Chapter - 4
Materials and Methods
CHAPTER 4
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4.1 Introduction:
In order to study the dimensional properties of double jersey fabrics, fifteen 1x1 rib fabric samples were made in a flat bed double jersey knitting machine and thirty 1x1 rib fabric samples were made in a circular bed double jersey knitting machine. Acrylic, Cotton, Polyester/Viscose staple yarn and Polyester multifilament yarn were used to prepare the fabric samples. The fabric samples were subjected to dry relaxation, wet relaxation, washing and ultrasonic treatment for full relaxation. The fabric samples under different states of relaxation were analysed. Experiment was also carried in flat bed machine for investigating ‘robbing back’.

4.2 Yarn types of making knitted fabric samples
Following types of yarns are used to prepare the fabric samples:

i) Flat Bed:
   - High bulk 2 ply acrylic yarn of count 73 tex
   - High bulk 3 ply acrylic yarn of count 158 tex
   - High bulk 4 ply acrylic yarn of count 146 tex

ii) Circular Bed:
   - Single cotton yarn of count 24 tex
   - Single P/V yarn of count 20 tex
   - Single cotton yarn of count 20 tex
   - Single cotton yarn of count 30 tex
   - Single acrylic yarn of count 20 tex
   - Polyester multifilament yarn of count 18 tex
4.3 Testing of Yarn Parameters

4.3.1 Yarn Count:

The yarn count was measured in the direct system (Tex) under normal testing conditions. The direct system of denoting linear density is based on measuring the weight per unit length of yarn. The essence of the method was that five yarn leas of 100 m length in each case were prepared by a Wrap Reel (Motorised).

Make: M/s. Ramesh Machine Works,
Type - R021A.

The yarn leas were weighed in an Electronic Balance
Make - Afoiset
Type – ER-120A.

From the above observations yarn linear density in terms of Tex was calculated.

4.3.2 Yarn Tensile Properties:

The tensile properties of the yarns were tested in the Instron Universal Tensile Tester.

Number - 4411 H2123,
Model – 4411.

Gauge length - 50 cm
Crosshead speed - 300 mm/min.

The Full Scale Load Range - 0.5 kN.

Total number of tests performed for each yarn sample was twenty five.

The Instrument works on the principle of Constant Rate of Elongation (CRE). The rate of increase of specimen length is uniform with time. The breaking load, % strain and tenacity for each type of yarn were calculated. The mean values of the test results are shown in the following Table 4.3.2.1.
Table 4.3.2.1: Yarn Tensile Testing Results

<table>
<thead>
<tr>
<th>SI No.</th>
<th>Yarn</th>
<th>Count (Tex)</th>
<th>Breaking Load (N)</th>
<th>% Strain</th>
<th>Tenacity (cN/tex)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>High bulk 3 ply acne</td>
<td>158</td>
<td>14.24</td>
<td>33.19</td>
<td>9.00</td>
</tr>
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<td></td>
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<td></td>
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<td>High bulk 2 ply acne</td>
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<td>38.55</td>
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<td>High bulk 4 ply acne</td>
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<tr>
<td>4</td>
<td>Cotton yarn</td>
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<td>4.30</td>
<td>13.52</td>
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<tr>
<td>5</td>
<td>P/V yarn</td>
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<td>4.68</td>
<td>9.34</td>
<td>23.83</td>
</tr>
<tr>
<td>6</td>
<td>Cotton yarn</td>
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<td>4.12</td>
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<tr>
<td>7</td>
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<td>4.77</td>
<td>11.92</td>
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<td>17.03</td>
<td>14.65</td>
</tr>
<tr>
<td>9</td>
<td>PET Multifilament</td>
<td>18</td>
<td>6.35</td>
<td>21.08</td>
<td>36.22</td>
</tr>
</tbody>
</table>

4.3.3 Yarn Evenness:

The yarn samples were tested to find unevenness, imperfections and hairiness in an Uster – UT-3 Evenness tester. The Uster Evenness tester measures the mass variation of a yarn on capacitance principle. The yarn to be assessed was passed through two parallel plates of a capacitor whose value was continuously measured electronically. The presence of the yarn between the plates changes the capacitance of the system which is governed by the mass of material between the plates and its relative permittivity (dielectric constant). The U % which is the average value for all the deviations from the mean calculated and expressed as a percentage of the overall mean deviation (percentage mean deviation), the coefficient of variation CV% and hairiness index for the yarn samples were measured. Hairiness Index is the ratio of the cumulative length of all hairs within a fixed test length with the test length itself. The summary of the test results are shown in the following Table 4.3.3.1.
Testing Speed: 100 m/min
Time: 3 minutes

Table 4.3.3.1: Yarn Evenness and Hairiness Results

<table>
<thead>
<tr>
<th>Sl No.</th>
<th>Yarn</th>
<th>Count (Tex)</th>
<th>U (%)</th>
<th>CV%</th>
<th>Hairiness Index</th>
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<tbody>
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<td>2.</td>
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<td>PET Multifilament Yarn</td>
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<td>7.35</td>
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4.3.4 Yarn Diameter:

The diameter of the high bulk 2 and 3 ply acrylic yarns were measured in Wild Leitz Combi stereo Microscope (Model - Wild M3Z, Make – Haerbrugg Switzerland). The average diameter of 2 ply acrylic yarn is 0.6237 mm and that of 3 ply acrylic yarn is 0.8630 mm based on twenty observations in each case. The diameter for these two yarns were only measured as these values were utilized for calculating the theoretical loop length at knitting point with the help of the geometrical model developed for the flat bed double jersey knitting machine.
1.4 Preparation of fabric samples

4.4.1 Machines used to prepare the fabric samples

The fabrics were knitted in the following two machines:

(a) Computerized Power driven Flat bed Double Jersey Machine

Make: M/s. Brothers Limited, Japan.
Gauge: 5.5, Width: 40 inches
Number of needles selected for preparing the yarn samples: 80
Fifteen samples were prepared in the Flat bed Machine.

(b) Circular Interlock Knitting Machine

Make: Knitting & Textile Machinery Works, Tirupur, India
Gauge: 16, Diameter: 12 inches, Type of feed: Positive

One set of needles (short needles) was removed from both the beds in order to get 1x1 rib gaiting and as a result, the gauge of the machine was converted to 8. Thirty samples were prepared in the Circular bed machine.

The codes of machine, yarn and process parameters for flat bed and circular bed machines are shown in Tables 4.4.1.1 and 4.4.1.2 respectively.

Table 4.4.1.1: Code for Flat Bed Knitting

<table>
<thead>
<tr>
<th>Code</th>
<th>Machine / Yarn / Process Parameter</th>
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<tbody>
<tr>
<td>A_F</td>
<td>Machine type</td>
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<tr>
<td>B_F</td>
<td>Machine gauge</td>
</tr>
<tr>
<td>C_F</td>
<td>Yarn count (Tex)</td>
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<tr>
<td>D_F</td>
<td>Yarn material</td>
</tr>
<tr>
<td>E_F</td>
<td>Front bed cam setting (mm)</td>
</tr>
<tr>
<td>F_F</td>
<td>Back bed cam setting (mm)</td>
</tr>
<tr>
<td>G_F</td>
<td>Input tension (gms)</td>
</tr>
<tr>
<td>H_F</td>
<td>Take down load (gm/wale)</td>
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Table 4.4.1.2 Code for Circular Bed Knitting

<table>
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<th>Code</th>
<th>Machine / Yarn / Process Parameter</th>
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<td>Ac</td>
<td>Machine type</td>
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<tr>
<td>Bc</td>
<td>Machine gauge</td>
</tr>
<tr>
<td>Cc</td>
<td>Yarn count (Tex)</td>
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<tr>
<td>Dc</td>
<td>Yarn material</td>
</tr>
<tr>
<td>Ec</td>
<td>Cylinder stitch cam setting (mm)</td>
</tr>
<tr>
<td>Fc</td>
<td>Dial stitch cam setting (mm)</td>
</tr>
<tr>
<td>Gc</td>
<td>Input tension (gms)</td>
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</tbody>
</table>

4.4.2 Total combination of input parameters

Total fifteen combinations of input parameters in Flat Bed Machine were chosen by varying stitch cam setting, take-down load and yarn for producing fabric samples. The samples are prepared by incorporating three different take down loads. The stitch cam settings were altered at three levels for both the beds. In certain cases combinations were made by keeping the setting of one particular bed constant and varying the others. The values of three different settings of the stitch cam and the three different takedown loads along with the different combinations incorporated for making the fabric samples are shown in Table 4.4.2.1. Similarly thirty fabric samples were produced in Circular Bed Machine by varying the input parameters like stitch cam setting, input tension and yarn. The yarn input tension was kept at three different levels. In each case the tension was measured by a Digital Tensiometer. The cylinder stitch cam settings were also kept at three different levels keeping the dial stitch cam setting constant. The values combinations are shown in Table 4.4.2.2.
Table 4.4.2.1: Machine and process parameters for Flat bed knitting machine

<table>
<thead>
<tr>
<th>Sl No</th>
<th>Fabric Code</th>
<th>A_F</th>
<th>B_F</th>
<th>C_F</th>
<th>D_F</th>
<th>E_F</th>
<th>F_F</th>
<th>G_F</th>
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Table 4.4.2.2: Machine and process parameters for circular knitting machine

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<th>Fabric Code</th>
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</tr>
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</table>
4.5 Relaxation Treatments

Knitted fabrics are similar to woven fabrics in that they are subject to relaxation shrinkage. However, it has been found difficult experimentally to determine when a fabric has reached a totally relaxed state in which it is in a stable state with the minimum energy. This is because the stable state of a knitted fabric is controlled by the interplay of forces required to shape the interlocking loops of yarn, whereas the stable state of a woven fabric is controlled by the balance of forces required to crimp the yarns. The resistance provided by inter-yarn friction prevents the yarn taking up its lowest energy state and the magnitude of the restoring forces in a knitted fabric is not great enough to overcome this. Due to this difficulty a number of relaxed states have been suggested. Hence, the fabric samples were subjected to the following relaxation treatments:

- **Dry relaxation treatment**: This is the condition the fabric reaches after a sufficient period of time subsequent to being removed from the knitting machine. Fabric samples were placed on a flat surface at room conditions for 24 hours.

- **Wet relaxation treatment**: This is achieved by a static soak in water and flat drying. Fabric samples were immersed in water for 24 hours followed by gentle rinsing and drying at room conditions on a flat surface for 24 hours.

- **Washing treatment**: This is achieved by soaking in water with agitation at around 60°C with 0.5 gms/Lt of non ionic detergent for 30 minutes followed by gentle rinsing and then drying at room conditions for 24 hours.

- **Ultrasonic treatment**: Fabric samples were subjected to Ultrasonic treatment for full relaxation. The specification of the Ultrasonic Cleaner used for the present experiment are cited below:
  
  Brand : PCI  
  Model : 3.5 L100H,  
  Capacity : 3 litres
Frequency: 33 kHz
Water temperature: 50°C
Relaxation time period: 15 minutes

Fabric samples were placed in the ultrasonic cleaning bath containing 3 litres of water. 0.5gms/lt of non ionic detergent was added in the bath before placing the fabric. Relaxation treatment was carried for 15 minutes at 50°C. The fabric samples were then taken out, rinsed and dried at room conditions for 24 hours. The relaxation treatment was repeated three times for every fabric sample. The first, second and third relaxation treatments are termed as Ultrasonic 1 (US-1), Ultrasonic 2 (US-2) and Ultrasonic 3 (US-3) states respectively.

The ultrasonic waves, generally used in various technical / industrial applications, could be an effective way of supplying energy for relaxation of knitted fabrics. Keeping in view this concept the technique of application of ultrasonic waves to obtain full relaxation of both flat bed and circular bed knitted fabrics was incorporated in the study. The ultrasonic treatment lowers down the energy in fabric to its lowest level. The vibrations of the ultrasonic waves obviously results in permitting more inter-yarn and inter-fibre slippage and thus facilitates the attainment of minimum energy level. The internal forces exerted during knitting operations are removed and thereby the potential energy of the fabrics is released. The high energy level of ultrasonic waves, probably due to microscopic disruptions in water of ultrasonic bath, reduces the energy level in the fabric. The ultrasonic wave causes increase in temperature and produces mechanical vibrations. Hence, the stresses and the internal forces of the loops are released. By using the ultrasonic method of relaxation, the fabric stabilization reaches to a higher degree than that by using other relaxation treatment method.

4.6 Method of Fabric Analysis:

In the present study, the dimensional parameters like courses per inch (cpi), wales or ribs per inch (wpi), loop length (l), length and width of the fabric samples were measured in the standard atmospheric conditions. A rib is defined as the wales which comprises a structural repeat width ways. In 1x1 rib fabric, the rib therefore consists of one face wale and one back wale, and the
number of ribs per inch is numerically equal to the number of face or back wales per inch. A loop or stitch is defined as the repeating unit of the structure, which for 1x1 rib is one face loop, one back loop, and the yarn segments joining these loops. Loop length is the length of yarn in inch or mm in one loop. Stitch Density (SD) is the term frequently used in Knitting and represents the total number of loops in a square area. It is the product of courses per inch and wales or ribs per inch.

1. Courses and Wales (Ribs) per inch: The numbers of courses and wales (ribs) in two inch length and width were counted randomly from ten different portions of the fabric samples for flat bed machine, with the help of a needle and a measuring scale. From the observed ten readings the number of courses and wales per inch were calculated separately. This was performed at all different relaxation stages. In case of circular bed knitted fabrics the numbers of courses and wales (ribs) in one inch were counted randomly from ten different portions with the help of a pick glass. This was also performed at all different relaxation stages.

2. Stitch density: Stitch density was calculated from the product of courses and wales (ribs) per inch for all the samples at all different relaxation stages.

3. Loop Length: In case of Flat Bed Knitting 80 number of needles were selected to prepare the samples. To measure the loop length the full course comprising of 80 loops was unraveled from the fabric sample. One end of the yarn was fixed on a support by means of a cello tape and a load of 0.5 gms per tex was applied at the other end to remove the crimp of the yarn or in other words to straighten the same. The length of the yarn was measured thereafter by means of a measuring tape. Twenty such observations were performed and the average value of the reading was calculated.

The loop length was calculated from the following formula:

\[ \text{Loop length} = \frac{\text{Uncrimped length of the yarn making 80 loops}}{80}. \]

In case of Circular Bed Knitting 100 number of loops were counted and marked along a course. This is done for twenty courses and accordingly the marked portion of the fabric
sample was cut with the help of a scissor. To measure the loop length the course comprising of 100 loops was unraveled from the fabric sample. One end of the yarn was fixed on a support by means of a cello tape and a load of 0.5 gms per tex was applied at the other end to remove the crimp of the yarn or in other words to straighten the same. The length of the yarn was measured thereafter by means of a measuring tape. Twenty such observations were performed and the average value of the readings were calculated.

The loop length was calculated from the following formula:

\[ \text{Loop length} (l) = \frac{\text{Uncrimped length of the yarn making 100 loops}}{100}. \]

The loop length was calculated for all the fabric samples at all different stages of relaxation.

4. Length, Width and Area: The fabric samples were laid on a flat surface. The length of fabric samples was measured at three different positions across the width with the help of a measuring tape and the average value was calculated. The width of fabric samples was measured from ten different positions across the length with the help of a measuring tape and the average value was calculated. These measurements were carried out at individual stages of relaxation. Thereafter the area of the individual fabric samples was calculated from its length and width.

4.7 Robbing Back Phenomenon

The phenomenon of ‘robbing back’ was suggested by Knapton and Munden \(^{12}\) and it is the reason for the measured or actual loop length in a knitted structure to be smaller than the theoretical loop length when calculated from the depth of the stitch cam setting. As the needles descend following the contour of the stitch cam, the tension required to pull the yarn from the package increases rapidly and it becomes easier to rob back yarn in the opposite direction from the already formed loops of needles further back which are now beginning to rise from their lowest or knock-over position.

The robbing back phenomenon was studied in the present work in the flat bed double jersey knitting machine only. For calculating the robbing back % the marked loop length was measured.
Marked loop length is the length of yarn contained in a loop at the knitting point during loop formation. For measuring or getting the marked loop length at the knitting point a particular needle in any bed was positioned at the knitting point and then mark was applied or given on the yarn supported by the two neighbouring needles of the opposite bed with the help of indelible ink. After preparing the fabric samples the marked yarns were unraveled and the value of the marked loop length was calculated from the marks by means of a measuring scale. This was repeated for thirty different courses and the average value was calculated. This was done for three different stitch cam settings both for front and back bed. The actual loop length for the fabric samples was calculated as per normal procedure discussed earlier in section 4.5. The theoretical loop length for both front and back bed knitting points was calculated from the geometrical model as discussed in Chapter 3.

The Robbing Back (%) values were calculated based on the marked loop length and theoretical loop length using the formula (i) and (ii) respectively:

i) Robbing Back(%) = \( \frac{(\text{Marked loop length} - \text{Actual loop length})}{\text{Marked loop length}} \times 100 \)

ii) Robbing Back(%) = \( \frac{(\text{Theoretical loop length} - \text{Actual loop length})}{\text{Theoretical loop length}} \times 100 \)

The robbing back % values for three different stitch cam settings are shown in Table 4.7.1.
Table 4.7.1: Robbing back (%) at three different stitch cam settings in Flat bed double jersey knitting machine

<table>
<thead>
<tr>
<th>SI No.</th>
<th>Stitch cam setting (mm)</th>
<th>Marked loop length at knitting point (mm)</th>
<th>Theoretical loop length calculated from the model (mm)</th>
<th>Actual loop length (mm)</th>
<th>Robbing Back (%) calculated from marked loop length</th>
<th>Robbing Back (%) calculated from theoretical loop length</th>
</tr>
</thead>
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<tr>
<td>1</td>
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<td>25.07</td>
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<td>26.20</td>
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</tbody>
</table>

From the Table 4.7.1 it is seen that the robbing back (%) calculated from the theoretical loop length obtained from the geometrical model is slightly higher as compared to that of the marked loop length. This is mainly due to two reasons. Firstly, the actual configuration of loop in the machine differs to some extent from the assumed loop configuration may be due to shifting of the cast-off loop from the verge point. Secondly, there may be human error in the measurement due to restricted accessibility inside the knitting zone mostly covered by the cam system.

It is observed that the robbing back (%) values are always higher while considering theoretical loop length at back bed knitting point compared to the same for front bed knitting point. From the Knitting Geometry, discussed in chapter 3, it is clearly observed that there is a difference in length of loop at the knitting point for front and back bed. In case of the back bed all the three needles participating in the formation of the loop are at their respective knitting points with equal length of leading and trailing arms. Whereas in the case of front bed, one of the back bed needle forming the loop has just reached the verge level i.e., yet to reach the knitting point and hence the trailing arm is shorter than the leading arm. This difference in loop forming situation results longer loop length in the case of back bed needle forming the loop at knitting point than the loop.
formed by the front bed needle. It is also observed that the robbing back (%) gradually increases with the decrease in the stitch cam settings for both front and back bed.