Chapter 3
Materials and Methods

3.1 Materials
3.1.1 Fibres

The tencel, polyester and cotton fibres were used in the present study. The cotton fibre (DCH 32) was obtained in form of combed sliver from an industry. The stress-strain diagrams and specifications of tencel, polyester and cotton fibres are given in Fig. 3.1 and Table 3.1 respectively. Amongst the three fibres, polyester is strongest and most extensible, whereas tencel has highest initial modulus. The linear densities of the three fibres are fairly close to each other. Fig. 3.2 shows the cross-sectional view of the three fibres as seen through SEM micrograph.

<table>
<thead>
<tr>
<th>Fibre</th>
<th>Length mm</th>
<th>Linear density dtex</th>
<th>Tenacity cN/tex</th>
<th>Breaking elongation %</th>
<th>Modulus cN/tex</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tencel</td>
<td>38</td>
<td>1.40</td>
<td>31.3</td>
<td>7.2</td>
<td>731.3</td>
</tr>
<tr>
<td>Polyester</td>
<td>38</td>
<td>1.33</td>
<td>56.2</td>
<td>10.8</td>
<td>698.9</td>
</tr>
<tr>
<td>Cotton</td>
<td>33.1(^a)</td>
<td>1.18</td>
<td>24.9</td>
<td>6.5</td>
<td>525.5</td>
</tr>
</tbody>
</table>

\(^a\)Span length, 2.5%
Fig. 3.1 – Stress-strain curve of fibres
Fig. 3.2 – Scanning electron micrographs of cross-section of tencel, polyester, and cotton fibres
3.2 Preparation of Yarn Samples

3.2.1 Ring Yarns

Yarns of 29.5 tex were spun from tencel and its blend with polyester and cotton fibres using different blend ratios (0:100, 25:75, 50:50, 75:25, 100:0) and six different tex twist factors ranging from 23.93 to 47.85 (Fig. 3.3). For blending tencel and polyester fibres, each of the two components was opened manually and sandwiched well to produce a homogeneous blend. However, for tencel-cotton blended yarns, the combed cotton sliver was blended with tencel fibre in the opening room. A predetermined quantity of fibres to be blended was mixed and processed in a Lakshmi Rieter’s blowroom line. The conversion to drawn sliver was carried out by using a MMC carding machine and Lakshmi Rieters’ drawframe DO/2S. Two drawing passages were given to the card sliver, the linear density of finisher sliver being adjusted to 3.69 ktex. The finisher sliver was converted into 492 tex roving on an OKK flyframe, which was used to produce 29.5 tex yarn on Lakshmi Rieters’ G5/1 ring frame using a spindle speed of 12,000 rpm.

3.2.2 Rotor and MJS Yarns

29.5 tex yarns were spun from tencel and its blend with polyester and cotton fibres on rotor and air-jet spinning machines (Fig. 3.4). For all fibre-mix, two passages of drawing were given for rotor-spun yarns, whereas for MJS yarns, the slivers were drawn thrice under identical processing conditions. The linear density of finisher sliver being adjusted to 3.69 ktex. The rotor yarns were spun on TRITEX miniature OE rotor spinning machine. The rotor spinning parameters involved a 43 mm rotor rotating at 45,000rpm and an opening roller speed of 8,000 rpm. The slivers were spun into yarn on Murata air-jet spinner 802 MJS operating at a spinning speed of 210 m/min. Prior to rotor-spinning, the twist factors for maximum yarn tenacity for tencel-polyester and tencel-cotton yarns were found out. In the case of air-jet spinning, the first and second nozzle pressures for maximum yarn tenacity for all fibre-mix were also found out. The twist factors and nozzle pressures used for spinning different yarns are given Table 3.2.
Table 3.2 – Process variables for ring, rotor and MJS yarns

<table>
<thead>
<tr>
<th>Fibre type</th>
<th>Blend ratio</th>
<th>Tex twist factor</th>
<th>Nozzle pressure, kg/cm²</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Ring yarn</td>
<td>Rotor yarn</td>
</tr>
<tr>
<td></td>
<td></td>
<td>First</td>
<td>Second</td>
</tr>
<tr>
<td>Tencel: Polyester</td>
<td>0:100</td>
<td>33.50</td>
<td>38.28</td>
</tr>
<tr>
<td></td>
<td>25:75</td>
<td>33.50</td>
<td>38.28</td>
</tr>
<tr>
<td></td>
<td>50:50</td>
<td>33.50</td>
<td>38.28</td>
</tr>
<tr>
<td></td>
<td>75:25</td>
<td>28.71</td>
<td>33.50</td>
</tr>
<tr>
<td></td>
<td>100:0</td>
<td>28.71</td>
<td>33.50</td>
</tr>
<tr>
<td>Tencel: Cotton</td>
<td>0:100</td>
<td>43.07</td>
<td>47.85</td>
</tr>
<tr>
<td></td>
<td>25:75</td>
<td>38.28</td>
<td>43.07</td>
</tr>
<tr>
<td></td>
<td>50:50</td>
<td>38.28</td>
<td>43.07</td>
</tr>
<tr>
<td></td>
<td>75:25</td>
<td>33.50</td>
<td>38.28</td>
</tr>
<tr>
<td></td>
<td>100:0</td>
<td>28.71</td>
<td>33.50</td>
</tr>
</tbody>
</table>
Fig. 3.3 – Sample plan of ring spun tencel blended yarns for different twist factors
Tencel and its blend with polyester and cotton fibres

Tencel:Polyester

- 0:100 SPUN YARNS -Ring, Rotor, MJS
- 25:75 SPUN YARNS -Ring, Rotor, MJS
- 50:50 SPUN YARNS -Ring, Rotor, MJS
- 75:25 SPUN YARNS -Ring, Rotor, MJS
- 100:0 SPUN YARNS -Ring, Rotor, MJS

Tencel:Cotton

- 0:100 SPUN YARNS -Ring, Rotor, MJS
- 25:75 SPUN YARNS -Ring, Rotor, MJS
- 50:50 SPUN YARNS -Ring, Rotor, MJS
- 75:25 SPUN YARNS -Ring, Rotor, MJS
- 100:0 SPUN YARNS -Ring, Rotor, MJS

Fig. 3.4 – Sample plan of tencel blended ring-, rotor- and MJS yarns
Fig. 3.5 – Process sequence for spinning ring, rotor and air-jet yarn

**Ring yarn**
- Blowroom (Lakshmi Rieter)
- Carding (MMC)
- Drawframe (LR DO/2S) 2 Passage; 3.69ktex
- Simplex (OKK) 492 tex
- Ring frame (LR G5/1)

**Rotor yarn**
- Blowroom (Lakshmi Rieter)
- Carding (MMC)
- Drawframe (LR DO/2S) 2 Passage; 3.69ktex
- Rotor spinning (TRYTEX)

**Air-jet yarn**
- Blowroom (Lakshmi Rieter)
- Carding (MMC)
- Drawframe (LR DO/2S) 3 Passage; 3.69ktex
- Air-jet spinning (Murata MJS 802)
3.3 Test Methods

3.3.1 Fibre Tensile Test

Instron tensile tester was used to measure the single fibre tenacity, breaking extension and initial modulus as per ASTM standard. The stress strain curve was also obtained for each fibre. For the measurement, single fibers were carefully separated from the bundles and both fiber ends were bonded to window-frame paper cards using an adhesive tape. The length of the window in the paper card was 20 mm and that was the gauge length for the testing fibre properties. The window paper for the fibre was cut before the start of the test. The load was measured by the 5N standard load cell and the rate of extension was adjusted so as to break the fibre in 20±2 sec. Fifty observations were taken for each sample.

3.3.2 Yarn Tests

3.3.2.1 Breaking Strength and Breaking Elongation

All the yarns were tested for single strand strength and breaking extension on Instron tensile tester according to ASTM standard. The work of rupture was also calculated from the following expression:

\[
Work \ of \ rupture = \frac{1}{2} \ [\text{Tenacity (g/den)} \times \text{Breaking extension (in decimal)}]
\]

The machine parameters used were:

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Model</td>
<td>4411</td>
</tr>
<tr>
<td>Type of Machine gauge</td>
<td>Bonded wire type strain</td>
</tr>
<tr>
<td>Principle</td>
<td>Constant rate of extension</td>
</tr>
<tr>
<td>Full scale load, kN</td>
<td>5</td>
</tr>
<tr>
<td>Gauge length, mm</td>
<td>500</td>
</tr>
<tr>
<td>Cross head speed, mm/min</td>
<td>Adjusted to maintain the time of breaking of the specimen within 20±2 sec.</td>
</tr>
<tr>
<td>No. of observations</td>
<td>50</td>
</tr>
</tbody>
</table>
3.3.2.2 Mass Irregularity and Imperfections

Yarn unevenness and imperfections were recorded by Uster Evenness Tester-3 (UT-3) with under mentioned test specifications:

- Yarn speed, m/min. : 50
- Test duration, min. : 1
- Sensitivity level
  - Thin places, -50%
  - Thick places, +50%
  - Neps, +200%

Ten observations were taken for each yarn sample.

3.3.2.3 Flexural Rigidity

All the yarn samples were tested for flexural rigidity on weighted ring yarn stiffness tester by ring loop method [110]. For each yarn sample, fifty observations were taken. The steam setting were given to all yarn sample for 15 min. before testing as for few yarns samples, yarns were very twist lively and it was very difficult to make a loop without distortion and deformations.

Flexural rigidity was calculated with the help of Riding and Owen’s table [110].

\[
G = \frac{ML^2}{Z} \text{ gm cm}^2
\]

Where, 
- \( M \) = Mass of rider, gm
- \( Z \) = Table value of non-dimensional load corresponding to value of \( d_1/L \)
- \( L \) = Length of loop, cm
- \( d_1 \) = Deflection produced by weight ‘M’, cm

Following precautions were taken while performing tests.

- Ring loop formed should be a perfect circle.
- Weight of rider should be chosen such that ratio of deflection and loop length may lie between 0.05 – 0.09.
3.3.2.4 Hairiness

Zweigle hairiness meter (Model G565) was used to record yarn hairiness. The hairiness measuring technique is based upon photo electric principle. The projecting fibers interrupt a light beam and bring about an alteration in the density. The hairs emerging from a yarn up to a length of 25 mm (projected length on an axis perpendicular to yarn axis) were counted by means of a series of photo transistor placed at 1,2,3,4,6,8,10,12,15,18,21 and 25mm from the yarn core. The number of hairs were represented on a logarithmic scale and plotted on the arithmetic scale in the form of N1, N2, N3, N4, N6, N8, N10, N12, N15, N18, N21, and N25. Hairiness was measured using following parameters:

- Test length, m : 200
- Yarn draw off speed, m/min : 50
- Number of test per sample : 5

3.3.2.5 Yarn Diameter and Packing Fraction

Yarn diameter was measured on Leica Q500 MC Image analyser. Average diameter was calculated by taking over 100 readings for each yarn sample. The packing fraction (K) of the yarns was calculated using the following expression:

\[
K = \frac{1.274 \, T \times 10^{-5}}{pd^2}
\]

Where T = Linear density of yarn (tex)

\[ p = \text{Fibre density (g/cm}^3\text{)} \]

\[ d = \text{Average diameter (cm) of yarn measured using projection microscope.} \]

3.3.2.6 Abrasion Resistance

Abrasion resistance of all the yarn samples was determined by CSI flex abrasion tester. By winding a yarn sheet on wrap reel, specimen was prepared for flexing and abrasion. The number of ends in the specimen has been calculated according to ASTM standards D 1379-55T.
Following parameters were used:

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>No. of threads/specimen</td>
<td>61</td>
</tr>
<tr>
<td>Flex weight, lbs</td>
<td>2.0</td>
</tr>
<tr>
<td>Spigot weight, lbs</td>
<td>0.5</td>
</tr>
</tbody>
</table>

The specimen was abraded for 200 cycles and the average breaking load was measured from 50 threads on Instron tensile tester by placing the abraded area midway between the clamps. The breaking load of an unabraded sample was also determined under the same condition. The abrasion resistance was expressed as percentage loss in breaking load, and calculated from the following expression:

\[
\text{Loss in breaking load, \%} = \left(\frac{A - B}{A}\right) \times 100
\]

where \(A\) and \(B\) are the breaking load before and after abrasion respectively.

3.3.2.7 Structural Integrity

All the yarns were tested for structural integrity on Instron tensile tester using 200 mm gauge length and 20 mm/min cross-head speed. The upper limit was fixed at 2 \% strain and twenty cycles were fixed on the Instron universal tester. The yarn performance was assessed in terms of percentage decay using the following expression:

\[
\text{Decay, \%} = \left(\frac{A_1 - A_{20}}{A_1}\right) \times 100
\]

where \(A_1\) and \(A_{20}\) are the areas under the curve for first and twentieth cycles. Twenty observations were recorded for each yarn sample.

3.3.2.8 Tensile Energy

The tensile energy required to extend the specimen to 2\% strain was measured on the Instron universal tester using 500 mm gauge length and 50 mm/min cross-head speed. The tensile resilience was calculated by expressing unloading curve area as
percentage of loading curve area (Fig. 3.6). Twenty observations were recorded for each yarn sample.

\[
\text{Tensile resilience, \%} = \frac{\text{Unloading curve area (A)}}{\text{Loading curve area (B)}} \times 100
\]

3.3.2.9 Recovery Properties

The recovery parameters of the yarns were determined using an Instron tensile tester (model 4411) according to ASTM D1774-79 procedure. The immediate elastic recovery (IER), the delayed elastic recovery (DR), and the permanent deformation (PS) were obtained for an initial extension level of 2% and 4%. Thirty observations were taken for each yarn sample. For each yarn sample, 500 mm long specimens were elongated at an extension rate of 200 mm/min. The yarn was extended up to a predetermined level ‘B’ and immediately retracted up to level ‘O’, the origin via point ‘G’ on tex/2g load line. After allowing the yarn to relax for 3 min, it was again extended till it crossed the tex/2g load line at point ‘F’. Fig. 3.7 shows the evolution of the tests.
Recovery components were calculated from the following expressions:

*Immediate elastic recovery (IER), % = \[ \frac{GH}{EH} \times 100 \]

*Delayed elastic recovery (DR), % = \[ \frac{FG}{EH} \times 100 \]

*Permanent set (PS), % = \[ \frac{EF}{EH} \times 100 \]

where E, F, G and H are the points shown in Fig. 3.7