.0260 65.06 3.31</td>
<td>Treated 0.0358 96.42 0.0187 0.0191 69.28 2.53</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>filament polyester</td>
<td>Un Treated 0.035 91.60 0.0201 0.0143 68.82 2.54</td>
<td>Treated 0.042 110 0.0199 0.0134 70.10 2.52</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>100% cotton</td>
<td>Un Treated 0.036 97.60 0.0209 0.0194 66.16 2.84</td>
<td>Treated 0.0377 100.3 0.0200 0.0179 67.44 2.73</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Moisture management finish treatment gives higher thermal conductivity and thermal absorptivity, lower wet thermal resistance and improved water vapor permeability for all five fabrics. Micro-denier polyester fabrics gave higher thermal conductivity. Micro-denier polyester and filament polyester fabrics showed lower wet thermal resistance and higher vapor permeability. Micro-denier polyester and filament Polyester fabrics exhibited higher thermal absorptivity. Spun polyester and polyester / cotton fabrics showed better thermal insulation.
8.3.3 Thermal Conductivity

Thermal conductivity is a phenomenon which indicates the capability of material to conduct heat from one point to another point.

![Graph showing thermal conductivity of different fabrics.](image)

**Figure 8.2 Thermal Conductivity of the Fabrics**

From Figure 8.2 and Table 8.2 it is seen that fabrics knitted with Microdenier polyester filament yarns have 10% higher thermal conductivity values than those knitted with spun yarns. On application of moisture management finish there is an increase in values between 8% to 16% for filament yarn fabrics and only a marginal increase of 2 to 4% for spun yarn fabrics. This may be due to the larger surface area of the continuous filament yarns thereby giving a higher pickup. Comparing the different fabrics it was seen that in fabrics made of filament yarns the air gaps are less because of higher fabric areal density. When fabric areal density increases the effect of interaction between the heat transfer in fibres and in the air becomes stronger thereby increasing thermal conductivity. Here fabric areal density plays a
crucial role in obtaining higher thermal conductivity. Spun polyester and polyester/cotton fabrics show lower values because of lower fabric areal density. This is due to more amount of entrapped air in these structures. Effect of moisture management finish on thermal conductivity of the micro-denier polyester and filament polyester fabrics have significant effect at 95% confidence level.

### 8.3.4 Thermal Absorptivity

Thermal absorptivity is a factor which indicates the ability of the material to regulate as per thermal condition. It allows assessment of the fabric’s character in the aspect of its ‘cool-warm’ feeling. The parameters that are taken into account for computing thermal absorptivity are thermal conductivity, specific heat and density.

![Figure 8.3 Thermal Absorptivity of the Fabrics](image-url)
From Figure 8.3 and Table 8.2 it is seen that knitted fabrics made of micro-denier polyester yarn has 10 % and 23% higher thermal absorptivity than filament polyester and polyester/cotton fabrics. Fabrics with a lower value of thermal absorptivity provide a “warm” feeling, since they provide better thermal insulation and warmer feeling at initial touch. Fabrics having a higher value give a “cool” feeling. On this basis spun polyester and polyester / cotton give a “warm” feeling than those of other fabrics. The fabrics after MMF show a higher value which implies “cooler” feeling at first contact.

Micro-denier polyester, filament polyester and polyester/cotton fabrics show 12 – 18 % increase in value after finish while spun polyester and cotton fabric shows 7% and 3% respectively. This situation can be explained by the higher contact area with the smooth surface structure of fabrics after MMF was applied. Moisture management finish gives a smooth and shiny feel to fabrics made from manmade fibres. Hence thermal absorptivity values are higher in filament and polyester fabrics and only marginal in cellulose cotton fabrics. Heat conduction transfer is higher in smoother surfaces and so they give cooler feeling. The same trend was observed by Pac et al (2001). Effect of moisture management finish on thermal absorptivity of the micro-denier polyester, filament polyester and polyester/ cotton fabrics have significant effect at 95 % confidence level.

8.3.5  Dry Thermal Resistance

Thermal resistance is an important parameter which is relevant to thermal insulation. It is directly proportional to thickness and inversely proportional to thermal conductivity.
From Figure 8.4 and Table 8.2 it is seen that spun polyester and polyester/cotton fabrics show 23% and 17% higher values than microdenier polyester and filament polyester fabrics. On MMF treatment there is a 10 to 23% reduction in values for spun polyester and polyester/cotton and only a marginal reduction for other fabrics. Effect of moisture management finish on dry thermal resistance of spun polyester and polyester/cotton fabrics have significant effect at 95% confidence level. The micro-denier polyester fabric has insignificant effect on moisture management finish treatment.

8.3.6 Wet Thermal Resistance

From Figure 8.5 and Table 8.2 it is seen that fabric sample of micro-denier polyester displayed the lower value. Spun polyester and polyester/cotton fabrics show two times higher value and cotton fabric show 1.6 times higher than microdenier polyester fabric. On MMF treatment there is uniform 8% decrease in values for micro-denier polyester, filament polyester and cotton while it is 20% for spun polyester and polyester/cotton. It
is interesting to note that the trend noticed in dry thermal resistance values is maintained in wet thermal resistance also for spun polyester and polyester / cotton. This shows that the finish has a significant effect on wet thermal resistance.

![Figure 8.5 Wet Thermal Resistance of the Fabrics](image_url)

**Figure 8.5 Wet Thermal Resistance of the Fabrics**

Comparing dry and wet thermal resistance, it was found that thermal resistance values in wet state decreased by 25 to 36% for micro-denier polyester and filament polyester. For cotton the reduction was 7 to 10%. The water vapour sorbed by the fabric replaced the entrapped air in the interstices between fibers and yarns and hence reduced the insulation effect of the fabric. This similar trend was observed by Sekar et al (2009). The extent of reduction falls in proportion to the amount of moisture, which varied with different fibres. The presence of moisture in the fabric caused a reduction in thermal resistance values. The same trend was observed by Indu Sekar et al (2001). It is interesting to note that the values for spun polyester and polyester / cotton fabrics more or less remain the same for dry and wet thermal resistance. This was due to the fact that polyester fibres
absorbs least water compared to other fibres and hence wetness does not alter their values. Effect of moisture management finish on wet thermal resistance of spun polyester and polyester / cotton fabrics have significant effect at 95% confidence level. The micro-denier polyester fabric has insignificant effect on MM Finish, since the nature of material itself has lower dry and wet thermal resistance. This is due to the fact that fabric structures with increasing thickness need not necessarily exhibit higher values since thermal resistance was found to be independent of the nature of fabric.

8.3.7 Relative Water Vapour Permeability

Relative water vapour permeability is the rate of water vapour transmission through a material.

![Figure 8.6 Relative Water Vapor Permeability of the Fabrics](chart)

From Figure 8.6 and Table 8.2 it is apparent that micro-denier polyester fabric has 5% higher water vapour permeability than filament polyester and cotton fabrics while spun polyester and polyester/cotton fabrics exhibit 8% lower value. Microdenier polyester fabric provides better water
vapour permeability values because of larger surface area and channeled fibre structure. Channeled structures form a transport system that pulls moisture away from the skin to the outer layer of the fabric. Also this is due to more number of filaments in the yarn cross section. The gap between the filaments inside the core of yarn is very less. Due to this, the rate of water vapour transfer through the fabric is more. Here the nature of material affects the relative water vapour permeability significantly. With regards to spun yarn fabrics cotton with higher moisture content show higher values than spun polyester and polyester/cotton fabrics. The MMF has improved water vapour permeability uniformly for all fabrics. Polyester/cotton shows 4% increase and all other fabrics exhibit 2% increase in values. Effect of moisture management finish on relative water vapour permeability of polyester/cotton fabric has significant effect at 95% confidence level.

8.3.8 Water Vapour Resistance

Water Vapour Resistance indicates the extent to which fabric is breathable to vapour transmission.

![Figure 8.7 Water Vapor Resistance of the Fabrics](image_url)
From Figure 8.7 and Table 8.2 polyester / cotton fabric shows a maximum value while microdenier polyester fabric displays a minimum value. A lower value is desirable for better moisture transport and a higher value indicates that the fabric is less breathable to vapor transmission. The application of MMF has led to a drop in resistance values by 20% for microdenier polyester and 23% for spun polyester and polyester/cotton fabrics while cotton showed 3% drop in values. It is interesting to note that microdenier polyester shows a lower value thus maintaining the performance observed before finishing. Fabrics having low water vapour resistance values, it is easier for water vapour to pass through the fabric and into the environment, resulting in drier skin thereby improving comfort. A similar trend was observed by Jintu Fan et al (2008). Effect of moisture management finish on water vapour resistance of different fabrics has significant effect at 95 % confidence level.

8.4 CONCLUSION

One of the objectives of this research work is to analyze the influence of MMF on thermal comfort characteristics of knitted fabrics made from different yarns. Thermal characteristics include thermal conductivity, thermal resistance, thermal absorptivity, relative water vapor permeability and water vapor resistance. The thermal comfort characteristics were compared between MMF treated and untreated fabrics.

Moisture management finished knitted fabric gives higher thermal conductivity, thermal absorptivity, lower wet thermal resistance and improved water vapor permeability for all five fabrics. Analysis of thermal characteristics such as thermal absorptivity, wet thermal resistance, relative water vapor permeability and water vapor resistance of moisture management finished fabrics made from different yarns have significant effect.
In the geometrical characteristics of MMF knitted fabrics, there is an increase of 7% in areal density and 9% in thickness for microdenier polyester and filament polyester fabrics. In the case of spun polyester there is 6% increase in areal density and 2% increase in thickness values. Polyester/cotton shows 9% increase in areal density and 4% increase in thickness values. Cotton exhibits a marginal 3% increase in areal density and 2% increase in thickness values. There is an increase of 8.5% in stitch density for all five fabrics. It is due to the reduction in loop length when compared to untreated fabrics for all five fabrics.

In the test conducted for thermal conductivity, it was observed that microdenier polyester and filament polyester fabrics showed 10% higher thermal conductivity values than spun polyester and polyester/cotton fabrics. MMF fabrics show an increase in thermal conductivity values between 8% to 16% for microdenier polyester and filament polyester fabrics and only a marginal increase of 2 to 4% for spun polyester and polyester/cotton fabrics.

In the thermal absorptivity test, microdenier polyester fabrics showed 10% and 23% higher values than filament polyester and polyester/cotton fabrics. MMF fabrics of microdenier polyester, filament polyester and polyester/cotton showed 12 – 18% increase in thermal absorptivity values while spun polyester and cotton fabric showed 7% and 3% increase respectively.

In the dry thermal resistance test, spun polyester and polyester / cotton fabrics showed 23% and 17% higher thermal resistance values than micro-denier polyester and filament polyester fabrics. In MMF fabrics of spun polyester and polyester / cotton there is a 10 to 23% reduction in thermal resistance values and only a marginal reduction for other fabrics.
In the wet thermal resistance test, micro-denier polyester displayed the lowest resistance value. Spun polyester and polyester/cotton fabrics showed two times higher value and cotton fabric showed 1.6 times higher values than microdenier polyester fabric. In MMF fabrics there is a uniform 8% decrease in resistance values for micro-denier polyester, filament polyester and cotton while it is 20% for spun polyester and polyester/cotton fabrics. Comparing dry and wet thermal resistance, it was found that thermal resistance values in wet state decreased by 25 to 36% when compared to dry state for microdenier polyester and filament polyester fabrics while it was 7% for cotton fabrics.

In the relative water vapour permeability test, micro-denier polyester fabric showed 5% higher water vapour permeability than filament polyester and cotton fabrics while spun polyester and polyester/cotton fabrics exhibited 8% lower value. In MMF fabrics the improvement in water vapour permeability for polyester / cotton fabrics showed 4% increase while all other four fabrics exhibited 2% increase in values.

In the water vapour resistance test, polyester / cotton fabric showed a maximum value while micro-denier polyester fabric displayed a minimum value. In MMF fabrics there is a drop in resistance values by 20% for microdenier polyester and 23% for spun polyester and polyester/cotton fabrics while cotton showed 3% drop in values.

Comparing the five selected fabrics, it was observed that microdenier polyester fabrics had shown superior performance in thermal comfort characteristics.