CHAPTER 6

INFLUENCE OF TUCK DENSITY ON MOISTURE TRANSFER CHARACTERISTICS OF DOUBLE-FACE KNITTED FABRICS

6.1 INTRODUCTION

Based on the finding from Chapter 5, it is understood that finer denier cotton and coarser denier polypropylene 120D C/240D PP double-face knitted fabric has shown better level of moisture transfer characteristics. As 120D C/240D PP double-face fabric shows better performance on moisture transfer characteristics an attempt has been made by changing the tuck position with 120 C/240D PP fabric in producing 3×3 double-face fabric, 6×6 double-face fabric, 9×9 double-face fabric and 12×9 double-face fabric. The influence of tuck density on moisture transfer characteristics with these fabrics has been studied.

6.2 METHODOLOGY

The influence of tuck density on moisture transfer characteristics of double-face knitted fabrics has been studied. In order to study this, combed cotton yarn of 120D and polypropylene dope dyed yarn of 240D (48 filaments) was selected for the study. Five different double-face knitted fabrics were produced from 120D C/240D PP as 6×9 double-face fabric, 6×6 double-face fabric, 3×3 double-face fabric, 9×9 double-face fabric and 12×9 double-face fabric. The polypropylene yarn selected was multifilament dope
dyed yarn (48 filaments) and the cotton of combed yarn. The selected yarns were knitted using high speed double circular knitting machine with speed of 25 rpm. Double-face fabrics are produced with tuck stitches at every 6\(^{th}\) wale and every 9\(^{th}\) course, tuck stitches at every 6\(^{th}\) wale and every 6\(^{th}\) course, tuck stitches at every 3\(^{rd}\) wale and every 3\(^{rd}\) course, tuck stitches at every 9\(^{th}\) wale and every 9\(^{th}\) course and tuck stitches at every 12\(^{th}\) wale and every 9\(^{th}\) course of the knitted fabric.

6.2.1 Production of 6\(^{th}\) Wale and 9\(^{th}\) Course Double-Face Fabric

The dial needle arrangement, cylinder needle arrangement, needle set out and cam set out for producing double-face fabric having tuck stitch at every 6\(^{th}\) wale and every 9\(^{th}\) course were discussed below:

Dial cam has two tracks of DN1 and DN2. The A and B needles move 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 move in track 1 and 2 respectively and the C needle moves in track 3. This was shown in the dial and cylinder needle arrangement below:

6.2.1.1 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
- A : Needle moving in track-1
All dial needles are fed with polypropylene yarn from 18 feeders to produce a layer of knit stitch structure.

6.2.1.2 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 cotton yarn from 18 feeders to produce a layer of knit stitch structure.
### Needle set out for 6th wale and 9th course double-face fabric

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

**Figure 6.1 Needle set out diagram of 6th wale and 9th course double-face fabric**

As shown in the Figure 6.1 every 6th needle of the cylinder produces a tuck stitch in wale wise with the corresponding 6th needle of the dial (i.e.) cotton yarn goes in to the loops of polypropylene yarn to produce double-face fabric. That is 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 produce knit stitch due to presence of knit cam.
6.2.1.4 Cam set out for 6\textsuperscript{th} wale and 9\textsuperscript{th} course double-face fabric

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Where : Miss Cam, × : Knit Cam, O : Tuck Cam

Figure 6.2 Cam set out diagram of 6\textsuperscript{th} wale and 9\textsuperscript{th} course double-face fabric

As shown in the Figure 6.2, Out of 36 feeders, the cylinder needles were controlled by tuck cam in 2\textsuperscript{nd} and 20\textsuperscript{th} feeder. Thus the cylinder needles produced tuck stitch with the dial needle. (i.e.) cotton yarn goes in to the loops of polypropylene yarn at every 9\textsuperscript{th} course to produce the double-face fabric of 6\textsuperscript{th} wale and 9\textsuperscript{th} course knitted structure.

6.2.1.5 Knitting loop formation of double-face fabric

As shown in the Figure 6.3, the dial and cylinder needle will perform miss and knit stitch simultaneously during fabric production. That is cotton yarn from feeder 1 forms miss stitch with dial needle and knit stitch with the cylinder needle. The polypropylene yarn from feeder 2 produces knit stitch with dial needle and miss stitch with the cylinder needle. Every 6\textsuperscript{th} needle of the cylinder in track 3 produces a tuck stitch in wale wise with the corresponding 6\textsuperscript{th} needle of the dial due to the presence of tuck cam. As the cylinder needles are controlled by tuck cam in 2\textsuperscript{nd} and 20\textsuperscript{th} feeder, the cylinder...
needle produces tuck stitch with the dial needle at every 9\textsuperscript{th} course to produce 6\textsuperscript{th} Wale and 9\textsuperscript{th} Course double-face fabric. This cycle was repeated throughout the knitted fabric production.

Figure 6.3  Knitting loop formation of 6\textsuperscript{th} wale and 9\textsuperscript{th} course double-face fabric

6.2.2 Production of 6\textsuperscript{th} Wale and 6\textsuperscript{th} Course Double-Face Fabric

The dial needle arrangement, cylinder needle arrangement, needle set out and cam set out for producing double-face fabric having tuck stitch at every 6\textsuperscript{th} wale and every 6\textsuperscript{th} course were discussed below.

Dial cam has two tracks of DN1 and DN2. The A and B needles move 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 move in track 1 and 2 respectively and the C needle moves in track 3. This was shown in the dial and cylinder needle arrangement below.

6.2.2.1 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
- A : Needle moving in track-1
  1 3 5 7 9 11 13 15 17 19……1871
- B : Needle moving in track-2
  2 4 6 8 10 12 14 16 18 20……1872

All dial needles were fed with polypropylene yarn from 18 feeders to produce a layer of knit stitch structure.

6.2.2.2 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
All cylinder needles were fed with cotton yarn from 18 feeders to produce a layer of knit stitch structure.

6.2.2.3 Needle set out for 6\textsuperscript{th} wale and 6\textsuperscript{th} course double-face fabric

As shown in the Figure 6.4, every 6\textsuperscript{th} needle of the cylinder produces a tuck stitch in wale wise with the corresponding 6\textsuperscript{th} needle of the dial (i.e.) cotton yarn goes in to the loops of polypropylene yarn to produce double-face fabric. That is 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 produce knit stitch due to presence of knit cam.
Where,  \( X \)- No of Needles in Wale wise, \( Y \)- No of Feeders in Course wise

**Figure 6.4** Needle set out diagram of 6\(^{th}\) wale and 6\(^{th}\) course double-face fabric

**6.2.2.4** Cam set out for 6\(^{th}\) Wale and 6\(^{th}\) course double-face fabric

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

**Figure 6.5** Cam set out diagram of 6\(^{th}\) wale and 6\(^{th}\) course double-face fabric
As shown in the Figure 6.5, out of 36 feeders, the cylinder needles were controlled by tuck cam in 2\textsuperscript{nd}, 14\textsuperscript{th} and 26\textsuperscript{th} feeder. Thus the cylinder needles produced tuck stitch with the dial needle. (i.e.) cotton yarn goes in to the loops of polypropylene yarn at every 6\textsuperscript{th} course to produce the double-face fabric of 6\textsuperscript{th} wale and 6\textsuperscript{th} course knitted structure.

6.2.2.5 Knitting loop formation of double-face fabric

As shown in the Figure 6.6, the dial and cylinder needle will perform miss and knit stitch simultaneously during fabric production.

![Figure 6.6 Knitting loop formation of 6\textsuperscript{th} wale and 6\textsuperscript{th} course double-face fabric](image)
The cotton yarn from feeder 1 forms miss stitch with dial needle and knit stitch with the cylinder needle. The polypropylene yarn from feeder 2 produces knit stitch with dial needle and miss stitch with the cylinder needle. Every 6th needle of the cylinder in track 3 produces 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 are controlled by tuck cam in 2nd, 14th and 26th feeder, the cylinder needle produces tuck stitch with the dial needle at every 6th course to produce 6th Wale and 6th Course double-face fabric. This cycle was repeated throughout the knitted fabric production.

6.2.3 Production of 3rd Wale and 3rd Course Double-Face Fabric

The dial needle arrangement, cylinder needle arrangement, needle set out and cam set out for producing double-face fabric with tuck stitch at every 3rd wale and every 3rd course were discussed below:

Dial cam has two tracks of DN1 and DN2. The A and B needles move 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 move in track 1 and 2 respectively and the C needle moves in track 3. This was shown in the dial and cylinder needle arrangement below.

6.2.3.1 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
All dial needles were fed with polypropylene yarn from 18 feeders to produce a layer of knit stitch structure.

6.2.3.2 Cylinder needle arrangement

- Total number of cylinder needle: 1872
- Number of needles in track - 1: 624
- Number of needles in track - 2: 624
- Number of needles in track - 3: 624
- 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
- B: Needle moving in track-2
- C: Needle moving in track-3
All cylinder needles were fed with cotton yarn from 18 feeders to produce a layer of knit stitch structure.

### 6.2.3.3 Needle set out for 3rd wale and 3rd course double-face fabric

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

**Figure 6.7 Needle set out diagram of 3rd wale and 3rd course double-face fabric**

As shown in the Figure 6.7, every 3rd needle of the cylinder produces a tuck stitch in wale wise with the corresponding 3rd needle of the dial (i.e.) cotton yarn goes in to the loops of polypropylene yarn to produce double-face fabric. That is the cylinder needles 1, 4, 7, 10, 13, 1872 from track 3.
produces tuck stitch due to the presence of tuck cam. The cylinder needles of 2-3, 5-6, 8-9, 1872 needles produce knit stitch due to presence of knit cam.

### 6.2.3.4 Cam set out for 3rd wale and 3rd course double-face fabric

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

**Figure 6.8 Cam set out diagram of 3rd wale and 3rd course double-face fabric**

As shown in the Figure 6.8, out of 36 feeders, the cylinder needles are controlled by tuck cam in 2nd, 8th, 14th, 20th, 26th and 32nd feeder. Thus the cylinder needles produce tuck stitch with the dial needle. (i.e.) cotton yarn goes in to the loops of polypropylene yarn at every 3rd course to produce the double-face fabric of 3rd wale and 3rd course knitted structure.

**6.2.3.5 Knitting loop formation of double-face fabric**

As shown in the Figure 6.9, the dial and cylinder needle will perform miss and knit stitch simultaneously during fabric production. That is cotton yarn from feeder 1 forms miss stitch with dial needle and knit stitch with the cylinder needle. The polypropylene yarn from feeder 2 produces knit stitch with dial needle and miss stitch with the cylinder needle. Every 3rd needle of the cylinder in track 3 produces a tuck stitch in wale wise with the corresponding 3rd needle of the dial due to the presence of tuck cam. As the
cylinder needles are controlled by tuck cam in $2^{nd}$, $8^{th}$, $14^{th}$, $20^{th}$, $26^{th}$ feeder and $32^{nd}$ feeder, the cylinder needle produces tuck stitch with the dial needle at every $3^{rd}$ course to produce $3^{rd}$ Wale and $3^{rd}$ Course double-face fabric. This cycle was repeated throughout the knitted fabric production.

![Knitting loop formation of 3rd wale and 3rd course double-face fabric](image)

**Figure 6.9** Knitting loop formation of 3rd wale and 3rd course double-face fabric

### 6.2.4 Production of 9th Wale and 9th Course Double-Face Fabric

The dial needle arrangement, cylinder needle arrangement, needle set out and cam set out for producing double-face fabric having tuck stitch at every $9^{th}$ wale and every $9^{th}$ course were discussed below:

Dial cam has two tracks of DN1 and DN2. The A and B needles move 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 move in track 1 and 2
respectively and the C needle moves in track 3. This was shown in the dial and cylinder needle arrangement below:

### 6.2.4.1 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
- A : Needle moving in track-1
  1 3 5 7 9 11 13 15 17 19……1871
- B : Needle moving in track-2
  2 4 6 8 10 12 14 16 18 20……1872

All dial needles were fed with polypropylene yarn from 18 feeders to produce a layer of knit stitch structure.

### 6.2.4.2 Cylinder needle arrangement

- Total number of cylinder needle : 1872
- Number of needles in track - 1 : 832
- Number of needles in track - 2 : 832
- Number of needles in track - 3 : 208
- 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 10 19…1863

All cylinder needles were fed with cotton yarn from 18 feeders to produce a layer of knit stitch structure.

6.2.4.3 Needle set out for 9th wale and 9th course double-face fabric

As shown in the Figure 6.10 every 9th needle of the cylinder produces a tuck stitch in wale wise with the corresponding 9th needle of the dial (i.e.) cotton yarn goes in to the loops of polypropylene yarn to produce double-face fabric. That is the cylinder needles 1,10,19,28,37, …1863 from track 3 produces tuck stitch due to the presence of tuck cam. The cylinder needles of 2-9, 11-18, 20-27, …1872 needles produce knit stitch due to presence of knit cam.
Where, X- No of Needles in Wale wise, Y- No of Feeders in Course wise

Figure 6.10 Needle set out diagram of 9th wale and 9th course double-face fabric

6.2.4.4 Cam set out for 9th 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>
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<td>x</td>
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</tr>
<tr>
<td>CN3</td>
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<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 6.11 Cam set out diagram of 9th wale and 9th course double-face fabric
As shown in the Figure 6.11, out of 36 feeders, the cylinder needles were controlled by tuck cam in 2\textsuperscript{nd} and 20\textsuperscript{th} feeder. Thus the cylinder needles produced tuck stitch with the dial needle. (i.e.) cotton yarn goes in to the loops of polypropylene yarn at every 9\textsuperscript{th} course to produce the double-face fabric of 9\textsuperscript{th} wale and 9\textsuperscript{th} course knitted structure.

6.2.4.5 Knitting loop formation of double-face fabric

![Figure 6.12 Knitting loop formation of 9\textsuperscript{th} wale and 9\textsuperscript{th} course double-face fabric](image)

As shown in the Figure 6.12, the dial and cylinder needle will perform miss and knit stitch simultaneously during fabric production. That is cotton yarn from feeder 1 forms miss stitch with dial needle and knit stitch with the cylinder needle. The polypropylene yarn from feeder 2 produces knit stitch with dial needle and miss stitch with the cylinder needle. Every 9\textsuperscript{th}
needle of the cylinder in track 3 produces a tuck stitch in wale wise with the corresponding 9th needle of the dial due to the presence of tuck cam. As the cylinder needles are controlled by tuck cam in 2nd and 20th feeder the cylinder needle produces tuck stitch with the dial needle at every 9th course to produce 9th Wale and 9th Course double-face fabric. This cycle was repeated throughout the knitted fabric production.

6.2.5 Production of 12th Wale and 9th Course Double-Face Fabric

The dial needle arrangement, cylinder needle arrangement, needle set out and cam set out for producing double-face fabric having tuck stitch at every 12th wale and every 9th course were discussed below.

Dial cam has two tracks of DN1 and DN2. The A and B needles moves 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 move in track 1 and 2 respectively and the C needle moves in track 3. This was shown in the dial and cylinder needle arrangement below.

6.2.5.1 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
- A : Needle moving in track-1
All dial needles were fed with polypropylene yarn from 18 feeders to produce a layer of knit stitch structure.

### 6.2.5.2 Cylinder needle arrangement

- Total number of cylinder needle : 1872
- Number of needles in track - 1 : 858
- Number of needles in track - 2 : 858
- Number of needles in track - 3 : 156
- 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 7 9 11…1871
- B : Needle moving in track-2
  2 4 6 8 10 12 14 16 18 20…1872
- C : Needle moving in track-3
  1 13 25…1860
All cylinder needles were fed with cotton yarn from 18 feeders to produce a layer of knit stitch structure.

6.2.5.3 Needle set out for 12\textsuperscript{th} wale and 9\textsuperscript{th} course double-face fabric

<table>
<thead>
<tr>
<th>X</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
<th>7</th>
<th>8</th>
<th>9</th>
<th>10</th>
<th>11</th>
<th>12</th>
<th>13</th>
<th>…1872</th>
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<tbody>
<tr>
<td>Y</td>
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<td>20</td>
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</tbody>
</table>

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

Figure 6.13 Needle set out diagram of 12\textsuperscript{th} wale and 9\textsuperscript{th} course double-face fabric

As shown in the Figure 6.13, every 12\textsuperscript{th} needle of the cylinder produces a tuck stitch in wale wise with the corresponding 12\textsuperscript{th} needle of the dial (i.e.) cotton yarn goes in to the loops of polypropylene yarn to produce double-face fabric. That is the cylinder needles 1,13,25,37, …1860 from track 3 produces tuck stitch due to the presence of tuck cam. The cylinder needles of 2-12, 14-24, 26-36, …1872 needles produce knit stitch due to presence of knit cam.
6.2.5.4 Cam set out for 12<sup>th</sup> wale and 9<sup>th</sup> 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>
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<td>-</td>
<td>x</td>
<td>-</td>
<td>x</td>
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<td>-</td>
<td>-</td>
</tr>
<tr>
<td>CN2</td>
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<td>-</td>
<td>x</td>
<td>-</td>
<td>x</td>
<td>-</td>
<td>x</td>
<td>-</td>
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</tr>
<tr>
<td>CN3</td>
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<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 6.14 Cam set out diagram of 12<sup>th</sup> wale and 9<sup>th</sup> course double-face fabric

As shown in the Figure 6.14, out of 36 feeders, the cylinder needles were controlled by tuck cam in 2<sup>nd</sup> and 20<sup>th</sup> feeder. Thus the cylinder needles produced tuck stitch with the dial needle. (i.e.) cotton yarn goes in to the loops of polypropylene yarn at every 9<sup>th</sup> course to produce the double-face fabric of 12<sup>th</sup> wale and 9<sup>th</sup> course knitted structure.

6.2.5.5 Knitting loop formation of double-face fabric

As shown in the Figure 6.15, the dial and cylinder needle will perform miss and knit stitch simultaneously during fabric production. That is cotton yarn from feeder 1 forms miss stitch with dial needle and knit stitch with the cylinder needle. The polypropylene yarn from feeder 2 produces knit stitch with dial needle and miss stitch with the cylinder needle.
Every 12th needle of the cylinder in track 3 produces a tuck stitch in wale wise with the corresponding 12th needle of the dial due to the presence of tuck cam. As the cylinder needles are controlled by tuck cam in 2nd and 20th feeder the cylinder needle produces tuck stitch with the dial needle at every 9th course to produce 12th Wale and 9th Course double-face fabric. This cycle was repeated throughout the knitted fabric production.

Figure 6.15  Knitting loop formation of 12th wale and 9th course double-face fabric
Figure 6.16   Process flow chart of double-face fabrics produced from different tuck density
6.3 **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.

6.4 **RESULTS AND DISCUSSION**

To study the effect of tuck density of yarns on moisture transfer characteristics such as wetting, vertical wicking, transverse wicking, drying, moisture vapour transfer and air permeability and thermal conductivity of double-face fabrics, five different double-face fabrics produced from 120D C/240D PP were used and denoted as 3×3 fabric for 3×3 double-face fabric, 6×6 fabric for 6×6 double-face fabric, 6×9 fabric for 6×9 double-face fabric, 9×9 fabric for 9×9 double-face fabric and 12×9 fabric for 12×9 double-face fabric.

6.4.1 **Geometrical Characteristics**

The geometrical properties of double-face fabrics were studied and the average value of 10 samples was given in the Table 6.1.

From the Table 6.1, it was found that change in tuck density affects the thickness of the double-face fabrics. The double-face fabric of 12×9 shows higher values for thickness when compared to other four fabrics.
**Table 6.1 Double-face fabric geometrical characteristics**

<table>
<thead>
<tr>
<th>Double-Face Fabric</th>
<th>Notation</th>
<th>Tuck density (Tucks per sq.cm)</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>
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</thead>
<tbody>
<tr>
<td>3×3 double-face fabric</td>
<td>3×3</td>
<td>18.12</td>
<td>12.74</td>
<td>16.78</td>
<td>213.77</td>
<td>237</td>
<td>2.9</td>
<td>0.92</td>
</tr>
<tr>
<td>6×6 double-face fabric</td>
<td>6×6</td>
<td>5.39</td>
<td>12.76</td>
<td>16.82</td>
<td>214.62</td>
<td>241</td>
<td>2.9</td>
<td>0.98</td>
</tr>
<tr>
<td>6×9 double-face fabric</td>
<td>6×9</td>
<td>3.28</td>
<td>12.80</td>
<td>16.94</td>
<td>216.83</td>
<td>245</td>
<td>3.0</td>
<td>1.04</td>
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<tr>
<td>9×9 double-face fabric</td>
<td>9×9</td>
<td>2.92</td>
<td>12.73</td>
<td>16.77</td>
<td>213.48</td>
<td>235</td>
<td>2.8</td>
<td>1.08</td>
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<td>12×9 double-face fabric</td>
<td>12×9</td>
<td>1.54</td>
<td>12.70</td>
<td>16.74</td>
<td>212.59</td>
<td>233</td>
<td>2.8</td>
<td>1.16</td>
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<td>Double-Face Fabrics 120DC / 240D PP with Notation</td>
<td>Transverse Wicking</td>
<td>Wetting</td>
<td>Dynamic transverse wicking</td>
<td>Vertical wicking</td>
<td>Moisture vapour transfer (%)</td>
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<td></td>
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<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 (mm$^2$)</td>
<td>Water spreading area for 1ml of water on back side of Bottom layer (mm$^2$)</td>
<td>Time taken for the double layered fabric to sink (s)</td>
<td>Time taken to reach saturation (s)</td>
<td>Area covered to reach saturation (mm$^2$)</td>
<td>Wicking height after 30 minutes (cm)</td>
<td>Reduction in height of water</td>
</tr>
<tr>
<td>3×3 Double-face fabric (3×3)</td>
<td>85</td>
<td>78</td>
<td>254</td>
<td>242</td>
<td>150</td>
<td>195</td>
<td>364</td>
<td>11.0</td>
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<tr>
<td>6×6 Double-face fabric (6×6)</td>
<td>83</td>
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<td>9×9 Double-face fabric (9×9)</td>
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<td>12×9 Double-face fabric (12×9)</td>
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<td>224</td>
<td>306</td>
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</table>
6.4.2 Moisture Transmission Characteristics

The moisture transmission characteristics such as wetting, transverse wicking, vertical wicking and moisture vapour transfer of double-face fabrics were analysed and the average values was given in the Table 6.2.

From the Table 6.2, it was found that 3×3 fabric takes lesser time to sink in water when compared to other four fabrics. The wicking height both in wale wise and course wise direction was higher for 6×9 fabric than other fabrics. The wale wise wicking height was more than the course wise wicking height for all the five fabrics. In transverse wicking and dynamic transverse wicking, the time taken to absorb one drop of water on face side of top layer of 6×9 fabric was lesser than the other fabrics. The area of water spread for one drop of water and the area of water spread to reach saturation was also found to be higher for 6×9 fabric.

6.4.3 Analysis of Wetting Characteristics

The ability of double-face fabrics to sink in water completely were studied and given in Table 6.2.

![Figure 6.17 Wetting characteristics of double-face fabrics](image-url)
From the Figure 6.17 and Table 6.2, it was found that 3 x 3 fabric shows quicker sinking time. The fabric transmits the water quickly to the cotton layer which absorbs and spread the water to the entire fabric surface. This makes the fabric to sink in water in lesser time as compared to other four fabrics. When the tuck density of the fabrics decreases, fabric pores increases, which makes the fabrics to sink quickly. 6 x 9 fabric show optimum value with respect to sinking time. The standard error bar shown in the Figure 6.17 indicates the significance level of 3x3 fabric with other fabrics with respect to sinking time. Effect of tuck density on wetting behavior of double-face knitted fabrics was significant at 95% confidence level (F calculated > F tabulated: p-value 1.27E-45).

6.4.4 Analysis of Wicking Characteristics

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

6.4.4.1 Longitudinal wicking rate

The rate of water spreading on various double-face fabrics were tested both for wale wise direction and course wise direction and given in the Figure 6.18 and Figure 6.19.

From the Figure 6.18 and Figure 6.19, the wicking height was analyzed for all the five fabrics in relation 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 five double-face fabrics at all time intervals of time. 6×9 fabric having 3.28 tucks per square centimeter has higher wicking height than the other four fabrics.
Figure 6.18  Longitudinal wicking rate of double-face fabrics – wale wise direction

Figure 6.19  Longitudinal wicking rate of double-face fabrics – course wise direction

Wicking height of the five fabrics increases with decreasing tuck density from 18.12 tucks per square centimeter to 3.28 tucks per square centimeter. After that wicking height of the fabrics was reduced from 3.28 tucks per square centimeter to 1.54 tucks per square centimeter. This trend
was observed in all wicking time intervals. Wicking height of the fabrics was higher in wale-wise direction than that of wicking height in course-wise direction. Inter yarn space between and with-in fabrics are increases when the tuck density decreases. This may be the reason for increasing wicking height from 3x3 fabrics to 6x9 fabrics. After that decrease in tuck density from 3.28 to 1.54 tucks per square centimeter, it makes the fabrics more porous and it doesn’t allow the water to arise. That’s why the fabrics 9x9 and 12 x 9 fabrics have lower wicking height. The equilibrium in wicking height was attained within 30 minutes and the values of wicking rate was given in the Table 6.3. The standard error bar shown in the Figure 6.18 and Figure 6.19 indicates the significance level of 6x9 fabric with other fabrics with respect to wicking height in wale wise and course wise direction respectively. Effect of tuck density on wicking in wale wise direction of double-face knitted fabrics was significant at 95% confidence level. (F calculated > F tabulated: p-value 3.41E-38). Effect of tuck density on wicking in course wise direction of double-face knitted fabrics was significant at 95% confidence level. (F calculated > F tabulated: p-value 1.4E-37).

Table 6.3  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>3X3 Fabric</td>
<td>11.0</td>
<td>10.5</td>
</tr>
<tr>
<td>6X6 Fabric</td>
<td>11.8</td>
<td>11.6</td>
</tr>
<tr>
<td>6X9 Fabric</td>
<td>12.2</td>
<td>11.7</td>
</tr>
<tr>
<td>9X9 Fabric</td>
<td>10.1</td>
<td>9.8</td>
</tr>
<tr>
<td>12X9 Fabric</td>
<td>9.8</td>
<td>9.5</td>
</tr>
</tbody>
</table>

From the Table 6.3, it was found that 6X9 fabric takes lesser time and higher wicking rate in reaching equilibrium when compared to other fabrics.
6.4.5 Analysis of Transverse Wicking and Dynamic Transverse Wicking Characteristics

The area covered by spreading one drop of water on various double-face fabrics for transverse wicking and dynamic transverse wicking were given below.

6.4.5.1 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 the 6.2.

From the Figure 6.20, Figure 6.21 and Table 6.2, the water spreading area of the double-face fabrics was measured as per the method described by (Sampath et al. 2009, 2011 & 2012).

![Area covered (mm²)](image)

**Figure 6.20** Area of water spread on face side of top layer of double-face fabrics
When one drop of water is placed on face side of top polypropylene layer of double-face fabrics, it first interacts with surface and was transported immediately to the next layer. This was due to transverse wicking. During this period water also travels longitudinally. As gravitational force is higher than wetting force, it comes to the next bottom cotton layer quickly without spreading much on top layer. So, it has minimum spreading area. As soon as droplet comes to bottom layer it travels both in transverse and longitudinal directions. Here, wetting force was higher than gravitational force and it also take time to travel in transverse direction. In the mean time, due to wetting force, water moves in longitudinal direction and reaches the bottom layer. That’s why bottom layer has more spreading area than top polypropylene layer.

From the Figure 6.20, Figure 6.21, and Table 6.2, it was found that 6x9 fabric having 3.28 tucks per square centimetre transmits one drop of water from polypropylene layer quickly to the cotton layer which absorbs and spread the water in cotton layer fabric surface. As it transfers the water quickly the spreading area was found less in polypropylene layer and more in
cotton layer. 6×9 fabric spreads the water quickly from polypropylene layer to cotton layer with minimum spreading area of water on polypropylene layer surface and maximum spreading area of water on cotton layer surface than the other four fabrics. This was real moisture management behavior of the double faced fabrics. It was achieved with the 6×9 fabric. The spreading of water at the back side of bottom layer has been measured by cutting the tuck stitches between cotton and polypropylene layers of all the double-face fabrics. The standard error bar shown in the Figure 6.20 and Figure 6.21 indicates the significance level of 6×9 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 tuck density to spread 1 ml of water on face side of top layer of double-face knitted fabrics was significant at 95% confidence level. (F calculated > F tabulated: p-value 1.12E-30). Effect of tuck density to spread 1 ml of water on face side of bottom layer of double-face knitted fabrics was significant at 95% confidence level. (F calculated > F tabulated: p-value 8.09E-43). Effect of tuck density to absorb 1 ml of water of double-face knitted fabrics was significant at 95% confidence level. (F calculated > F tabulated: p-value 1.12E-30).

6.4.5.2 Area of water spread and time taken to reach saturation

The area covered and the time taken to reach saturation point of the double-face fabrics were studied and given in the Table 6.2.
Figure 6.22 Area of water spread on double-face fabrics to reach saturation

From the Figure 6.22 and Table 6.2, the water spreading area of the double-face fabrics to reach saturation was measured as per the method described by (Sampath et al. 2009, 2011 & 2012). From Figure 6.21 and Table 6.2, it was found that 6×9 fabric having 3.28 tucks per square centimetre transfers the water quickly from polypropylene layer to cotton layer and get saturated in minimum time with maximum spreading area than the other four fabrics. As 6X6 fabric has 5.39 tucks per square centimetre and 3×3 fabric has 18.12 tucks per square centimeter the time taken for water to get transfer from polypropylene layer to cotton layer increases with decrease in spreading area. As 9×9 fabric has 2.92 tucks per square centimeter and 12×9 fabric has 1.53 tucks per square centimeter the space between the two layers of these double-face fabrics are very high respectively which increases the water transferring time with decreased water spreading area. The standard error bar shown in the Figure 6.22 indicates the significance level of 6×9 fabric with other fabrics with respect to effect with 3×3 fabric, 9×9 fabric and 12×9 fabrics with respect to area of water spread and time taken to area of
water spread and time taken to absorb water in reaching saturation. Effect of tuck density to spread water in reaching saturation of double-face knitted fabrics was significant at 95% confidence level. (F calculated > F tabulated: p-value $1.16E{-66}$). Effect of tuck density to absorb water in reaching saturation of double-face knitted fabrics was significant at 95% confidence level. (F calculated > F tabulated: p-value $1.96E{-50}$).

6.4.6 Analysis of Moisture Vapour Transfer Behaviour

The rate at which the moisture vapour get transferred to the double-face fabrics were tested and given in the Table 6.2. Number of tucks per unit space influences the moisture vapour transfer behavior of the fabrics. Moisture vapour transfer rate of the fabrics decreases with decrease in tuck density. Tuck stitch in the fabric allows the water vapour to pass out of the fabric. As 3x3 fabric was porous than 6x6 and 6x9 fabric it allows more moisture to pass through the fabric. As the space between the two layers are more in 9x9 and 12x9 fabrics due to lower tuck density, these fabrics allow less moisture to pass through them. The standard error bar shown in the Figure 6.23 indicates the significance level of 3x3 fabrics with other fabrics with respect to moisture vapour transfer. Effect of tuck density on moisture vapour transfer in reduction in height of water of double-face knitted fabrics was significant at 95% confidence level. (F calculated > F tabulated: p-value $3.08E{-70}$). Effect of tuck density on moisture vapour transfer in reduction in weight of water of double-face knitted fabrics was significant at 95% confidence level. (F calculated > F tabulated: p-value $3.38E{-64}$).
6.4.7 Analysis of Drying Characteristics

Drying rate of the double-face fabrics was calculated and expressed as average weight loss over initial water content per unit area. It was the ability of the double-face fabrics to evaporate the moisture present on the fabric surface.

From the Figure 6.24, it was found that 6×9 fabric has quicker drying time to return to its original weight when compared to other four fabrics. This was due to minimum water holding capacity of the fabric. The trend observed was as tucks per square centimeter increases to 5.39 for 6x6 fabric and 18.12 for 3×3 fabric, the time taken for these fabrics to get dried was found high in these fabrics. As 9×9 fabric has 2.92 tucks per square centimeter and 12×9 fabric has 1.53 tucks per square centimeter the space between the two layers of these double-face fabrics are very high respectively which results in higher drying time in these fabrics. The standard error bar shown in the Figure 6.24 indicates the significance level of 6×9 fabric with

![Figure 6.23 Moisture vapour transfer for height and weight reduction of water of double-face fabrics](image)

**Figure 6.23** Moisture vapour transfer for height and weight reduction of water of double-face fabrics
other fabrics with respect to drying rate. Effect of tuck density on drying rate of double-face knitted fabrics was significant at 95% confidence level (F calculated > F tabulated: p-value 1.78E-54).

![Figure 6.24 Drying rate of double-face fabrics](image)

**Figure 6.24 Drying rate of double-face fabrics**

### 6.4.8 Air Permeability Characteristics

The rate of airflow through the double-face fabrics were tested and shown in Figure 6.25.

From the Figure 6.25, it was found that 3×3 fabric has higher air permeability than the other four fabrics. The air permeability decreases with decrease in tuck density. As 3×3 fabric was porous than 6×6 and 6×9 fabric it allows more air to pass through the fabric. As the space between the two layers are more in 9×9 and 12×9 fabrics due to lower tuck density, these fabrics allow less air to pass through them. The standard error bar shown in the Figure 6.25 indicates the significant level of 3×3 fabric with other fabrics with respect to air permeability. Effect of tuck density on air permeability of
double-face knitted fabrics was significant at 95% confidence level. (F calculated > F tabulated: p-value 2.27E-32).

Figure 6.25 Air permeability of double-face fabrics

6.4.9 Thermal Conductivity Characteristics

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

It was found that there was a good correlation between air permeability and thermal conductivity value of the selected five fabrics. Tuck density decreases with increasing fabric thickness. Fabric thickness influences the thermal conductivity. Thermal conductivity of the fabrics increases with increasing fabric thickness. This trend was observed from 3×3 fabrics to 6×9 fabrics. After that thermal conductivity values decrease for 9×9 and 12×9 fabrics though the fabric thickness value was in increasing trend. This may be due to higher entrapped air between layers of the fabrics. The standard
error bar shown in the Figure 6.26 indicates the significant level of 6×9 fabric with other fabrics with respect to thermal conductivity. Effect of tuck density on thermal conductivity of double-face knitted fabrics was significant at 95% confidence level. (F calculated > F tabulated: p-value 3.26E-39).

![Thermal Conductivity of Double-Face Knitted Fabrics](image)

**Figure 6.26** Thermal conductivity of double-face knitted fabrics

### 6.5 CONCLUSION

This chapter mainly focuses on the influence of tuck density on moisture transfer characteristics of double-face knitted fabrics suitable for making sportswear. Moisture transfer characteristics such as wetting, vertical wicking, transverse wicking, dynamic transverse wicking, and moisture vapour transfer and dryness, air permeability and thermal conductivity were analyzed for all the five double-face fabrics.

It is observed that in the wetting test, 6×9 fabric took optimum time to sink in water when compared to other four fabrics. The wicking height in
wale wise direction was higher than course wise direction for all samples and at all time intervals. However 6×9 fabric shows higher wicking rate than the other four fabrics. In transverse wicking, 6×9 fabric shows decrease in area of spread on top polypropylene layer and an increase in area of spread on bottom cotton layer than the other four fabrics. 6×9 fabric also shows lesser time in absorbing one drop of water on the fabric surface than the other four fabrics. In dynamic transverse wicking, 6×9 fabric shows an increase in area of spread on bottom cotton layer than the other four fabrics. 6×9 fabric further shows lesser time in reaching the saturation point on the fabric surface than the other four fabrics. In moisture vapour transfer test, 6×9 fabric shows optimum value when compared to other four fabrics. In drying test, 6×9 fabric shows less time in drying the fabric when compared to other four fabrics. In air permeability test, 6×9 fabric shows optimum air permeability when compared to other four fabrics.

In thermal conductivity test, 6×9 fabric shows an increase in thermal conductivity value than the other four fabrics. Comparing all the selected double-face fabrics, it is found that 120D C/240D PP 6×9 fabric having optimum tucks (3.28 tucks per square centimeter) has given better level of moisture transfer characteristics and suits in making sportswear. It is concluded that the tuck density (number of tucks per square centimeter) plays a major role in deciding the moisture transfer characteristics of double-face fabrics to achieve suitability for making sportswear.