CHAPTER 4

MATERIALS AND METHODS

4.1 INTRODUCTION

This chapter is concerned with the materials and methods used in the study. All instruments which are commercially available for testing are described.

4.2 MATERIALS

Details of yarn samples used for knitting were described in chapter 3.

4.2.1 Fabric Production

A series of single jersey and pique fabrics was knitted from yarns of 30° carded cotton and 40° combed cotton yarns, whose characteristics were given in chapter 3.

Each yarn was used to knit a length of knitted fabric. The following weft-knitting machines were used for the production of weft-knitted fabrics from the yarns produced on circular knitting machines.
1. A 17" diameter circular knitting machine with 24 gauge, 24 feeders and with a positive feed device.

2. A 18" diameter with 54 feeders, 24 gauge with 4-track arrangement. This machine was used for producing pique fabrics which are single jersey derivatives. For the purpose of producing pique fabrics which differ in run-in ratio. Yarn characteristics are provided in chapter for these yarns.

With the above machines it was found possible to produce samples from the single yarn. No additional take-down tension was employed in order to avoid changes in fabric geometry arising from this source.

It was also possible to vary the loop length of the knitted fabrics with a view to varying the geometrical properties. The WEMSTAR was used for measuring the yarn feeding speed per revolution of the cylinder, and the adjustment of the yarn feeding speed was done by using IRO and HPF yarn feeding device. Loop length was calculated by dividing the length of yarn per revolution of the cylinder by the total number of needles knitting.

\[
\text{Loop length} = \frac{\text{Yarn feeding speed (mm/rev)}}{\text{Total number of needles (mm/rev)}}
\]

To obtain loop lengths of 2.5, 2.7 and 3.0 mm respectively the yarn feeding speeds per cylinder revolution were set at 3360 mm, 3640 mm and 4040 mm respectively. These, when divided by 1344 which is the total number of needles provides loop length.

A total of 9 samples, three of single jersey, three of air tex and three of lacoste was produced. All these were subjected to scouring, bleaching mercerising and dyeing and 36 samples were obtained.
For the purpose of giving sanding treatment, commercially knitted fabrics such as loop knit rib and interlock were used.

4.2.2 Chemical Treatments

With a view to investigating the effects of chemical treatments on the properties of knitted fabrics, they were subjected to chemical treatments; these are described below. Commercially obtained chemicals were used in all the treatments.

4.2.2.1 Scouring

The knitted fabrics were scoured by pressure boiling method which was carried out in an autoclave at a pressure of 2.15 kg/cm². The scouring solution contained the following ingredients:

<table>
<thead>
<tr>
<th>Ingredient</th>
<th>Percentage</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sodium hydroxide</td>
<td>2.0%</td>
</tr>
<tr>
<td>Sodium silicate</td>
<td>0.1%</td>
</tr>
<tr>
<td>Sodium carbonate (anhydrous)</td>
<td>2.5%</td>
</tr>
<tr>
<td>Soap</td>
<td>1.0%</td>
</tr>
<tr>
<td>Wetting agent</td>
<td>0.2%</td>
</tr>
<tr>
<td>M : L</td>
<td>1:20</td>
</tr>
<tr>
<td>Reaction time</td>
<td>2 hours</td>
</tr>
</tbody>
</table>

After treating the fabrics for two hours, the fabrics were taken out of scouring solution and washed alternatively with sufficient amount of hot and cold water. To remove the traces of alkali, the fabrics were soured with 0.1% acetic acid and washed thoroughly.
4.2.2.2 Bleaching

Grey fabrics are directly taken up for bleaching without scouring. The fabrics, which were scoured by pressure boiling, were used for normal bleaching. Normal bleaching was carried out with solution containing 2 g/l available chlorine keeping material to liquor ratio 1:20. The pH of the bath was maintained at 10.2. The reaction was carried out for 2 hours at 27°C temperature. It was followed by sourcing with 0.25% HCl and antichlorine treatment with sodium meta bisulphite. The fabrics were finally washed.

Direct bleaching was carried out in two steps. In step I, the grey fabrics were bleached with a solution of 3 g/l available chlorine. Other conditions were same as used in normal bleaching. In step II, the bleached fabrics from step I were rebleached with solution containing hydrogen peroxide (0.75 g/l), sodium hydroxide (0.5 g/l) with sodium silicate (1.25 g/l). The reaction was carried out for 2 hours. Finally, the fabrics were sourced with 0.25% HCl, antichlored with 1% sodium metabisulphite and washed thoroughly.

The fabrics scoured by pressure boiling and bleached by normal method were used for mercerising.

4.2.2.3 Mercerisation

The knitted fabrics were impregnated with a solution of 24% sodium hydroxide with wetting agent for 90 sec at 20°C. After 90 seconds, the fabrics were washed with hot water at 70°C to remove the alkali and then washed with cold water. The fabrics were then soured with 0.1% acetic acid to remove traces of alkali and washed again.
4.2.2.4 Dyeing

The fabrics were dyed using cold brand reactive dyes.

4.2.2.5 Relaxation Treatments
4.2.2.5.1 Dry relaxation

All the knitted fabrics were laid free from any constraint on a flat surface and allowed to condition for at least 72 hours in a standard atmosphere. The desired fabric parameters were then measured and recorded.

4.2.2.5.2 Full relaxation

The fabrics were washed and tumble dried for 5 times following the steps suggested by STARFISH project undertaken by the International Institute of Cotton (I.I.C), Manchester, U.K. The steps involved are given below:

a) Washing in domestic washing machine at 60°C.
b) Tumble dry until the fabric is dried.
c) Wet-out in washing machine
d) Repeat steps (b) and (c) three times.
e) Conditioning the sample.

All the knitted fabrics, whether treated or untreated were subjected to the above treatments to bring them to the stable state before they are taken up for testing.
4.2.3 Measurements of fabric parameters

4.2.3.1 Fabric dimensions

Courses/cm and wales/cm were counted with a counting glass. By marking 1 cm perpendicular to the wales and pulling out the yarns, the number of courses can be counted. Ten measurements for each dimension were made at different places on each side of the tubular fabric. Mean values of courses/cm and wales/cm were then calculated.

4.2.3.2 Friction testing apparatus

Friction tests on knitted fabrics were made on an Instron tensile tester. A polished aluminium block fitted with a frictionless pulley at one end was mounted on the cross head of the tester. The fabric to be tested was fixed to the block and the material against which the fabric was to be tested was placed on the fabric. Attached to this material was a thread which went round the frictionless pulley and passed vertically upwards to be attached to the load cell of the tester.

Chart and cross-head speeds of 10 and 5 cm/min, respectively were used. Five tests were made in each of the course wise and wale wise directions. Tests were made against a brass block.

4.2.3.3 Determination of flammability

Flammability test was performed as per the recommendations of ASTM D 1230.
4.2.3.4 Wicking behaviour

Wicking tests were carried out on fully relaxed samples. The fabrics were laid on a flat horizontal surface for at least 24 hours in the standard atmosphere (25°C, 65% RH), the wrinkles were removed without stretching. Strips (40 x 350 mm) parallel to the wale direction were cut from samples. All the samples were marked at intervals of 10 mm along their length using a pen to make the movement of the water through the fabric more easily measured. A pin weighing one gram was then inserted through the lower edge of strip to weigh it to ensure that the end dipped in water. Then the strip was suspended vertically in the wale direction with one end of the threads clamped into the clamping bar. The other weighted end dipped 5 mm into the reservoir of water by using the height adjusted. Each sample was hung freely. Thus the end of each specimen was put in water (all samples were at the same level). The height of water that wicked through the fabric at different periods of time was recorded. For each type of samples, the tests were repeated three times according to a random sampling order to further reduce any experimental errors due to slight change in the testing environment, distilled water was used for the experiment. The duration of each experiment was roughly about one hour.

4.2.3.5 Loop length

In order to find out the actual loop length of the knitted fabrics at both dry and fully relaxed states, the side knitted first of each sample was levelled out and a cut of approximately 5 cm was carefully made parallel to the wale direction in this tubular form of fabric. Six courses were then unroved from each sample and measured for their lengths on Shirley Crimp Tester under pre-determined tensions i.e., 0.1 g/tex. The mean value of course length was calculated and thereafter divided by the number of needles yielding the loop length.
The actual loop lengths at both dry and fully relaxed states and the corresponding measured values of yarn linear densities were used to calculate the actual tightness factor according to the following formula:

\[
\text{Tightness Factor} = \frac{\sqrt{\text{Tex}}}{l} \quad \ldots (4.1)
\]

where \( l \) is the loop length.

The number of readings was 10 for each fabric.

### 4.2.3.6 Determination of CPC, WPC, stitch density per cm\(^2\), \( K_C \), \( K_w \), \( K_s \), \( K_C/K_w \) and course and wale spacings

A laboratory travelling microscope provided with a source of light was used to determine the courses per cm (CPC) and wales per cm (WPC). Five measurements for each dimension were made at different places. The value of stitch density (S) was calculated by multiplying the corresponding mean values of courses and wales per cm.

The geometrical parameters of the corresponding knitted samples at both dry and fully relaxed states were calculated according to the following formulae:

\[
K_C = \text{CPC} \times l \quad \ldots (4.2)
\]
\[
K_w = \text{WPC} \times l \quad \ldots (4.3)
\]
\[
K_s = K_C \times K_w \quad \ldots (4.4)
\]

The shape factor of the knitted fabrics, i.e. the ratio of wale spacing to course spacing was calculated by dividing the courses per cm by the wales per cm. Course spacing (C) and wale spacing (W) were calculated
by the inverse of the corresponding courses and wales per cm of the respective samples.

4.2.3.7 Fabric thickness (t)

The fabric thickness parameter (t) was measured on "Essdiel" thickness gauge using the minimum possible load of 20 gf/cm² which is equivalent to a pressure of 1.96 kN/m² (1.96 kPa). Choice of this pressure was also governed by Postle's (1971) paper on compression curves for cotton single jersey fabrics, which shows that around a pressure of 2 kPa flattening of protruding fibres as well as of buckles in the fabric take place.

The tubular form of the knitted fabric was cut along the wale line, and then spread carefully without strain on the gauge tester and then tested for its thickness. Ten readings at different places of each sample were taken to calculate the average value of the respective sample thickness.

4.2.3.8 Tests of mechanical properties

In practical terms, the extension or stress applied to woven fabrics during manufacturing finishing, garment constructions and wear are generally within the low-stress region of their characteristic stress-strain behaviour. The major stress involved in fabric deformation under low stress conditions are tensile shear, bending and compression. Thus the analyses in the present work are based on the charts and mechanical properties tested on the Kawabata Evaluation System (KES).

The KES is a testing methodology that has been used for fabric objective measurement. The KES system consists of four precision instruments originally designed to measure key mechanical properties
related to the hand drape and formability of fabrics. All samples were tested in both the warp and weft directions for:

1) Tensile and shear properties.
2) Pure bending properties.
3) Compression properties, and
4) Surface and friction properties.

The full sets of the KES digital and graphical output generated by the instruments were used to characterise the deformation and recovery behaviour of fabrics. These charts, graphical output also give comprehensive picture in all modes of deformation of fabrics. Generally speaking, the KES system has the following several features:

1) The testing is very comprehensive five charts and 16 parameters in wale and course ways can be obtained in one system, which almost covers all aspects of physical properties of a fabric, in contrast to those testers which test single deformation modes.

2) The tested strain regions are very similar to what happens when the fabrics are handled or when they spread, cut, fused sewn, or shaped and wearing.

3) A sample of the same size (20 cm x 20 cm) can be tested through the whole system. Particularly the size of the samples used for tensile testing is different from the conventional big ratio of length/width such as is used on the Instron machine.

4) It is highly automated and results from testing can be shown accurately on the computer attached to it, with charts and print outs of property parameters.
Detailed information on the KES instruments and the principles of measurement can be found in KES-FB manuals (1-4).

### 4.2.3.9 Experiments

The following is the list of the instrument settings used in KES testing.

### 4.2.3.10 KES settings to measure fabrics

1. **Tensile and Shear Tester**

   **A. Tensile**
   - Maximum stress: 50 gf/cm
   - Rate of deformation: 0.2 mm/sec
   - Sample length (between jaws): 5 cm
   - Sample width: 20 cm

   **B. Shear**
   - Maximum deformation: 8 degree
   - Rate of deformation: 0.417 mm/sec
   - Sample length (between jaws): 5 cm
   - Sample width: 20 cm
   - Constant normal stress: 200 gf

2. **Pure Bending Tester**
   - Maximum curvature: 2.5 cm\(^{-1}\)
   - Sample length (between clamps): 1 cm
   - Sample width: 20 cm
   - Rate of deformation: 0.5 cm\(^{2}/\)sec
3. **Compression Tester**

- Maximum stress: 50 gf/cm²
- Area of compression: 2 cm²/sec
- Rate of compression: 1 mm/50 sec

4. **Surface Tester**

- Normal load: 50 gf
- Rate of sensing: 1 mm/sec
- Tension applied to sample: 20 gf/cm
- Size of sample: (20 x 20) cm

The parameters obtained from the tensile test are:

- **EMT** - Percentage tensile elongation which is the ratio of actual extension to the original sample length in percentage.

- **WT** - Tensile energy of work done in tensile deformation represented by area under the stress-strain curve.

- **RT** - Tensile resilience which is the ratio of work recovered to the work done in tensile deformation expressed in a percentage, and

- **LT** - A measure that defines the extent of non linearity of the stress/strain curves. LT values below 1.0 indicate that the stress/strain curve rises below a 45° straight line while LT values greater than 1:0 indicate that the stress/strain curve falls above a 45° straight line.
The shear test is carried out on the same instrument that is used for conducting the tensile test. Physical parameters evaluated to characterise the shear behaviour are:

- G - Shear modulus which is the slope of the shear curve that falls between shear angles 0.5° and 5°.
- 2HG - Hysteresis width at the shear angle of 0.5°, and
- 2HG5 - Hysteresis width at a shear angle of 5°. The bending test involves bending of a specimen to a standard curvature and then reversing the bending motion in order to study both bending and recovery behaviour.
- B - Bending stiffness which is the slope of the bending curve that lies between the radius of curvatures of 0.5 cm\(^{-1}\) and 1.5 cm\(^{-1}\) and
- 2HB - Hysteresis width at a bending curvature of 0.1 cm\(^{-1}\).

In the compression test a standard area of the fabric is subjected to a known compressive load and then the load is gradually relieved. The load is applied through a movable plunger that moves up and down and compresses the fabric on a stationary platform. The following mechanical parameters characterise the compression and recovery behaviour of the fabric:

- \(T_0\) - Fabric thickness (mm) at a very low compressive stress of 0.5 g\(\text{f}/\text{cm}^2\),
T_m - Fabric thickness at a maximum compressive load of 50 gf/cm²

WC - Work done in compression represented by the area under the compressive curve.

RC - Compressive resilience is the work recovered to the work done, expressed as a percentage.

LC - Compression linearity is a measure of the deviation of the deformation curve from a straight line. Higher values of LC imply a higher initial resistance to compression.

In general, all fabrics have low values of linearity compared with tensile testing. Values range from 0.25 - 0.36.

The surface tester uses two sensors that record the geometrical roughness of fabric surface and the coefficient of surface friction respectively, as the fabric moves to and fro underneath the two sensors.

The parameters from the surface test are:

MIU - Coefficient of surface friction as measured over three cm length of fabric.

MMD - Mean deviation of coefficient of friction; and

SMD - Surface roughness (mean deviation of surface peaks representing thick and thin places).
All mechanical properties measured on the KES system are summarised in Table 4.1.

The principles involved in the characterisation of fabric responses to various stresses and some typical deformation/recovery curves are as follows:

1) Stiffness, the resistance to deformation, or the ability of deformation, they are parameters: B, G, E - Young’s modulus is indicated indirectly by EMT and WT due to the difficulty of the measurement, E may be related with 50/EMT; compression resistance may be indicated indirectly by WC.

2) Linearity via non linearity, they are parameters: LT, LC, LB, LG in which LB = LG = 1 are omitted;

3) Viscosity and plasticity: They are: RT, 2HB, 2HG, 2HG5, RC

4) Surface and dimensional properties SMD, MIU, MMD, T.

Shear rigidity was determined by FAST technique in which the bias extension is measured.

Flexural rigidity was measured by cantilever bending tester.
<table>
<thead>
<tr>
<th>Block</th>
<th>Property</th>
<th>Description</th>
<th>Unit</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tensile</td>
<td>LT</td>
<td>Linearity of stress-strain curve</td>
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</tr>
<tr>
<td></td>
<td>WT</td>
<td>Tensile energy</td>
<td>gf.cm/cm²</td>
</tr>
<tr>
<td></td>
<td>RT</td>
<td>Tensile resilience</td>
<td>%</td>
</tr>
<tr>
<td></td>
<td>EMT</td>
<td>Strain at 50 gf/cm stress</td>
<td>%</td>
</tr>
<tr>
<td>Bending</td>
<td>B</td>
<td>Bending stiffness</td>
<td>gf.cm²/cm</td>
</tr>
<tr>
<td></td>
<td>2HB</td>
<td>Hysteresis of bending moment</td>
<td>gf.cm/cm</td>
</tr>
<tr>
<td>Shear</td>
<td>G</td>
<td>Shear stiffness</td>
<td>gf/cm.deg</td>
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<tr>
<td></td>
<td>2HG</td>
<td>Hysteresis of shear stress at 0.5</td>
<td>gf/cm</td>
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<td></td>
<td>2HG5</td>
<td>Hysteresis of shear stress at 5⁰</td>
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<tr>
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<td></td>
<td>WC</td>
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<td>RC</td>
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<tr>
<td></td>
<td>Tm</td>
<td>Thickness at 50 gf/cm³ stress</td>
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