CHAPTER 4

INFLUENCE OF YARN TYPE ON MOISTURE TRANSFER CHARACTERISTICS OF DOUBLE-FACE KNITTED FABRICS

4.1 INTRODUCTION

Single jersey cotton knitted fabrics are preferred for sportswear as they have greater elasticity and stretchability than that of woven fabrics. But the problem arises during high level of physical exertion; the fabric becomes wet as it absorbs the perspiration and delay in transferring it to the atmosphere. This causes clamminess and the feel of discomfort to the person who involved in sports. This problem can be reduced by producing a double-face knitted fabric in which the inner layer can transfer the moisture to the outer layer which absorbs and evaporates the moisture to the external environment. Good moisture management property is found with hydrophobic material whereas good storage and evaporation properties are found in hydrophilic material.

Generally the fabrics used in the sportswear are made as single layered knitted fabrics. During strenuous activity, cotton fibers absorb high levels of moisture, leading to a feeling of wetness and cling. Single layered cotton fabric possess very slow wicking rate and unsuitable during strenuous activity. None of the textile material possess the property of both moisture transmission and moisture absorbency property. In order to understand the inherent characteristics of double-face fabrics, the commercially available
materials such as cotton, polypropylene, polyester, nylon and acrylic were selected for the study.

In order to study the influence of yarn on moisture transfer characteristics, four double-face knitted fabrics were produced with cotton yarn as outer layer and polypropylene, polyester, acrylic and nylon yarns as inner layer. The double-face fabrics produced were tested for the moisture transfer characteristics such as wetting, longitudinal wicking, transverse wicking, moisture vapour transfer and dryness, air permeability and thermal conductivity.

4.2 METHODOLOGY

The influence of yarn type on moisture transfer characteristics of double-face fabrics were studied by selecting 120 denier of polypropylene, polyester, acrylic, nylon yarn and the cotton yarn of 120 denier combed cotton yarn. The twist per inch of the selected yarns was found out by using the Electronic yarn twist tester and the average values of 10 samples was given in the Table 4.1.

<table>
<thead>
<tr>
<th>Yarns</th>
<th>Twist per inch</th>
</tr>
</thead>
<tbody>
<tr>
<td>120D Cotton</td>
<td>22.76</td>
</tr>
<tr>
<td>120 D Polypropylene</td>
<td>23.12</td>
</tr>
<tr>
<td>120D Polyester</td>
<td>24.40</td>
</tr>
<tr>
<td>120D Acrylic</td>
<td>23.82</td>
</tr>
<tr>
<td>120D Nylon</td>
<td>24.55</td>
</tr>
</tbody>
</table>

From the Table 4.1, it was found that twist per inch of the selected yarns have no significant difference.
The selected yarns were knitted using high speed double circular knitting machine with speed of 25 rpm to produce four different double-face fabrics containing 3 mm stitch length having tuck stitch at every 6th wale and every 9th course with inner layer as manmade fabric and outer layer as cotton fabric.

The dial needle arrangement, cylinder needle arrangement, needle set out and cam set out for producing four different double-face fabrics having tuck stitch at every 6th wale and every 9th course were discussed below.

Dial cam had two tracks of DN1 and DN2. The A and B needles were moving in track 1 and 2 respectively. Cylinder cam has four tracks, out of which the fourth track was kept idle. The A and B needles were moving in track 1 and 2 respectively and the C needle was moving in track 3. This was shown in the dial and cylinder needle arrangement below:

4.2.1 Dial Needle Arrangement

- Total number of dial needle : 1872
- Number of needles in track - 1 : 936
- Number of needles in track - 2 : 936
- DN1 : Dial needle track - 1
- DN2 : Dial needle track – 2
- N : Needle
- F2 : Feeder 2
- Feeders : 18
- A : Needle moving in track-1

1 3 5 7 9 11 13 15 17 19……1871
All dial needles were fed with hydrophobic yarn from 18 feeders to produce a layer of knit stitch structure.

### 4.2.2 Cylinder Needle Arrangement

- **Total number of cylinder needle**: 1872
- **Number of needles in track - 1**: 780
- **Number of needles in track - 2**: 780
- **Number of needles in track - 3**: 312
- **CN1**: Cylinder needle track-1
- **CN2**: Cylinder needle track-2
- **CN3**: Cylinder needle track-3
- **N**: Needle
- **F1**: Feeder 1
- **Feeders**: 18
- **A**: Needle moving in track-1
  - 3 5 9 …1871
- **B**: Needle moving in track-2
  - 2 4 6 8 …1872
- **C**: Needle moving in track-3
  - 1 7 13 19…1867
All cylinder needles were fed with hydrophilic yarn from 18 feeders to produce a layer of knit stitch structure.

### 4.2.3 Needle Set out of 6th Wale and 9th Course Double-Face Fabric

<table>
<thead>
<tr>
<th>Y</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
<th>7</th>
<th>1872</th>
</tr>
</thead>
<tbody>
<tr>
<td>36</td>
<td></td>
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<tr>
<td>18</td>
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<td>16</td>
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<tr>
<td>14</td>
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<td>12</td>
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<td>10</td>
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<td></td>
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<tr>
<td>8</td>
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<tr>
<td>6</td>
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<td>4</td>
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<td></td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>×</td>
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<td></td>
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<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Where, X - No of Needles in Wale wise; Y - No of Feeders in Course wise

**Figure 4.1 Needle set out diagram of 6th wale and 9th course double-face fabric**

As shown in the Figure 4.1, every 6th needle of the cylinder produced a tuck stitch in wale wise with the corresponding 6th needle of the dial (i.e.) hydrophilic yarn goes in to the loops of hydrophobic yarn to produce double-face fabric. Thus, the cylinder needles 1,7,13,19...1867 from track 3 produces tuck stitch due to the presence of tuck cam. The cylinder needles of 2-6, 8-12, 14-16, 20-24...1872 needles produced knit stitch due to presence of knit cam.
4.2.4 Cam Set Out of 6th Wale and 9th Course Double-Face Fabric

<table>
<thead>
<tr>
<th>F1</th>
<th>F2</th>
<th>F3</th>
<th>F4</th>
<th>F5</th>
<th>F6</th>
<th>F7…</th>
<th>F20</th>
<th>F21…</th>
<th>F36</th>
</tr>
</thead>
<tbody>
<tr>
<td>DN1</td>
<td>-</td>
<td>x</td>
<td>-</td>
<td>x</td>
<td>-</td>
<td>x</td>
<td>-</td>
<td>x</td>
<td>x</td>
</tr>
<tr>
<td>DN2</td>
<td>-</td>
<td>x</td>
<td>-</td>
<td>x</td>
<td>-</td>
<td>x</td>
<td>-</td>
<td>x</td>
<td>-</td>
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<tr>
<td>CN1</td>
<td>x</td>
<td>-</td>
<td>x</td>
<td>-</td>
<td>x</td>
<td>-</td>
<td>x</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>CN2</td>
<td>x</td>
<td>-</td>
<td>x</td>
<td>-</td>
<td>x</td>
<td>-</td>
<td>x</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>CN3</td>
<td>x</td>
<td>O</td>
<td>x</td>
<td>-</td>
<td>x</td>
<td>-</td>
<td>x</td>
<td>O</td>
<td>x</td>
</tr>
</tbody>
</table>

Where - : Miss Cam,  x : Knit Cam, O : Tuck Cam

Figure 4.2 Cam set out diagram of 6th wale and 9th course double-face fabric

As shown in the Figure 4.2, Out of 36 feeders, the cylinder needles were controlled by tuck cam in 2nd and 20th feeder. Thus the cylinder needles produced tuck stitch with the dial needle (i.e.) hydrophilic yarn goes in to the loops of hydrophobic yarn at every 9th course to produce the double-face fabric of 6th wale and 9th course knitted structure.

4.2.5 Knitting Loop Formation of Double-Face Fabric

As shown in the Figure 4.3, the dial and cylinder needle performed miss and knit stitch simultaneously during fabric production. That is yarn from feeder 1 formed miss stitch with dial needle and knit stitch with the cylinder needle. The yarn from feeder 2 produced knit stitch with dial needle and miss stitch with the cylinder needle. Every 6th needle of the cylinder in track 3 produced a tuck stitch in wale wise with the corresponding 6th needle of the dial due to the presence of tuck cam. As the cylinder needles were controlled by tuck cam in 2nd and 20th feeder, the cylinder needle produced
tuck stitch with the dial needle at every 9th course to produce 6th Wale and 9th Course double-face fabric. This cycle was repeated throughout the knitted fabric production.

Thus four different double-face fabrics of 6th wale and 9th course structure were produced by using polypropylene yarn, polyester yarn, acrylic yarn and nylon yarn in dial needles and cotton yarns in cylinder needles.

Figure 4.3  Knitting loop formation of 6th wale and 9th course double-
Figure 4.4 Process flow chart of double-face fabrics produced from different types of yarn

4.3 PROCESSING

The double-face fabrics were subjected to hot wash and bleached with hydrogen peroxide at 3% owm at 100°C and dyed with hot brand reactive dye at 5% owm at 90°C in winch dyeing machine. Then it was washed and dried in a stenter at 150-160°C and subjected to relaxation for 48 hours. Then the fabric samples were tested for its geometrical and moisture transfer characteristics as shown in the Table 4.2, Table 4.3 and Table 4.4.
4.4 RESULTS AND DISCUSSION

To study the effect of yarn type on moisture transfer characteristics such as wetting, vertical wicking, transverse wicking, drying, moisture vapour transfer, air permeability and thermal conductivity of double-face fabrics, four different double-face fabrics were used and denoted as C/PP fabric for 120D C/120D PP fabric, C/P fabric for 120D C/120D P fabric, C/A fabric for 120D C/120D A fabric and C/N fabric for 120D C/120D N fabric.

4.4.1 Geometrical Characteristics

The geometrical properties of the fabrics were studied and the average value of 10 samples was given in the Table 4.2 and Table 4.3.

<table>
<thead>
<tr>
<th>Double-Face Fabric</th>
<th>Notation</th>
<th>Wales per cm</th>
<th>Course 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>120DC/120D PP</td>
<td>C/PP</td>
<td>12.24</td>
<td>16.31</td>
<td>199.63</td>
<td>188</td>
<td>2.9</td>
<td>0.91</td>
</tr>
<tr>
<td>120D C/120D P</td>
<td>C/P</td>
<td>12.10</td>
<td>15.83</td>
<td>191.53</td>
<td>185</td>
<td>2.8</td>
<td>0.88</td>
</tr>
<tr>
<td>120D C/120D A</td>
<td>C/A</td>
<td>12.32</td>
<td>16.10</td>
<td>198.35</td>
<td>181</td>
<td>2.8</td>
<td>0.89</td>
</tr>
<tr>
<td>120D C/120D N</td>
<td>C/N</td>
<td>11.96</td>
<td>15.76</td>
<td>188.49</td>
<td>183</td>
<td>2.7</td>
<td>0.87</td>
</tr>
</tbody>
</table>

C - Cotton, PP - Polypropylene, P - Polyester, A - Acrylic, N - Nylon

From the Table 4.2, it was found that change in yarn type has no impact with geometrical characteristics of the fabrics related to wales per centimeter and course per centimeter. But small change in areal density was found with change in the type of yarn.
Table 4.3 Double-face fabric geometrical characteristics - II

<table>
<thead>
<tr>
<th>Double-Face Fabric</th>
<th>Fabric density (grams/cm³)</th>
<th>Fabric packing factor</th>
<th>Fabric porosity (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>120DC/120D PP</td>
<td>0.21</td>
<td>0.20</td>
<td>80</td>
</tr>
<tr>
<td>120D C/120D P</td>
<td>0.22</td>
<td>0.17</td>
<td>83</td>
</tr>
<tr>
<td>120D C/120D A</td>
<td>0.20</td>
<td>0.14</td>
<td>86</td>
</tr>
<tr>
<td>120D C/120D N</td>
<td>0.21</td>
<td>0.13</td>
<td>87</td>
</tr>
</tbody>
</table>

C-Cotton, PP-Polypropylene, P-Polyester A-Acrylic, N-Nylon

From the Table 4.3, it was found that 120DC/120D PP fabric had lesser porosity than the other three fabrics.

4.4.2 Moisture Transmission Characteristics

The moisture transmission characteristics such as wetting, transverse wicking, vertical wicking and moisture vapour transfer of fabrics were analysed and the average values were given in the Table 4.4.

From the Table 4.4, it was found that C/PP fabric, had taken lesser time to sink in water when comparing to other three fabrics. The wicking height both in wale wise and course wise direction was higher for C/PP fabric than other fabrics. Also the wale wise wicking height was more than the course wise wicking height for all the four fabrics. In transverse wicking and dynamic transverse wicking, the time taken to absorb one drop of water on face side of top layer of C/PP fabric was lesser than the other fabrics. Also the area of water spread for one drop of water and the area of water spread to reach saturation was found to be higher for C/PP fabric.
Table 4.4  Moisture transmission characteristics

<table>
<thead>
<tr>
<th>Double-Face Fabrics with Notation</th>
<th>Transverse Wicking</th>
<th>Wetting</th>
<th>Dynamic transverse wicking</th>
<th>Vertical wicking</th>
<th>Moisture vapour transfer (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Time taken to absorb 1ml of water (s)</td>
<td>Water spreading area for 1ml of water on face side of Top layer (mm²)</td>
<td>Water spreading area for 1ml of water on face side of Bottom layer (mm²)</td>
<td>Time taken for the double-face fabric to sink (s)</td>
<td>Time taken to reach Saturation (s)</td>
</tr>
<tr>
<td>120D C/120D PP (C/PP)</td>
<td>100</td>
<td>95</td>
<td>211</td>
<td>201</td>
<td>180</td>
</tr>
<tr>
<td>120D C/120D P (C/P)</td>
<td>192</td>
<td>118</td>
<td>195</td>
<td>184</td>
<td>296</td>
</tr>
<tr>
<td>120D C/120D A (C/A)</td>
<td>210</td>
<td>132</td>
<td>168</td>
<td>153</td>
<td>341</td>
</tr>
<tr>
<td>120D C/120D N (C/N)</td>
<td>245</td>
<td>148</td>
<td>130</td>
<td>121</td>
<td>382</td>
</tr>
</tbody>
</table>

C-Cotton, PP-Polypropylene, P-Polyester A-Acrylic, N-Nylon
4.4.3 **Analysis of Wicking Characteristics**

The rate of water spreading due to capillarity was studied and given below.

4.4.3.1 **Longitudinal wicking rate of yarns**

The selected yarns of polypropylene, polyester, acrylic, and nylon were tested for vertical wicking in order to find out the wicking rate in these yarns and was given in Figure 4.5.

![Figure 4.5](image_url)  
*Figure 4.5  Longitudinal wicking rate of yarns*

From the Figure 4.5, the wicking height was analyzed for all the four selected yarns in relation to wicking time from 1 minute to 30 minutes. It was found that the wicking rate of polypropylene yarn was found to be higher than the other three yarns. The rate of water rise was very fast at the beginning and slowed down gradually, as observed by researchers.
(Chattopadhyay & Chauhan 2004). The equilibrium in wicking height was attained within 30 minutes and the values of wicking rate were given in the Table 4.5 as follows:

### Table 4.5 Equilibrium wicking height of yarns

<table>
<thead>
<tr>
<th>Yarns</th>
<th>Wicking height (cms)</th>
<th>Time (min)</th>
</tr>
</thead>
<tbody>
<tr>
<td>120 D Polypropylene</td>
<td>7.4</td>
<td>11.3</td>
</tr>
<tr>
<td>120D Polyester</td>
<td>6.4</td>
<td>12.6</td>
</tr>
<tr>
<td>120D Acrylic</td>
<td>5.5</td>
<td>13.4</td>
</tr>
<tr>
<td>120D Nylon</td>
<td>4.2</td>
<td>14.2</td>
</tr>
</tbody>
</table>

From the Table 4.5, it was found that 120D polypropylene yarn takes lesser time and higher wicking rate in reaching equilibrium when compared to other yarns.

As the wicking height was found higher for polypropylene yarn, the double-face fabrics produced were tested for vertical wicking in order to found the influence of polypropylene yarn and was discussed in 4.4.3.2.

#### 4.4.3.2 Longitudinal wicking rate of double-face fabrics

The rate of water spreading on various fabrics was tested both for wale wise direction and course wise direction and given in the Figures 4.6 and 4.7.

From the Figures 4.6 and 4.7, the wicking height was analyzed for all the four fabrics in related to wicking time from 1 minute to 30 minutes. In general, wicking height increases with wicking time in both wale wise and course wise direction for all the four fabrics. The wicking height in wale
wise direction was higher than in course wise direction for all samples and at all time intervals.

**Figure 4.6** Longitudinal wicking rate of double-face fabrics – wale wise direction

**Figure 4.7** Longitudinal wicking rate of double-face fabrics – course wise direction
C/PP fabric showed higher wicking rate than the other three fabrics. The reason was as the polypropylene having high moisture transfer property than polyester, acrylic and nylon transfers and wick the water quickly. The rate of water rise was very fast at the beginning and slows down gradually, as observed by researchers (Chattopadhyay & Chauhan 2004). The wicking rate was found to be increased from 1 minute to 15 minutes both in wale wise direction and course wise direction for all the four knitted fabrics. Interestingly after 15 minutes it was observed that there was no increase in the wicking height for any of the fabrics. The equilibrium in wicking height was attained within 30 minutes and the values of wicking rate was given in the Table 4.5. The standard error bar shown in the Figure 4.6 and Figure 4.7 indicates the significance level of C/PP fabric with other fabrics with respect to wicking height in wale wise direction and course wise direction respectively. Effect of yarn type on wicking in wale wise direction of double-face knitted fabrics was significant at 95% confidence level (F calculated > F tabulated: p-value 8.18E-42). Effect of yarn type on wicking in course wise direction of double-face knitted fabrics was significant at 95% confidence level. (F calculated > F tabulated: p-value 6.04E-38).

**Table 4.6 Equilibrium wicking height of double-face fabrics**

<table>
<thead>
<tr>
<th>Double-face fabrics</th>
<th>Wicking height (cms)</th>
<th>Time (min)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Wale wise</td>
<td>Course wise</td>
</tr>
<tr>
<td>C/PP</td>
<td>10.2</td>
<td>9.5</td>
</tr>
<tr>
<td>C/P</td>
<td>8.6</td>
<td>8.2</td>
</tr>
<tr>
<td>C/A</td>
<td>7.0</td>
<td>6.4</td>
</tr>
<tr>
<td>C/N</td>
<td>6.3</td>
<td>5.6</td>
</tr>
</tbody>
</table>
From the Table 4.6, it was found that C/PP fabric took lesser time and higher wicking rate in reaching equilibrium when compared to other fabrics.

As the wicking height was found higher for polypropylene yarn, the same trend of higher wicking rate was found with C/PP double-face fabric. This clearly indicated that the polypropylene yarn had influenced the wicking rate in the double-face fabric also.

4.4.4 Analysis of Wetting Characteristics

The ability of fabrics to sink in water completely was studied and given in Table 4.3.

Figure 4.8 Wetting characteristics of double-face fabrics
From the Figure 4.8 and Table 4.3, it was found that C/PP fabric takes lesser time for sinking than the other fabrics. The reason behind this was as wetting mechanism involves immersion, capillary sorption, adhesion and spreading. The polypropylene layer with high water transmission property comes in contact with the water surface and transmits the water quickly to the cotton layer which absorbs and spread the water to the entire fabric surface, thus making the fabric to sink in water. This trend was observed by (Rita M Crow & Randall J Osczewski 1998) and (Gamzen Supuren et al. 2011). The standard error bar shown in the Figure 4.5 indicates the significance level of C/PP fabric with other fabrics with respect to sinking time. Effect of yarn type on wetting behavior of double-face knitted fabrics was significant at 95% confidence level (F calculated > F tabulated: p-value 2.22E-55).

4.4.5 **Analysis of Transverse Wicking and Dynamic Transverse Wicking Characteristics**

The area covered by spreading one drop of water on the various fabrics for transverse wicking and dynamic transverse wicking was given below.

4.4.5.1 **Area of water spread for one drop of water**

The area covered by spreading one drop (1 ml) of water was tested and given in Table 4.3.

From the Figure 4.9, Figure 4.10 and Table 4.3, the water spreading area of the fabrics was measured as per the method described by (Sampath et al. 2009, 2011, 2012).
When one drop of water is placed on face side of top layer of fabrics, first it interacted with surface and immediately transported to the next layer. This was because of transverse wicking.

**Figure 4.9** Area of water spread on face side of top layer of fabrics

**Figure 4.10** Area of water spread on face side of bottom layer of fabrics
During this period water also travels longitudinally. As gravitational force is higher than wetting force, it comes to the next layer quickly without spreading much on first layer. So, it has minimum spreading area. As soon as droplet comes to bottom layer it travels in both transverse and longitudinal directions. Here, wetting force is higher than gravitational force. It takes time to travel in transverse direction. In the mean time, due to wetting force, water moves in longitudinal direction. Slowly it reaches the bottom layer. Hence bottom layer has more spreading area than top layer.

From the Figure 4.9, Figure 4.10 and Table 4.3, it is found that when one drop of water is placed on top layer of polypropylene surface of C/PP fabric, it interacts and the polypropylene surface quickly transmits the water from its surface to the bottom cotton layer. As the bottom cotton layer has good water absorbing property, it absorbs the water. The same trend is observed in all the other three fabrics. However polypropylene top layer has quicker wetting time and low area of spread when comparing to other fabrics. The reason is polypropylene has high moisture transfer property, which transfers the water at a faster rate than the polyester, acrylic and nylon fabrics. Therefore the water spreading area of cotton bottom layer is higher than the polypropylene top layer.

A similar trend is observed by (Rita M Crow & Randall J Osczevski 1998) and (Rene M Rossi et al. 2004). C/PP fabric shows decrease in area of spread on top polypropylene layer and increase in area of spread on bottom cotton layer than the other three fabrics. The C/PP fabric shows lesser time in absorbing one drop of water on the fabric surface than the other three fabrics. The standard error bar shown in the Figure 4.9. and Figure 4.10 indicates the significance level of C/PP fabric with other fabrics with respect to water spread on face side of top layer and water spread on face side of bottom layer respectively. Effect of yarn type to spread 1 ml of water on face
side of top layer of double-face knitted fabrics is significant at 95% confidence level (F calculated > F tabulated: p-value 1.27E-42). Effect of yarn type to spread 1 ml of water on face side of bottom layer of double-face knitted fabrics is significant at 95% confidence level (F calculated > F tabulated: p-value 4.16E-49). Effect of yarn type to absorb 1 ml of water of double-face knitted fabrics is significant at 95% confidence level (F calculated > F tabulated: p-value 2.39E-54).

4.4.5.2 Area of water spread and time taken to reach saturation

The area covered and the time taken to reach saturation point of the fabrics were studied and given in the Table 4.3.

![Figure 4.11 Area of water spread on fabrics to reach saturation](image)

From the Figure 4.11 and Table 4.3, the water spreading area of the fabrics to reach saturation is measured as per the method described by (Sampath et al. 2009, 2011, 2012)
One ml of water was allowed to drop on the top layer of the fabrics from a height of 6 mm for every 3 seconds. The water droplet percolation time was noted at the bottom layer of the fabric. It was noted as saturation point, in seconds. Also the area covered to reach saturation is noted in square millimeter.

From the Figure 4.11 and Table 4.3, C/PP fabric shows lesser wetting time on top polypropylene layer and more area of water spread on bottom cotton layer than the other three fabrics. A similar trend was observed by (Rita M Crow & Randall J Osczevski 1998) and (Rene M.Rossi et al. 2004). The C/PP fabric shows increase in area of spread on bottom cotton layer than the other three fabrics. The C/PP fabric shows time reduction in reaching the saturation point on the knitted fabric surface than the other three fabrics.

The standard error bar shown in the Figure 4.11 indicates the significance level of C/PP fabric with other fabrics with respect to area of water spread and time taken to reach saturation. Effect of yarn type to spread water in reaching saturation of double-face knitted fabrics was significant at 95% confidence level (F calculated > F tabulated: p-value 6.23E-48). Effect of yarn type to absorb water in reaching saturation of double-face knitted fabrics was significant at 95% confidence level. (F calculated > F tabulated: p-value 3.06E-57).

4.4.6 Analysis of Moisture Vapour Transfer Behaviour

The rate at which the moisture vapour got transferred to the fabrics was tested and given in the Table 4.3.

From the Figure 4.12 and Table 4.3, it was found that C/PP fabric has higher moisture vapour transfer when compared to C/P, C/A fabric and
C/N fabric. As polypropylene has high moisture transmission property than polyester, acrylic and nylon. Polypropylene layer of C/PP fabric transfers the moisture to the cotton layer which absorbs the moisture. The standard error bar shown in the Figure 4.12 indicates the significance level of C/PP fabric with other fabrics with respect to moisture vapour transfer.

![Figure 4.12 Moisture vapour transfer for height and weight reduction of water of double-face fabrics](image)

Effect of yarn type on moisture vapour transfer in reduction in height of water of double-face knitted fabrics is significant at 95% confidence level (F calculated > F tabulated: p-value 5.66E-48). Effect of yarn type on moisture vapour transfer in reduction in weight of water of double-face knitted fabrics is significant at 95% confidence level (F calculated > F tabulated: p-value 1.63E-53).

### 4.4.7 Analysis of Drying Characteristics

Drying rate of the fabrics was calculated and expressed as average weight loss over initial water content per unit area. It was the ability of the fabrics to evaporate the moisture present on the fabric surface.
From the Figure 4.13, it was found that C/PP fabric had quicker drying time to return to its original weight when compared to other three fabrics. As discussed in area of water spread and time taken to reach saturation, when water is continuously poured on the selected four different fabrics, the inner layer of polypropylene does not absorb water and it transfers to the outer layer of cotton. But in case of other fabrics inner layer alone absorbs maximum amount of water. Only minimum amount of water has transferred to the outer layer. That’s why C/PP fabric when subjected to drying takes lesser time to dry. For all other three fabrics it takes higher time because both inner and outer layer has to dry. The standard error bar shown in the Figure 4.13 indicates the significance level of C/PP fabric with other fabrics with respect to drying rate. Effect of yarn type on drying rate of double-face knitted fabrics was significant at 95% confidence level. (F calculated > F tabulated: p-value 6.79E-47).

![Figure 4.13 Drying rate of double-face fabrics](image-url)
4.4.8 Air Permeability Characteristics

The rate of airflow through the fabrics was tested and shown in the Figure 4.13. From the Figure 4.14, it was found that C/PP fabric had higher air permeability when compared to other three fabrics. Though outer cotton layer was same for all four fabrics, polypropylene inner layer had low density which allowed the air better than all the other three fabrics.

![Air permeability of different double-face fabrics](image)

**Figure 4.14 Air permeability of double-face Fabrics**

The standard error bar shown in the Figure 4.14 indicates the significance level of C/PP fabric with other fabrics with respect to air permeability. Effect of yarn type on air permeability of double-face knitted fabrics is significant at 95% confidence level. (F calculated > F tabulated: p-value 5.13E-26).

4.4.9 Thermal Conductivity Characteristics

Thermal conductivity of the fabrics is the ability of the fabric to conduct heat.
Figure 4.15 Thermal conductivity of double-face fabrics

From the Table 4.3 and Figure 4.15, it was found that C/PP fabric had higher thermal conductivity when compared to other three fabrics. The thermal conductivity increased with decrease in porosity. The porosity was found lesser for C/PP fabric when compared to other three fabrics. That’s why the C/PP fabric had higher thermal conductivity. The standard error bar shown in the Figure 4.15 indicated the significance level of C/PP fabric with other fabrics in related to thermal conductivity. Effect of yarn type on thermal conductivity of double-face knitted fabrics is significant at 95% confidence level ($F$ calculated $>$ $F$ tabulated: $p$-value $3.54E-32$).
4.5 CONCLUSION

This chapter mainly focuses to study the influence of yarn type on moisture transfer characteristics of the selected double-face fabrics suitable for making sportswear. Moisture transfer characteristics such as wetting, vertical wicking, transverse wicking, dynamic transverse wicking, moisture vapour transfer and dryness, air permeability and thermal conductivity were analyzed for all the four fabrics.

It is observed that in the wetting test, C/PP fabric took lesser time to sink in water than other three fabrics. The wicking height in wale wise direction is higher than course wise direction for all samples and at all time intervals. However C/PP fabric shows higher wicking rate than the other three fabrics. In transverse wicking, C/PP fabric shows decrease in area of spread on top polypropylene layer and increase in area of spread on bottom cotton layer than the other three fabrics. The C/PP fabric takes lesser time in absorbing one drop of water on the fabric surface than the other three fabrics. In dynamic transverse wicking, C/PP fabric shows an increase in area of spread on bottom cotton layer than the other three fabrics.

C/PP fabric takes lesser time in reaching the saturation point, lesser drying time, increase in moisture vapour transfer, air permeability and thermal conductivity than the other three fabrics. Comparing all the selected double-face knitted fabrics, it is found that cotton/polypropylene (C/PP) fabric gives better level of moisture transfer properties and suits in making sportswear. It is concluded that the selection of yarn plays a major role in determining the moisture transfer characteristics of double-face fabrics to achieve suitability for making sportswear.