Fiber to Yarn Engineering
Part I: Short staple spinning
Prof. Sayed Ibrahim
Content:

- Importance of fiber properties for spinning and end-use
- Challenges meeting fiber to yarn conversion system
- Short spinning systems
  - Preparation for spinning
  - Spinning
  - Classical ring spinning
  - Developments based on ring spinning systems (siro, solo, core, compact yarn spinning)
  - New principles of spinning systems (Open-end, Dref, Air jet, Vortex Spinning Systems)
- Yarn irregularity and faults and yarn cleaning
- Special yarn production systems, fancy yarn, elastomeric, sewing threads
Hierarchical Relationships of Fiber, Yarn, Fabric and Garment to the Performance of Clothing

Fibers are the fundamental and the smallest elements constituting textile materials. The mechanical functional performance of garments are very much dependent on the fiber mechanical and surface properties, which are largely determined by the constituting polymeric molecules, internal structural features and surface morphological characteristics of individual fibers. Scientific understanding and knowledge of the fiber properties and modeling the mechanical behavior of fibers are essential for engineering of clothing and textile products.
Definition of Fiber Characteristics

Fiber Morphology

*Fiber morphology:* The morphology of fibers includes *macrostructure, microstructure, sub-microscopic structure and fine structure of fibers.*

**Macrostructure:** includes

*a) Fiber size:* has a very important influence on fiber stiffness, which affects the stiffness of the fabric, and hence the fabric drape and how soft it feels.

*b) Fiber length:* fiber length is the most important property of a fiber. Fiber length is critical in processing of fibers and yarns and in the translation of fiber strength to yarn strength. In general, a longer fiber length is preferred. Textile fibers are either staple or filament. Short staple fibers range from 2 to 46 cm; filament fibers are of infinite length. All natural fibers except silk are of staple length. Silk and manufactured fibers may be staple or filament fibers.

*c) Fiber crimp:* Crimp refers to waves, bends, twists or curls along the fiber length. It is expressed as Crimps per unit length. Some natural fibers are linear, others form two-dimensional or three-dimensional crimps as shown in the Figure. Crimped fibers tend to have higher elongation than linear fibers.
**Microstructure of fibers:** includes their surface contour and cross-sectional shape. It may be round, triangular, dog-bone, kidney-bean, flat, and so on. The shape of a fiber’s cross-section is important in many applications. It has influence on bending stiffness and torsional stiffness of the fiber. Cotton has the least resistance to bending.

**Submicroscopic structure:** details of fibers on the surface, as well as in the inner side, are observable. The figure shows the schematic microscopic structure of wool fiber.

**Fine structure:** All fibers are assemblies of macromolecules, called polymers, in the form of hundreds or even thousands of individual chemical units, covalently bonded together one after the other as illustrated in the figure. Fine structure describes the length, width, shape, and chemical composition of these polymers. It largely determines the ability of a fiber to withstand mechanical forces. There are three types of polymers comprising textile fibers: homo-polymers, copolymers, and block polymers. In homo-polymers, the most common type, one monomer (one chemical compound) repeats itself along the polymer chain. In copolymers, two or more monomers comprise the polymer chain. In block polymers, blocks comprised of homo-polymers are repeated along the polymer chain. Polymer length is specified as the number of times the monomer is repeated along the chain, called the degree of polymerization. Polymer length plays a role in fiber tensile properties.
Definition of Fiber Characteristics
(Mechanical behavior – Tensile properties)

**Mechanical behavior:** The mechanical properties of fibers are their responses to applied forces and to recovery from those forces. They contribute both to the behavior of fibers in processing to yarns and to the properties of the final products so that a knowledge of fiber behavior is essential to an understanding of yarn mechanics and fabrics mechanics.

**Tensile properties:**

*Stress–strain curve:* Because of the linear shape of a fiber, the tensile properties (the behavior under forces and deformations applied along the fiber axially) are the most important properties and are the most studied. The figure illustrates the tensile deformation. In general engineering, the tensile stress = force/area, \( \sigma = \frac{F}{A_o} \)

the tensile strain = change in length/original length, \( \varepsilon = \frac{\Delta l}{l_o} \).

In textile technology, a specific stress is often used instead of the general stress used in engineering area.

Specific stress (Tenacity) = force/linear density, \( \sigma = \frac{F}{T} \).
Definition of Fiber Characteristics
(Mechanical behavior – Tensile properties)

Stress – Strain diagram

The figure shows a model stress–strain curve. The curve begins with a straight-line segment that rises as stress is increased (AB) and then suddenly flattens and rises at a slower rate (BC). Close to the failure point, the curve rises steeply (CD). The details of each of the regions is addressed as follows:

In region AB, the deformation is a result of bond stretching and flexing. It is completely reversible. Hooke’s law is obeyed: \( \sigma = E \varepsilon \) where \( E \) is the slope of the line, called Young’s modulus. As the fiber extends along the axial direction, it contracts laterally. Poisson’s ratio, defined as the ratio of lateral contraction to axial extension, is another important material characteristic that deals with the behavior in the elastic region. After the yield point, deformation becomes nonlinear, and it is usually plastic.
**Resilience:** The resilience, also called work of recovery, of a fiber is the ratio of energy returned to energy absorbed when a fiber is deformed and then released. It may be extensional, flexural, compressional, or torsional. In the forgoing figure, the fiber resilience of extension is the ratio of area $x$ to area $x + y$.

**Creep and stress relaxation** are the tests developed to probe their time-dependent behavior. In the creep test, the strain increases with time in a sample under constant load. In the stress relaxation test, the stress decays with time after the sample is given an instantaneous strain. *Moisture* also affects the mechanical behaviors of fibers. Basically, the moisture lodges in the non-crystalline regions and plasticizes them, reducing the modulus.

**Bending:** When a fiber is bent, the under curvature will compress; those on the upper curvature will extend; and those on the center plane will be unchanged in length. Flexural rigidity (resistance to bending, stiffness) of a fiber is defined as the couple required to bend the fiber to unit curvature. The flexural rigidity can be expressed in terms of the Young’s modulus $E$ as:

$$B = \frac{1}{4\pi} \frac{\eta ET^2}{\rho}$$

where, $\eta$ is a shape factor related to the cross-section of the fiber, $\rho$ and $T$, are the density and linear density respectively.
The specific flexural rigidity, $R_f$, is equal to the flexure rigidity of a filament of unit tex $R_f = \frac{1}{4\pi} \cdot \frac{\eta E}{\rho}$.

Flexural rigidity is defined as the force couple required to bend a rigid structure to a unit curvature.

**Shear and torsion:** the figure shows the shear deformation of a solid cube unit. The shear stress $\tau$ is expressed as $F/A_0$ and the shear strain is calculated as $\delta x/y$. Then, in the elastic region, the shear modulus $G$ can be defined as the ratio of shear stress to shear strain: $G = \gamma / \tau$.

**Compression:** The figure shows a cylinder under axial compression. A compression stress is simply negative to tensile stress and a compression strain is also a negative one. The initial compressive modulus is generally the same as the initial tensile modulus. However, as the compression force increasing, the fiber will buckle easily.
The torsional rigidity: The figure shows the twisting deformation of a fiber of circular cross-section. If we look at a small region, the fiber is sheared. The torsional rigidity of a fiber, its resistance to twisting, is defined as the couple needed to achieve unit angular deflection between the ends of a specimen of unit length. Usually the specific torsional rigidity, \( R_t \), the torsional rigidity of a specimen of unit linear density (in tex), independent of the fineness of the particular specimen, is used. The bending rigidity can be obtained in terms of the Young’s modulus: \( R_t = \eta n / \rho \). Here, \( \rho \) and \( \eta \) are the density and the shape factor of the fiber respectively and \( n \) is shear modulus and expressing the twist per unit length.

\[
\tau = (1/2\pi)\phi / l
\]

Fiber friction is the force that holds together the fiber in a spun yarn and the interlacing threads in a fabric. Here, high friction is an advantage to enable a greater proportion of the strength of the individual fibers to be obtained. However, lower friction of a fiber may be desired in other cases, such as in minimizing wear of fibers and fabrics, providing good fabric drape, and so on. Friction coefficient, \( \mu \), is used to denote the friction property of a fiber.
Trend of world production
Of textile fibers
CLASSIFICATION OF FIBERS

NATURAL
- Vegetable
  - Cotton
  - Jute
  - Hemp
  - Flax / Linen
  - Bamboo (Natural)
- Animal
  - Wool
  - Silk
- Inorganic
  - Glass
  - Asbestos
  - Metal
  - Ceramic

MAN-MADE
- Synthetic
  - Polyester
  - Polyamide (Nylon)
  - Acrylic
  - Polyolefin
  - Spandex / Elastane (Lycra)
- Regenerated
  - CELLULOSE BASED
    - Viscose Rayon
    - Cupra Rayon
    - Acetate Rayon
    - Bamboo Viscose
    - Modal
    - Lyocell (Tencel)
  - PROTEIN BASED
    - Protein (Soya)
<table>
<thead>
<tr>
<th>FIBRE</th>
<th>Density g/cm³</th>
<th>Tenacity cN/tex</th>
<th>Elongation at break %</th>
<th>Specific Flexural Rigidity mN mm² tex⁻²</th>
<th>Specific Torsional Rigidity mN mm² tex⁻²</th>
<th>Electrical Resistance at 65% RH Ohm-cm</th>
<th>Moisture Regain at 65% RH %</th>
<th>Melting Point °C</th>
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</thead>
<tbody>
<tr>
<td>COTTON</td>
<td>1.52</td>
<td>35</td>
<td>7</td>
<td>0.53</td>
<td>0.16</td>
<td>10⁷</td>
<td>7-8</td>
<td>decomposes</td>
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<tr>
<td>FLAX</td>
<td>1.52</td>
<td>55</td>
<td>3</td>
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<td>NA</td>
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<td>JUTE</td>
<td>1.52</td>
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<td>2</td>
<td>NA</td>
<td>NA</td>
<td>10⁷</td>
<td>12</td>
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<td>WOOL</td>
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<td>SILK</td>
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<td>40</td>
<td>23</td>
<td>0.60</td>
<td>0.16</td>
<td>10¹⁰</td>
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<tr>
<td>VISCOSO</td>
<td>1.46 - 1.54</td>
<td>20</td>
<td>20</td>
<td>0.35</td>
<td>0.06</td>
<td>10⁷</td>
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<td>NA</td>
<td>10⁷</td>
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<tr>
<td>ACETATE</td>
<td>1.32</td>
<td>13</td>
<td>24</td>
<td>0.26</td>
<td>0.08</td>
<td>10⁻¹³</td>
<td>6</td>
<td>230</td>
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<tr>
<td>TENCEL</td>
<td>1.5</td>
<td>37.7</td>
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<td>NA</td>
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<td>NA</td>
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<tr>
<td>NYLON 6</td>
<td>1.14</td>
<td>32-65</td>
<td>23-43</td>
<td>0.20</td>
<td>0.05</td>
<td>&gt;10¹²</td>
<td>2.8-5.0</td>
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<td>NA</td>
<td>NA</td>
<td>&gt;10¹²</td>
<td>2.8-5.0</td>
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<td>1.34 - 1.50</td>
<td>25-54</td>
<td>30-55</td>
<td>0.30</td>
<td>0.07</td>
<td>&gt;10¹²</td>
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<td>ACRYLIC</td>
<td>1.16</td>
<td>20-30</td>
<td>20-28</td>
<td>0.40</td>
<td>0.15</td>
<td>&gt;10¹²</td>
<td>1.5</td>
<td>Sticks at 235</td>
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<tr>
<td>LYCRA</td>
<td>1.21</td>
<td>0-6</td>
<td>444 - 555</td>
<td>NA</td>
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<td>NA</td>
<td>1.3</td>
<td>230</td>
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* Value is much lower with antistatic agents

NA = DATA NOT AVAILABLE
# Durability Properties of Fibers & Their Fabrics

## Table: Durability Properties of Fibres & Their Fabrics

<table>
<thead>
<tr>
<th>Properties</th>
<th>Cotton</th>
<th>Wool</th>
<th>Silk</th>
<th>Rayon</th>
<th>Nylon</th>
<th>Polyester</th>
<th>Acrylic</th>
<th>Tencel</th>
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<tr>
<td>Strength</td>
<td>Good</td>
<td>Fair</td>
<td>Very Good</td>
<td>Fair</td>
<td>Very Good</td>
<td>Very Good</td>
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<td>Moisture Absorbency</td>
<td>Very Good</td>
<td>Excellent</td>
<td>Excellent</td>
<td>Very Good</td>
<td>Poor</td>
<td>Very Poor</td>
<td>Very Poor</td>
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<td>Resistance to Abrasion</td>
<td>Good</td>
<td>Fair</td>
<td>Fair</td>
<td>Very Poor</td>
<td>Excellent</td>
<td>Very Good</td>
<td>Fair</td>
<td>Very Good</td>
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<tr>
<td>Durability</td>
<td>Fair</td>
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<td>Fair</td>
<td>Poor</td>
<td>Good</td>
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<td>Stability to Laundering</td>
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<td>Good</td>
<td>Good</td>
<td>Fair</td>
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<td>Wash &amp; Wear</td>
<td>Poor</td>
<td>Fair</td>
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<td>Pressed Crease Retention</td>
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<td>Very good</td>
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<td>Poor</td>
<td>Good</td>
<td>Very Good</td>
<td>Very Good</td>
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<tr>
<td>Pilling Resistance</td>
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<td>Poor</td>
<td>Good</td>
<td>Good</td>
<td>Fair</td>
<td>Fair</td>
<td>Fair</td>
<td>Very Good</td>
</tr>
<tr>
<td>Resistance to Mildew</td>
<td>Very Good</td>
<td>Excellent</td>
<td>Excellent</td>
<td>Very Poor</td>
<td>Excellent</td>
<td>Excellent</td>
<td>Excellent</td>
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<tr>
<td>Resistance to Moth/Insects</td>
<td>Excellent</td>
<td>Very Poor</td>
<td>Poor</td>
<td>Excellent</td>
<td>Excellent</td>
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<td>Insufficient Data</td>
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<tr>
<td>Effect of Bleaching</td>
<td>Becomes weak in con/hot bleaching soln.</td>
<td>CI bleach harms Careful use of $\text{H}_2\text{O}_2$/ Perborates</td>
<td>CI bleach harms Careful use of $\text{H}_2\text{O}_2$</td>
<td>Becomes weak by con/hot soln.</td>
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<td>Good</td>
<td>Very Good</td>
<td>Insufficient Data</td>
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# Selection of Dyes for Various Fibers

<table>
<thead>
<tr>
<th>Fibre</th>
<th>Acid Dyes</th>
<th>Basic Dyes</th>
<th>Direct Dyes</th>
<th>Azoic Dyes</th>
<th>Vat Dyes</th>
<th>Solubilised Vat Dyes</th>
<th>Sulphur Dyes</th>
<th>Reactive Dyes</th>
<th>Disperse Dyes</th>
<th>Acid Mordant Dyes</th>
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<tbody>
<tr>
<td>Cotton</td>
<td>O</td>
<td>M</td>
<td>I</td>
<td>I</td>
<td>I</td>
<td>I</td>
<td>I</td>
<td>I</td>
<td>O</td>
<td>M</td>
</tr>
<tr>
<td>Linen</td>
<td>O</td>
<td>M</td>
<td>I</td>
<td>I</td>
<td>I</td>
<td>O</td>
<td>I</td>
<td>I</td>
<td>O</td>
<td>M</td>
</tr>
<tr>
<td>Wool</td>
<td>I</td>
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<td>O</td>
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<tr>
<td>Silk</td>
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<td>I</td>
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<tr>
<td>Viscose</td>
<td>O</td>
<td>M</td>
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<td>I</td>
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<td>Nylon</td>
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<td>O</td>
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<tr>
<td>Polyester</td>
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<td>O</td>
<td>O</td>
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<tr>
<td>Acrylic</td>
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<td>Acetate</td>
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<td>I</td>
<td>O</td>
</tr>
<tr>
<td>Tencel</td>
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<td>O</td>
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<td>O</td>
<td>O</td>
<td>O</td>
<td>I</td>
<td>O</td>
<td>O</td>
</tr>
</tbody>
</table>

I - Suitable
II - Suitable & Widely Used
M - Suitable after Mordanting
O - Not Suitable
Cotton is a natural cellulosic fiber obtained from bushy perennial cotton plants. The cotton plant belongs to the species Gossypium. Fiber Length, Strength, Fineness (Micronaire value), Maturity, Colour and Uniformity are the important requirements for fiber selection. Fiber Length, Fiber Strength, Micronaire value and the type of yarn decide the Count range. Cotton is a very versatile fiber and is used in many textile and non-textile applications. China, India, USA, Brazil, Pakistan, Turkey & Uzbekistan are important cotton producing countries. Since Cotton cultivation requires a huge amount of Pesticides, Genetically Modified (GM) Cotton was developed to reduce the dependency of pesticides. Organic Cotton is produced without the use of insecticides & pesticides.
# Physical Properties of Fibers

## Cotton

<table>
<thead>
<tr>
<th>Merits</th>
<th>Demerits</th>
</tr>
</thead>
<tbody>
<tr>
<td>Strong</td>
<td>Wrinkles easily</td>
</tr>
<tr>
<td>comfortable</td>
<td>Easily attacked by Mildew</td>
</tr>
<tr>
<td>Versatile</td>
<td>Long drying time</td>
</tr>
<tr>
<td>Non-allergenic</td>
<td>Poor crease resistant</td>
</tr>
<tr>
<td>Easy to wash</td>
<td>Flammable</td>
</tr>
</tbody>
</table>

![Diagram of cotton processing stages](image-url)
Jute is natural cellulosic fiber belonging to bast fibers group. Jutes belong to the family Tiliaceae. The two species are Corchorus capsularis and Corchorus olitorius. The strand of Jute fibers lie just beneath the bark of the Jute Plant. The plant is cut and the Jute fibers are removed from the plant by the retting process. Then the fibers are separated from one another by drying, softening & scotching. The colour varies from yellow to brown. The fiber are coarse and the length ranges from 150 mm to 350 mm. India & Bangladesh are the major Jute producing countries. Jute is the second most important natural fiber nest to cotton and has a variety of uses. Jute fabrics are Hessian cloth and the Jute bags are called Gunny bags. These are very much useful in packing & transporting. Jute is 100% bio-degradable & eco-friendly. It is useful in industrial fabrics, nets, packaging, agriculture, floor covering, ropes, twines, geo-textiles & technical textiles.
### Physical Properties of Fibers: Jute

<table>
<thead>
<tr>
<th>Merits</th>
<th>Demerits</th>
</tr>
</thead>
<tbody>
<tr>
<td>100% bio-degradable</td>
<td>Poor extensibility</td>
</tr>
<tr>
<td>Very strong</td>
<td>Poor drapability</td>
</tr>
<tr>
<td>Breathability</td>
<td>Poor crease resistant</td>
</tr>
<tr>
<td>Acoustic &amp; Thermal insulating properties</td>
<td>Brittleness</td>
</tr>
<tr>
<td>Non-allergenic</td>
<td>Fiber shedding</td>
</tr>
<tr>
<td>Moderate moisture re</td>
<td>Yellowing in sun-light</td>
</tr>
</tbody>
</table>

*Phisical properties of fibers: Jute*
Flax is cellulosic bast fiber. Flax plant is a member of the genus Linum usitatissimum. Flax plants grow up to 1.2 m tall with slender stems. Flax is grown for both its Flax Seeds and Flax fibers. Flax fibers are recovered from the Plant by the retting & scotching process. Flax fibers are also called Linen fibers. Linen fibers generally have a length of 25 cm to 125 cm.

After the fibers have been separated and processed, they are spun into yarns and woven or knit into linen textiles. Generally textiles with linen-weave texture from cotton and other non-flax fibers are also called as linen.

Linen threads are used in stitching upholstery, life belts, tarpaulins. Linen fabrics are used in making costly handkerchiefs, parachutes, mail bags, table & bed-linen. Linen fabrics are used in bed & baths cloths, wall-coverings, oil painting, luggages, suits, canvas etc.
# Fiber science

## PHYSICAL PROPERTIES OF FIBERS

### FLAX & LINEN

<table>
<thead>
<tr>
<th>Merits</th>
<th>Demerits</th>
</tr>
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<tbody>
<tr>
<td>Very strong</td>
<td>Poor elastic</td>
</tr>
<tr>
<td>Highly absorbent</td>
<td>Wrinkles easily</td>
</tr>
<tr>
<td>Smooth</td>
<td>Poor press-crease resistant</td>
</tr>
<tr>
<td>No pilling / no lint shedding</td>
<td>Poor mildew resistant in damp condition</td>
</tr>
<tr>
<td>Very durable</td>
<td>Longer drying time</td>
</tr>
<tr>
<td>Withstands high temperatures</td>
<td>Flammable</td>
</tr>
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</table>

- **Flax Plant**
- **Linen Fibres**
- **Linen yarn**
- **Linen Fabrics**
- **Bed linen**
Wool, common name applied to the soft, curly fibers obtained chiefly from the fleece of domesticated sheep, and used extensively in textile manufacturing. The fleece of sheep raised for wool is generally shorn once yearly, in the spring or early summer. In regions where the climate is warm throughout the year, shearing may occur twice annually. The fleece is cut close to the skin, usually with mechanical shears, and removed in one piece.

The value of wool on the market depends primarily on fineness and length of fiber. Strength, elasticity, amount of crimp, and uniformity are also considered. Two different systems are followed in wool processing, the woolen system and the worsted system. In the woolen system, the fibers are carded and then spun. In the worsted system, the fibers proceed to a combing process, which separates the long from the short fibers. Before the wool can be used for commercial purposes it must be scoured or cleaned. Scouring & cleaning may be done using warm water, detergent, alkali & carbonization.

Wool is used in clothing, shirting, suiting, woolen sweaters, blankets, upholsteries, felt, horse rug, carpets, insulation.
# Fiber science

## PHYSICAL PROPERTIES OF FIBERS

### WOOL

<table>
<thead>
<tr>
<th>Merits</th>
<th>Demerits</th>
</tr>
</thead>
<tbody>
<tr>
<td>High absorbency</td>
<td>Easily felts in moist heat &amp; friction</td>
</tr>
<tr>
<td>Provides warmth</td>
<td>Stretches during wear</td>
</tr>
<tr>
<td>Wrinkle resistant</td>
<td>Easily attacked by moths</td>
</tr>
<tr>
<td>Elastic</td>
<td>Allergic to some people</td>
</tr>
<tr>
<td>Can be easily dyed</td>
<td>Builds up static electricity</td>
</tr>
</tbody>
</table>

Sheep | Woolen Fibres | Woolen Spinning | Woolen yarn | Worsted fabrics | Worsted suiting |
Silk is a natural protein fiber used in producing textiles. Silk fibers are produced as a cocoon covering by the silkworm. Although cocoon coverings of fiber are made by a large number of insects, only those of the mulberry silk moth, Bombyx mori, and a few other moths closely akin to it, are used by the silk industry. The cocoons are first heated in boiling water to dissolve the gummy substance that holds the cocoon filament in place. After this heating, the filaments from four to eight cocoons are joined and twisted and are then combined with a number of other similarly twisted filaments to make a thread that is wound on a reel to give filament silk. The damaged outer portion & inner portion of the cocoons after brushing give staple silk which is spun to produce spun silk.

Silk fibers have a triangular cross section with rounded corners. This reflects light at many different angles, giving silk a natural shine. Silk is used for clothing such as shirts, blouses, formal dresses, high fashion clothes, negligees, pyjamas, robes, skirt suits, sun dresses, underwear, furnishing applications, upholstery, wall coverings, bedding etc.
### Merits

- Lustre & soft
- Strong
- Absorbent
- Warm & suitable for winter
- Highly drapable

### Demerits

- Perspiration & sunlight weakens
- Sensitive to alkali & acids
- Insects attack silk easily
- Yellowing with aging
- Leaves water spots

---

**Silk worms**  
**Cocoons**  
**Silk reeling**  
**Silk Twisting**  
**Silk yarn**  
**Silk fabric**  
**Silk sari**  
**Silk Garment**
Fiber science

PHISICAL PRPERTIES OF FIBERS
VICOSE RAYON

There are many types of Rayon namely, Nitrocellulose, Acetate, Cuprammonium, Viscose etc., Here we consider Viscose rayon only. Viscose Rayon is a regenerated cellulosic fiber. It is made from cellulose extracted from wood pulp produced from trees. The wood pulp obtained from trees is bleached and then sent to Rayon factories in the form of sheets and boards which contains about 87 to 98% cellulose.

The Viscose fibers are produced both in filament form & staple form. The fibers are produced in cut lengths of 28, 32, 38, 44, 51 & 60 mm for cotton spinning system. The deniers are generally 1.2, 1.5, 2.0, 3.0 & 4.0.

Rayon is a very versatile fiber and has the same comfort properties as natural fibers. It can imitate the feel and texture of silk, wool, cotton and linen. Rayon is easily bio-degradable.

Rayon is used in making apparel (e.g. blouses, dresses, jackets, lingerie, linings, scarves, suits, ties, hats, socks), furnishings (e.g. bedspreads, blankets, window treatments, upholstery, slipcovers), industrial uses (e.g. medical surgery products, non-woven products, tire cord), and other uses (e.g. yarn, feminine hygiene products, diapers).

High Wet Modulus rayon (HWM) is a modified version of viscose that has a greater strength when wet and can be mercerized like cotton. HWM rayons are also known as “POLYNOSIC“ and has a trade name MODAL. High Tenacity rayon is another modified version of viscose that has almost twice the strength of HWM. This type of rayon is typically used for industrial purposes such as tyre cords.
<table>
<thead>
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</table>

**Fiber science**

**PHYSICAL PROPERTIES OF FIBERS**

**VISCOSE RAYON**

![Diagram of wood pulp processing](image)

![Images of wood pulp trees, wood pulp, viscose fibres, viscose yarn, and viscose fabrics](images)
Polyester is a synthetic fiber produced from the polymer Poly Ethylene Terephthalate (PET). PET is produced by reacting Purified Terephthalic Acid (PTA) or Dimethyl Terephthalate (DMT) with Mono Ethylene Glycol (MEG). All these raw-materials are from Petroleum products. From the PET polymer Polyester fibers are produced in various forms namely Staple fibers (PSF) and Filament forms Partially Oriented Yarn (POY), Draw Textured Yarn (DTY), Fully Drawn Yarn (FDY).

PSF are produced in cut lengths of 38, 44 & 51 mm and in deniers of 1.0, 1.2, 1.4, 1.5, 2.0, 2.25 and 3.0. POY have deniers of 51 to 245 with number of filaments between 14-34. Crimping is done PSF which facilitates production of spun yarns.

PSF are sold in various strengths namely Low-pill fibers, Medium Tenacity, High Tenacity & Super High Tenacity. Various lustre level fibers are available like Bright, Semi dull, Dull & Extra dull.

Polyester woven fabrics are used in apparel and home furnishings such as bed sheets, beds, curtains and draperies. Industrial polyesters are used in tyre reinforcements, ropes, fabrics for conveyor belts, safety belts, coated fabrics and plastic reinforcements with high . Polyester fiber-fills are also used to stuff pillows, beds and cushion padding.

Polyester fabrics have a "less natural" feel when compared to natural fibers like cotton in textile uses. Polyester fibers are spun together with other natural fibers to produce a cloth having the merits of both synthetic & natural fibers.
## Fiber science

### PHYSICAL PROPERTIES OF FIBERS

<table>
<thead>
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<th>Merits</th>
<th>Demerits</th>
</tr>
</thead>
<tbody>
<tr>
<td>Strong</td>
<td>Collects static electricity</td>
</tr>
<tr>
<td>Wrinkle &amp; abrasion resistant</td>
<td>Sensitive to heat</td>
</tr>
<tr>
<td>Shrink resistant</td>
<td>Pilling</td>
</tr>
<tr>
<td>High dimensional stability</td>
<td>Low moisture absorption</td>
</tr>
<tr>
<td>Mildew resistant</td>
<td>Affinity for oily stains</td>
</tr>
<tr>
<td>Easy care</td>
<td>Melts in fire</td>
</tr>
</tbody>
</table>

![Polyester Production Process Diagram](image-url)
Nylon is synthetic fiber generally called Polyamide fibers. Nylon 6 is produced from Caprolactam. Nylon 6, 6 is produced from Hexamethylene diamine & Adipic acid. Nylon is a thermoplastic fiber, round, smooth, and shiny. Its cross sections can be either trilobal or multilobal. Its most widely used structures are, monofilament, multi-filament, staple or tow and is available as partially drawn or as finished filaments. Regular nylon has a round cross section and is perfectly uniform. The filaments are generally completely transparent unless they have been delustered or solution dyed. Nylon is related chemically to the protein fibers silk and wool. Nylon is used in carpets, apparel, clothing, bags, panty-hose, wind-cloths, air-bags, swim-wear, umbrella, slings, ropes, climbing gears, parachutes, balloons, tooth-brush bristle, etc.,
## Physical Properties of Fibers

### Polyamide (Nylon)

<table>
<thead>
<tr>
<th>Merits</th>
<th>Demerits</th>
</tr>
</thead>
<tbody>
<tr>
<td>Very strong</td>
<td>Very low moisture absorbency</td>
</tr>
<tr>
<td>Resistant to abrasion</td>
<td>Collects static electricity</td>
</tr>
<tr>
<td>Good dimensional stability</td>
<td>Pilling</td>
</tr>
<tr>
<td>Resistant to mildew</td>
<td>Holds oils</td>
</tr>
<tr>
<td>Highly durable</td>
<td>Yellowing</td>
</tr>
</tbody>
</table>

![Nylon Filament Yarn](image1.png)  
![Nylon Fabrics](image2.png)  
![Nylon Garment](image3.png)
Acrylic fibers are synthetic fibers made from a polymer Polyacrylonitrile. The polymer is formed by free-radical polymerization in aqueous suspension. The fiber is produced by dissolving the polymer in a solvent such as N,N-dimethylformamide or aqueous sodium thiocyanate, metering it through a multi-hole spinnerets and coagulating the resultant filaments in an aqueous solution of the same solvent (wet spinning) or evaporating the solvent in a stream of heated inert gas (dry spinning). Washing, stretching, drying and crimping complete the processing. Practically all acrylic fibers are produced in staple fiber from with lengths varying from 38 to 64 mm for the cotton system and 75– to 125 for worsted system. The deniers range from 1.2 to 3.0 for normal application and 5, 7 & 15 for special applications. Acrylic is lightweight, soft, and warm, with a wool-like feel. It has excellent colourfastness. It is resilient, retains its shape, and resists shrinkage and wrinkles. Acrylic is used in clothing as an alternative to wool.
Lyocell is "a cellulosic fiber and is classified under the sub-category of rayon. Lyocell is the generic name of the Tencel fiber. Lyocell is produced from wood pulp by solvent spinning methods. The wood pulp is dissolved in N-Methylmorpholine N-oxide, creating a solution called "dope." The dope is then pushed through a spinneret to form the individual fibers. After the dope has been spun into lyocell fibers, it is washed and the chemicals are retrieved from the water, purified, and recycled. This is an eco-friendly process because most of the solvent used is recycled and there are relatively lesser by-products.

Lenzing and the former Courtaulds each obtained a license from Akzo, the predecessor of Akzo Nobel, to develop Akzo's lyocell technology. Courtaulds commercialized lyocell under the Tencel brand name in 1992 and Lenzing commercialized lyocell by brand Lenzing Lyocell in 1997.

Tencel’s Lyocell plants are in the USA (Mobile, Alabama) and UK (Grimsby). Lenzing AG’s Lyocell plant is at Heiligenkreuz, Austria.

Akzo acquired Courtaulds in 1998 and combined the companies' fiber businesses, including Tencel, to create Acordis. Another company CVC bought a 64% stake in Acordis in 1999: Akzo owns 21% and the Acordis management holds the rest. Corsadi BV was created as part of the international financial group CVC to keep the Acordis Tencel business with it. Then Tencel business of Acordis was taken over by Lenzing AG, Austria. Now Lenzing AG is the only producer of Lyocell in the World and now marketed in the name of Tencel.
Tencel has the breathability & absorbency of natural fibers and durability & ease care performance of man-made fibers with smoothness, resilience and drape. It has softness of silk, coolness of linen, warmth of wool and strength of polyester. Because of its special structure it has a sensual, suede-like and peach touch. After dyeing it has very high colour vibrancy. It can be machine washed and dried and it retains its shape, colour and appearance.

MERITS: Nanofibrils, better moisture management, natural cooling, smooth, non allergic to skin, non-irritating, better temperature control, chemical free, bacterial growth reduction, numerous applications, high tenacity and eco-friendly manufacturing process.
Bamboo fibers are cellulosic fibers produced from Bamboo Plants a type of grass. There are two methods of producing bamboo fibers namely Mechanical method & Chemical method. Mechanical methods are similar to Flax production (retting, enzyme treatment, boiling, scutching, cutting etc.,) and this gives Natural bamboo fibers. There are two types of Chemical methods namely Bamboo Viscose Rayon method & Bamboo Lyocell method.

Bamboo Viscose Rayon method produces Bamboo fibers in the same way as Viscose Rayon production methods. Bamboo Lyocell method produces Bamboo fibers in the same way as Lyocel / Tencel production methods. But the majority of the bamboo fibers for textile application is produced by the Viscose Rayon Production methods. Bamboo fibers & Textiles are used in bed linen, bath robes, flannels, bath mats, towels, aprons, oven gloves, tea towels, nappies, sanitary napkins, intimate apparels, include sweaters, bath-suits, blankets, underwear, swimwear, tight t-shirt, socks, bandages, mask, surgical cloths, wall paper, curtains & furnishing fabrics.

MERITS: Soft, silky to touch, natural sheen, drapes well, highly absorbent material, quick drying, machine washable, anti microbial properties, anti UV, breathability, bio-degradable, and odour absorption properties.
Fiber science

PHYSICAL PROPERTIES OF FIBERS

BAMBOO

1. Shredded bamboo
2. Treated with Sodium hydroxide to form alkali cellulose
3. Ageing
4. Treated with Carbon disulphide
5. Formation of viscose cellulose sodium xanthogenate
6. Viscose solution is passed through spinnerets in a sulphuric acid bath
7. Bamboo Viscose Rayon Fibres

Bamboo Towels
Bamboo Garments
Bamboo Fabrics
Bamboo Non-woven
YARN FORMING
# Yarn Classification

<table>
<thead>
<tr>
<th>Group</th>
<th>Sub-group</th>
<th>Examples</th>
</tr>
</thead>
<tbody>
<tr>
<td>Continuous filament yarns</td>
<td>Un-textured (flat)</td>
<td>Twisted, Interlaced, Tape.</td>
</tr>
<tr>
<td></td>
<td>Textured</td>
<td>False twisted, Stuffer box crimp</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Bi-component, Air-jet.</td>
</tr>
<tr>
<td>Staple Spun Yarns</td>
<td>Non-effect/Plain</td>
<td>Carded, Combed Ring Spun,</td>
</tr>
<tr>
<td></td>
<td>Or (Conventional)</td>
<td>Worsted, Semi-worsted, Woolen.</td>
</tr>
<tr>
<td></td>
<td>Non-effect/Plain (Unconventional)</td>
<td>Rotor, Compact, Air-jet, Vortex,</td>
</tr>
<tr>
<td></td>
<td>Fiber blend</td>
<td>Friction, Hollow-spindle wrap, Repco</td>
</tr>
<tr>
<td>Composite Yarns</td>
<td>Effect/fancy</td>
<td>Blend of two or more fiber types comprising non-effect yarn</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Fancy twisted, Hollow-spindle fancy yarn, Spun effects</td>
</tr>
<tr>
<td>Folded/Plied/Doubled</td>
<td>Filament core</td>
<td>Core spun (filament or staple fibers forming core) and staple fibers as sheath</td>
</tr>
<tr>
<td></td>
<td>Staple core</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Filament Staple</td>
<td>Two or more yarns twisted together</td>
</tr>
</tbody>
</table>
Production Chain of Garment Production

Choice of Fiber
Natural, Manmade, or Blends
Criteria: Softness, Easy care, etc.

Yarn Forming
Yarn Structure
(Plain, Fancy, Plied)

Fabric Forming
Fabric Structure
(Weave: Plain, Twill, etc)
(knit: Single or double Jersey, etc.)

Fully Fashioned

Finished Fabric
(Cotton, worsted, Woolen, etc.)

Garment Production

Production of a particular end use fabric:
Choose type of Fibers
Spinning into a yarn structure of specified properties
Woven or knitted structure give the desired fabric aesthetic and/or technical performance
Nonwoven is also widely used for technical and industrial purposes.
YARN Numbering SYSTEMS

• It is not the practice to set up a spinning machine to produce a specified yarn diameter. A more useful and practical measure that indirectly gives an indication of yarn thickness is a parameter that is termed the yarn count or yarn number.

• The linear density is defined as the mass per unit length. In System International (SI) units, the mass is in grams, and the unit length is meters.

• Direct system. This expresses the count as the mass of a standard length. The mass is measured in grams, and the specific length is either 1 km for tex and 9 km for denier.

• Indirect system. This gives the length that weighs a standard mass. The standard mass is either 1 kg for metric count or 1 lb for English count, and the associated length is, respectively, in meters or yards respectively.

• The standard length can be 1 km, 840 yd, 560 yd, or 256 yd. The standard lengths in yards are commonly called hanks, or some cases skeins.

• We can now say that the indirect system gives the number of kilometers that weigh a kilogram (metric units) or the number of hanks that weigh one pound (English Imperial units).

• For carded and combed ring spun yarns, an 840-yd hank is used; a 560-yd hank is associated with worsted and semi-worsted yarns, and a 256-yd hank with woolen yarns.
Conversion between yarn numbering systems

With reference to the yarn helix model, the yarn diameter is related to the count as follows:

\[ T_y = \frac{1000\pi d_y^2}{4\delta_y} \]

Where \( \delta_y \) = the specific volume in g/m3, \( T_y \) and \( d_y \) can be measured, and \( \delta_y \) can be calculated.
Twist of plied yarns

1. Direction of Twist
2. Twist Angle
3. Twist Level (degree of twist or twist intensity)
4. Twist Multiplier.

\[
\text{Count}_{\text{plied}} = \text{Count}_1 + \text{Count}_2 \\
\text{tex}_{\text{plied}} = \text{tex}_1 + \text{tex}_2 \\
\frac{1}{\text{count}_{\text{plied}}} = \frac{1}{\text{count}_1} + \frac{1}{\text{count}_2} \\
\frac{1}{N_{\text{plied}}} = \frac{1}{N_{e1}} + \frac{1}{N_{e2}}
\]
Carding

Carding

Combed yarns finer than 15 tex

Carded yarns coarser than 15 tex

Preparation for Combing

Drawing: Further fiber straigtening and equalizing the slivers

Drawing I & II passages

Fiber Straightening and equalizing the slivers

Lap Forming

Elimination of short fibers and impurities

Combing

Roving Frame

Forming fine, small twisted strand of fibers

Dref Spinning  Murata Jet Spinning  Open-End Spinning  Ring Spinning

Winding & Cleaning if required

Automatic Bale opener

Opening to individual fiber, further cleaning and straigtening the fibers. Card Sliver

Opening to small tufts, cleaning and trashes, and blending the fibers together

Winding with technology if required
Principle of Twist Insertion Systems

Drafting to Individual Fiber Separation

Open End: Twist of Fibers into Yarn Structure

Package Winding

Open-End Spinning

Feed

False Twist

Delivery

Feed

Real Twist

Delivery
Tasks of the fiber to yarn conversion system

**Fiber Mix** → **Spinning Preparation** → **Prepared fiber strand** → **Yarn Forming (Spinning)** → **Yarn**

- Massive Bulk of Fibers
- Immense number of Fibers
- High Variability within Fiber Bales
- High Variability Between Bales
- Trash and Foreign Matter
- Fiber Neps, seed coats, Short fibers

- Very long linear strand
- Consistent appearance along yarn length
- Consistent Properties along yarn length
- Trash free
- High productivity at economical level
• Convert a high variable raw material to a very consistent fiber strand.
• Variability exists Within bales, Between bales within one mix, and Between mixes (lay downs).
• Quality criteria is high degree of uniformity, consistent properties along the yarn.
• Fibers are normally intermingled with all kinds of trash, dust, seed coat fragments,…
• The yarn produced must be pure, clean and defect free and high efficiency.
Flow chart
Cotton Ring Spinning

CARDED YARN
COTTON BALES
BLOW ROOM
CARDING
DRAWING
SPEED FRAME (ROVING)
RING SPINNING
WINDING / AUTOCONER / REELING (HANKS)

COTTON BALES
BLOW ROOM
CARDING
PRE DRAWING
LAP FORMING & COMBING
FINSKER DRAWING
SPEED FRAME (ROVING)
RING SPINNING
WINDING / AUTOCONER / REELING (HANKS)

COMBED YARN
Blowing room

Short Staple Pre-Spinning Machinery

• All Modern Spinning mills are equipped by some sort of Automatic Bale Opener.
  • In General short lines, does not need material handling, and hence less reliable for faults.

• Short staple pre-spinning emphasized compact lines with integrated multi-functional equipment.

• Major emphases were placed upon equipment allowing for a compact 800 Kg/hr opening line, an integrated separator, a more precise removal of foreign fibers, and a waste control measuring system.
Rieter opening line

The main task of opening room is to open the big flocks to small tufts, cleaning i.e. trash removing, fiber mixing and even feed for carding machine.

Rieter VarioSet Blowing room/Carding room
The Different machines comprising the opining line are multi functional
New features are installed such foreign matter separator to prevent mixing of different fibers in the blend
Completely automated and computerized control, vision system is enabled on-line
Blending Bale Opener

working width of 1720 mm and a machine length of 50 m, about 130 bales can be accommodated (one or two sided). The BLENDOMAT with a working width of 2300 mm even accommodates up to 180 bales. Assuming a cleaning line production rate of 800 kg/h, this allows unattended operation for two days (48 h).

(1) Control unit, (2) fiber bales, (3) working head with tooth discs, (4) Swivel tower, (5) air duct for material transport, and, 6) protective light barrier.
Waste Opener:
Process waste with high fiber content (usually from the intermediate process to spinning, up-stream of the blowroom) may be recycled by feeding into the process line around 5% of waste with the virgin fiber.
Since the waste is usually made up of fibers that have previously passed through the blowroom, it is important to keep further mechanical treatment to a minimum, so as to reduce fiber breakage.
heavy particle detection and extraction

1. The material is sucked off an automatic bale opener.
2. Fan automatically control the constant negative pressure.
3. A new guiding profile for the aerodynamic heavy particle separator.
4. The spark sensor detects burning material.
5. In the air flow separator the dusty air is separated.
6. Metal detector detects any kind of metals.
7. The diverter is actively opened and closed.
8. Fan in front of the mixer, sucks the material off here.
9. A flap feeds the separated heavy particles.
10. The two waste containers are large-size.
11. A fire extinguishing unit extinguishes the burning material in the waste container.
12. A heat sensor monitors the waste container for fire.
13. The dusty exhaust air.

Multi-Function Separator SP-Mf
The direct feeding of a cleaner of the CLEANOMAT system by an integrated mixer MX-I is an important element of the compact blowroom. This mixer produces a homogeneous and even web for feeding the cleaner. The air separation at the mixer provides additional dust removal. This combination of a cleaner with a mixer is the solution which ensures the greatest savings in floor space and energy and is the preferred solution when processing cotton.
Gentle opening is achieved by having the first beater clothed in pins angled ca. 10° from the vertical, and the remaining beaters having saw-tooth clothing, the tooth angle increasing from roller to roller (e.g. 15°, 30°, 40°). The teeth density (number of points per cm²) should also progressively increase from beater 1 to 4, depending on fineness of the fiber being produced. Importantly, the beater speeds should progressively increase from beater 1 to 4 (for example 300, 500, 800, 1200, rmin⁻¹). Hence, the mean tuft size is decreased (approximate figures) from 1 mg by the first beater to 0.7 mg, 0.5 mg and 0.1 mg by the second, third and fourth beaters, respectively. It is only the fourth beater that reaches a sufficiently high surface speed at which the finest trash particles are ejected.
Details of Cameras and Separation Nozzles

Separation of foreign fibers is optically detected. Cotton should be highly opened. This is provided directly before feeding the Material to the card. The SECURMAT SP-F is used.
Carding Process

**Introduction:**
The card is the heart of the spinning mill or Well Carded is half Spun. There is no processing stage that changes the form, assignment, condition, and composition of the cotton so strongly as the carding process does. Opened and cleaned materials arrive at the carding stage in the form of small tufts composed of entangled fibers. The purpose of the carding stage is to disentangle these tufts into a collection of individual fibers, the collection being in the form of a web of fibers, and then to consolidate this collection into a sliver. Rate of production and quality should be optimized.

**High production**
Production rate increased since 1965 from 5 kg/h to 100 kg/h

**Concept of carding machine is unchanged since 1770**

**Definition:** Carding is the action of reducing tufts of entangled fibers into a filmy web of individual fibers by working the tufts between closely spaced surfaces clothed with opposing sharp points.

**THE TASKS OF CARD**
Opening to individual fibers, Elimination of impurities, Elimination of dust, Disentangling of neps, Elimination of short fibers, Fiber blending, Fiber orientation, Sliver formation.

Three types that are of importance in the processing of:
cotton, wool and man-made fibers: 1. revolving flat card, 2. worsted card, 3. woolen card
THE REVOLVING FLAT CARD

Basic Elements of carding

Carding action

Doffing action

Revolving flats

Cotton flats strip
Types of card clothing

Taker in Flats (half rigid)

Flexible wire

Cylinder

Flats (half rigid)

Saw teeth wire
Details of carding machine

1- High volume upper trunk
2- Integrated air volume separator
3- Feed roll, electrically coupled to the feed roll of the card
4- Segmented tray to secure clamping
5- Opening roll with pins
6- Closed air circuit with integrated fan
7- Self cleaning air outlet combs.

Chute feed system

Feed system

The feed system of the card TC 03
1) A special clothing of the feed roll prevents lap formation
2) Spring-loaded feed table
3) Spring-loaded measuring lever
4) Spring elements
5) First roll of the WEBFEED unit

The deflection of all 10 spring elements are processed to become one signal for the short-wave regulation. Thus it is possible to avoid thickness variation and to feed an even web to the Licker-in system.

WEBFEED

Flats setting

Web feed

Increasing active clothing
**Drawing** is the term applied to the operation involving the doubling and roller drafting of slivers.

**Doubling** is the combination of several slivers that are then attenuated by a draft equal in number to the slivers combined, thereby resulting in one sliver of a similar count.

**Roller drafting** is the process of attenuating the count of a material using a combination of pairs of rollers.

**Principles of Doubling:**
This involves placing several slivers in parallel (usually 6 or 8) and roller drafting the combination using a draft.
Objective of Drawing

• Equalizing
  Relationship between the of ideal evenness and doubling, Drawing Ideal unevenness
• Parallelizing
• Blending
• Dust removal

The drafting system must be:
Simple in construction, Stable in design, suitable for all raw materials
Optimal control over the movement of the fibers
High precision both of operation and adjustment
Rapid and simple adjustability of rollers

Drawing frame

Operating principle

1) Can, 2) Feed roller, 3) Drafting system, 4) Guide tube, 5) Calenders, 6) Coiler and 7) Draw sliver

The drafting arrangement

Basic definitions
Features of drawing frame

- 3 over three and 4 over 3 drafting system

- Highly dynamic, digitally controlled, maintenance free direct drivers
- Comprehensive quality monitoring
- Sliver weight
- Sliver evenness
- Thick places
- Spectrogram
- Self optimizing adjustment of break draft
- Reliable sensors development
- Active lifting of top rollers during machine still stand
- Computer control with touch screen
- Infinitely variable setting of draft, break draft, sliver weight and delivery speed.

Laying of sliver

large coils is $dc / dB = 1.45$, and for small coils $dc / dB = 2.5$
Process steps that do not exist do not produce any fault and do not cost any money.

Coupling of Card to draw frame i.e. one drawing passage is a good example for open-end spinning.

In combed spinning mill, process cutting with integrated draw frame is not useful.
Integrated Draw Frame IDF

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THE COMBING PROCESS

The combing process is normally used to produce Smoother, finer, stronger and more uniform yarns
• Combing is also used for upgrading the quality of medium staple fibers
• Production coast is increased by about 1 US$/Kg

Tasks of combing:
• Elimination of precisely pre-determined quantity of short fibers
• Elimination of the remaining impurities
• Elimination of a large proportion of the neps
• Formation of a sliver having maximum possible evenness
• Producing of more straight and parallel fibers

Elimination of short fibers improves mainly the staple length. Micronaire value of combed sliver is slightly higher than that of feedstock.

Types of applications:
• Long staple combing:
  High quality cotton, containing a low proportion of short fibers
• Medium-staple combing:
  • medium cotton qualities, spun to medium (to fine) yarns of good quality at economic production costs.
• Short (to medium) staple combing mills:
  • Upgrading quality of cotton, extracting low level noil level (6 – 14%)
Methods for Preparation for Combing I

Conventional (Lap Doubling) method:

Sliver Lap (D=16...24, V=1.1 ....2) and Ribbon Lap (D=6, V=6)

- 16 to 32 are fed to a sliver lap machine, of three pairs of drafting rolls followed by two pairs of calender rolls
- Lap pf 50 to 70 g/m, width of 230 to 300 mm and diameter of 500mm and weight of to 27Kg. Draft ratio commonly is 1.5 to 2.5. Draft ratio commonly is 1.5 to 2.5. Laps from the sliver lap machine are taken to the ribbon lap machine thin sheets from the heads are led down over a curved plate, which turns at a right angles, inverts them and superimpose one upon the others
Methods for Preparation for Combing II

(Sliver Doubling): e.g. Super lap from Whitin
About 20 drawing slivers are fed to a vertical 2/3 daft system, and drafted 3 to 5x.
The laps are super imposed (width of 293 mm) through a pair of calander rolls, the batt is compressed and the lap is formed

Unilap from Rieter (drawing/ lap)
• two steps: a standard drawing process in which a number of card slivers (typically 20 – 24) are drawn Together to form a drawn sheet lap weight 50 – 70 g/m delivery speed up to 100 m/min production rate is up 360 kg/h.
  Laps of up to 25 Kg weight, 250-300 mm width
• The Unilap system is designed
• to achieve fully automatic doffing
• and transportation of laps to the combing.
The Combing Machine
The Combing Cycle 1

Step 1: Feeding
The feed roller feeds the lap forward
(a small distance 4-7 mm). The nippers are open

Step 2: Nipping
The upper nipper is lowered onto the cushion plate so that fibers are clamped between them

Step 3: Bottom Combing Action [Rotary Combing]
The bottom circular comb is now acting on the nipped fibers to remove all fibers or wastes that are not nipped
The Combing Cycle 2

Step 4: Nippers Forward/Web Return
The nippers open again and move towards the detaching rollers. Meanwhile, the detaching rollers have returned part of the previously drawn off material by means of a reverse rotation, so that a portion of the web is projecting from the back of the detaching device.

Step 5: Piecing
During the forward movement of the nippers, the projecting fiber fringe is placed upon the returned material for piecing the two ends.

Step 6: Detaching/Top Combing
The detaching rollers begin to rotate forward drawing the fiber material held by the feed roller. Before the start of the detaching action, the top comb has moved to act with its row of needles onto the fiber fringe. As the fibers are pulled through the needles of the top comb, the trailing part of the fringe which was not handled by the bottom comb is combed.

Step 7: Noil Removal
This is achieved using a rotating brush
Influence of combing operation on quality

Dependence of various quality parameters n noil. A, improvement of yarn quality %; B, Noil in %)
a) yarn strength, b) yarn evenness; ) yarn Imperfections.

Staple diagram before combing

After

Noil
The roving frame is a necessary evil
The draft needed 300 to 500
- Draw frame cans represent the worst mode of transport
- The roving frame itself is a complicated, liable to faults, causes defects
- Automation of the machine is very difficult
- Demands placed upon modern roving frame:
  - Design of simpler machines, less liable to faults; Increasing in spindle rotation rates; Large packages;
  - Automation of machine and of package transport
- Tasks of the roving frame:
  - Attenuation the sliver to a fine strand
  - A protective twist must be inserted, that the roving can be wound on a package transported
  - Roving winding makes the roving frame relatively complex winding requires in addition to the spindle and flyer, a cone drive transmission (or variable gear), a differential gear and a builder motion.
**Imparting twist:**
The flyer inserts twist. Each flyer rotation creates one turn in the roving.

**The spindle:**
The spindle is simply a support and drive element for the flyer.

**The flyer**
one of the two legs has usually been “hollow”, i.e. with a deep guide groove that is open in a direction opposite to the direction of rotation the strand has low level of twist “only protective twist”
Details of roving frame

As the flyer rotates with the centre spindle, twist is inserted into the drafted ribbon issuing from the front rollers of the drafting system, thereby forming the roving. The contact between the roving and the rim of the flyer inlet imparts an added false twist), which strengthens the roving length between the flyer and front drafting rollers, permitting a low value of real twist to be used.

the hollow spindle rotates at a higher speed than the center spindle, and the rail lifts and lowers the bobbin past the presser arm to build successive layers of roving coils and make a full bobbin. This is often referred to as winding-up by bobbin lead.

If the bobbin rotates at speed $Nb$, and the spindle at $Ns$, then the speed, $Vw$, at which the roving would be wound onto the bobbin tube is given by

$$V_w = \pi D_b (N_b - N_s)$$

where $Db = \text{the bobbin tube diameter (in meters) at the instant of winding}$
Various designs of flyer

Derive of top mounted flyer

Spindle mounted flyers Top mounted flyers Closed flyers

Automatic doffing
The American Thorp invented the ring-spinning machine in year 1828. In 1830, Another American, Jencks contributed the traveler rotating on the ring. During the last 160 years, the machine has passed many considerable modifications, but the principle of yarn forming remained unchanged. In spite of the many yarn forming introduced, the ring spinning frame will continue for some time for the following reasons: It is universally applicable, i. e. processes any material for any count, quantities.

- It delivers a yarn with optimal characteristics (regarding structure and properties).
- It is uncomplicated and easy to master,
- The know-how for operation is well established and friendly use.
- It is flexible as regards (blend and lot size.)

Basic Principle of Spinning:
- Drafting mechanism
- Consolidation mechanism
- Winding and package forming mechanism.

- The ring spinning is characterized by two main features:
  1) Continuity of fiber flow roving to yarn.
  2) Tension-controlled spinning process.
In practice, spindle speed (rpm) is used instead of traveler speed (rpm) in the above equation; this results in a slightly over-estimated value of twist because $n_{\text{spindle}}$ is slightly greater than $n_{\text{traveler}}$. The difference in speed between spindle and traveler causes the yarn to wind on the package. The increase or a decrease in twist is mainly a result of a change in the speed of the delivery roller. Thus twist affect level affect productivity.

Yarn count ranges: 6’s to 250’s
Recent developments in ring spinning machines

- The “standard” for judging yarn quality;
- Improvements in recent years:
  - higher traveler velocity,
  - automatic doffing,
  - longer machines
  - link winding,
  - splicing,
  - smaller ring sizes
  have interacted to yield cumulative benefits
  (potential spindle speed increase from 10,000 to 25,000);

- Longer machines (1488 spindles available)?
- High drafts?
- “Heavy roving” or “light weight sliver” feed?
- Higher traveller speed (or alternative)?
- Compact Spinning?
- Spindle ID# used with defect detection at winding?
Ring and traveller

Key Main Machine Variables
- Balloon Control
- Lift (balloon height)
- Spindle Speed
- Ring/Traveller
Suspended disk with yarn go through the eye

CERATWINE
Ceramic ring with claimed advantages associated with:
- wear resistance;
- break-in;
- lubrication;
- yarn quality;
- productivity.

HOWA
Individual Spindle Drives,
Rotating Rings

Stator part of the magnetic system
Modification of Ring Spinning

1 – Compact Spinning
2 – Siro Spinning System
3 – Solo Spun
4 – Core Yarn Spinning
Principle of Compact Spinning

1) Draft arrangement
   1a) Condensing element
   1b) Perforated apron

2) Yarn Balloon with new Structure
3) Traveler,
4) Ring
5) Spindle,
6) Ring carriage
7) Cop,
8) Balloon limiter
9) Yarn guide,
10) Roving

E) Spinning triangle of compact spinning
Compact spinning is essentially a ring spinning with additional feature to eliminate or reduce yarn hairiness in the so called condensing zone. This is done to improve surface integrity and increase yarn strength. The spinning triangle is reduced or eliminated to condensing the fibers in a narrow path. The close and parallel device is closely situated before the twist imparting. There are two basis systems, air flow or mechanical one. Compact spinning offers near perfect structure by applying air suction or magnetic system for condensing the fibers before twisting, thereby eliminating of the spinning triangle. Compact spinning has been shown to significantly improve yarn tensile properties and reduction in yarn hairiness. Both characteristics are crucial for performance in downstream manufacturing operations. Compact spinning was introduced as a trial system in 1995.
Factors Affecting Compact Spinning

Condensing zone is heart of compact spinning.

Fiber length, fineness and stiffness are factors affecting the fiber transport by air flow, this necessitates apron moving to be less than delivery rollers (condensing).

Changing the perforation width increases air velocity.

Smooth guides gives better twist propagation.

Hairs of less than 2mm, give better cover factor,

Hairs> 3 mm are Problematic for processing
The Com4 system was conceived by Dr. Ernst Fehrert, the founder of friction spinning. The condensing system of Rieter consists of a perforated drum, just situated after the double apron arrangement and works simultaneously as a delivery roller of the draft system. On the perforated drum, two pressure are situated. The first roller acts as nipping point of the draft system, while the second roller works as twist stop to prevent twist escaping to the condensing zone. The fiber bundling occurs through the suction zone, which is found inside the perforated roller, and in the region between the two pressure rollers. Under this air suction, fibers merging from the delivery nip of the drafting unit are held against the drum surface and moved at the same circumferential speed as the drum surface. In ATME 2000 Rieter south Carolina introduced an innovation in the air guide providing more fiber compactness both against the drum and in lateral direction. This innovation is known as K44-C.om4.
Suessen compact system consists of a tubular profile, subjected to a negative pressure and closely embraced a lattice apron. The delivery top roller fitted with rubber cots, presses the lattice apron against the hollow profile and drives the apron, at the same time forming the delivery nipping line. The tubular profile has a small slot in the direction of the fiber flow, which commences at the immediate vicinity of the front roll nipping line in the region of the delivery nipping line. This creates an air current through the lattice apron via the slot towards the inside of the profile tube. The air current seizes the fibers after they leave the front roller nipping line and condenses the fiber strand, which is conveyed by the lattice apron over a curved path and transported to the delivery nipping line. As the slot, being under negative pressure, reaches right up to the delivery nipping line, the fiber assembly remains totally compacted. This results in a substantial disappearance of the spinning triangle.
The system of Zinser, is characterized by extending the draft system by a double roller. A perforated apron is moved over the upper roller, where the suction profile element is found. Between the delivery roller and the perforated apron, the condensing zone occurs. The roller pair is working in a classical way as in ordinary draft system.
RoCos, the Rotorcraft compact spinning system

The rocos spinning system avoids using air with its complexity and expanse. It works without air suction and uses magnetic-mechanical principle only. Rotorcraft’s magnetic compacting system is claimed to produce 80% less hairiness, 10% greater strength than systems based on pneumatic compacting. Twin RoCos application for siro spun system. Rocos for core spun yarn and denim and other coarser yarns.
Siro Spun Twofold Yarn

The SiroSPUN™ process adapted some of the self-twist discoveries of CSIRO to the ring spinning technology of the worsted system, and combined spinning and doubling in the one operation. The technology maintains two separate strands during the spinning process, and this allows a number of fiber-binding mechanisms to operate before the strands are twisted about each other. An important aspect of the SiroSPUN™ system is a simple device to break out the remaining strand if one of the strands should be accidentally broken. SiroSPUN™ is used also for short staple fibers as cotton and blends. The roving strands, which are drafted parallel, are combined after passing the front rollers at the exit from the drafting system, with some twist being produced in the individual strands right up to the nip point. Once past the front roller of the drafting system, the two strands are combined producing a twofold-like yarn. The yarn has uni-directional twist like a singles yarn but the fibers are bound sufficiently for the yarn to survive weaving.
Multi folded Threads

To achieve higher quality requirements, multi folded threads are manufactured on compact yarns twisted together.
Core Spun Yarns are produced on Ring Spinning machines or Compact R.S Machines. Essentially is adapting the tension of the filament yarn. Also the percentage of Core/sheath determine the yarn characteristics.
Different Types of Multi Folded Yarns

Siro Yarn    Single yarn    compact Plied    Multi Plied compact    R.S.Plied
Solo spun

SOLOSPUN yarns are made using a small patented roller attachment which simply clips onto the shaft of the front drafting roller. It does not affect the normal operation of the machine and is compatible with auto-doffing mechanisms. Roller life is expected to be more than six months in a typical production operation. SOLOSPUN units are easily fitted or removed from the spinning frame. Easily set up on most spinning frames. Fits all drafting arms. Fits 100 spindles in one hour. Independent adjustment of roller position and pressure. Tenacity, extensibility and evenness of SOLOSPUN yarns are not much different from conventional two-fold weaving yarns. Yarn cross-section is more circular than two-fold yarn so SOLOSPUN yarn is a little harder and less bulky. SOLOSPUN yarns are less hairy than conventional singles yarns because the individual fibers are bound securely into the body of the yarn at several points along the fiber length. Fiber ends are far less likely to be rubbed up as 'hairs'. Woven cloth has a smoother finish and cleaner appearance. 55% cheaper

SOLOSPUN yarn is a singles worsted yarn which can be woven as a warp without plying, sizing or any other yarn finishing treatment. To achieve this, the fiber geometry within the yarn structure is modified so that all the fibers are securely bound within the yarn. The resulting SOLOSPUN yarn has a very high level of resistance to the abrasive forces imposed by the weaving process.
Non-Conventional Spinning Systems

1 – Open end Spinning

2- Core Spun Rotor Spinning
   (Rotona)

Dref spinning system

3 – Air Jet Spinning
   Murata Air Jet Spinning
   Murata Vortex Spinning
In rotor spinning, the drafting mechanism consists of three main operations: (i) mechanical opening using an opening roll, (ii) air drafting using an air stream and transporting duct, and (iii) doubling mechanism. The mechanical drafting is achieved using a toothed opening roll. In order to minimize fiber disorientation, the airflow in the duct should have a velocity exceeding that of the surface speed of the opening roll. To obtain such an airflow, the inside of the rotor is run at a vacuum which may be achieved by designing the rotor with radial holes to allow the rotor to generate its own vacuum (self-pumping effect).

\[
\frac{n_{df}}{n_{yf}} \cdot \frac{\text{tex}}{V_f} = \frac{n_{yf}}{V_y} \cdot \rho
\]

Thus,

\[
\frac{n_{yf}}{n_{df}} = \frac{V_f}{V_y}
\]
Rotor-Yarn Structure:

The low tension, and the subsequent lack of torque control results in a structure that is unique for rotor-spun yarns. In general, this structure consists of a core, which is fully twisted (similar to ring-spun yarns), and an outer-layer that is partially twisted. In addition, some fibers called "belly or belt fibers" are randomly deposited on the yarn surface. These fibers result from the interfacing between the processes of laying fibers on the rotor-collecting surface and the peeling off of the yarn from the collecting surface (see previous Figure). This interface occurs once per each rotor revolution. These bellybands are laid at these times; they may take a clockwise or an anti-clockwise direction.

As a result of the partial true twist in rotor-spun yarns, the yarn has a natural curling (or snarling) tendency, similar to ring-spun yarns. The major difference, however, lies in the fact that in rotor-spun yarn, the natural torque resulting from the real twist is partially balanced by a torque caused by the wrapping effect of the belly bands.

The curling tendency can be determined by the residual twist or the difference between the measured yarn twist and the nominal twist ($\Delta T$). The assumption made here is that the higher the value of $\Delta T$, the lower the curling tendency, and the higher the number of bellybands or the higher the level of their tightness. Typical $\Delta T$ values may range from 10% to 40%. Using this value, Artzt et al examined the cause and effect of curling tendency and made the following important points:

- The main spinning parameters influencing the twist difference (or curling tendency) are rotor speed and rotor diameter (or the ratio of rotor diameter to fiber length, $d_R/FL$).
Important Fiber Properties in Rotor-Spinning I

• From the above discussion, which clearly point at many of the fiber properties that are important in rotor spinning. Perhaps, the most important fiber property is fiber fineness. This is due to the structural limitations of rotor-spun yarn discussed earlier, which require more fibers per yarn cross-section to compensate for the loss of fiber contribution to yarn strength. For the same reason, fiber strength is another important characteristic. Indeed, the introduction of rotor spinning has greatly shifted the attention to these two properties.

• With regard to fiber length, rotor spinning has altered the traditional view that ring spinning had established for many years; that is, fiber length is the most important fiber property. The reason for this is that long fibers are likely to be more disturbed by turbulent airflow than medium or short fibers.

• Some early studies revealed that long fibers result in lower rotor-yarn strength compared to that of ring-spun yarn. A high level of short fibers will result in low yarn strength and excessive ends-down.
Important Fiber Properties in Rotor-Spinning II

• They also revealed that the longer the fiber length, the higher the C.V% evenness of rotor-spun yarns compared to that of ring yarns. However, the key length parameter in rotor spinning is short fiber content. A high level of short fibers will result in low yarn strength and excessive ends-down.

• In addition to the above fiber characteristics, rotor spinning has set new standards for the level of fine trash and dust in the fiber strand. This is due to the fact that trash content is the primary cause of spinning ends-down. Values of trash percent of less than 0.2% in the fed sliver are recommended for rotor spinning.
Core Open-End Spun Yarns (Rotona)

The filament entered to the rotor through the shaft. The fibers forming the Open end yarn wraps around the filament, which has no twist.

It is also important to keep the tension at a constant value. The yarn produced can be compared with the classical ring spun core spun yarns.

The production speed is up to seven times as ring spinning.

Better elasticity of yarns

The counts produced Ne. 5-30

The yarns can be used in sport wears and in rubber industry.
The classical air-jet spinning uses the principle of false-twisting to produce a yarn of uniquely different structure from that of ring or rotor spun yarn. While ring-spinning is characterized by a continuity in the fiber flow, and rotor spinning is characterized by a complete separation of fibers prior to spinning, air-jet spinning exhibits an intermediate feature in which part of the fiber strand flows continuously and another part is separated.
Air-Jet Spinning

The classical air-jet spinning uses the principle of false-twisting to produce a yarn of uniquely different structure from that of ring or rotor spun yarn. While ring-spinning is characterized by a continuity in the fiber flow, and rotor spinning is characterized by a complete separation of fibers prior to spinning, air-jet spinning exhibits an intermediate feature in which part of the fiber strand flows continuously and another part is separated.

Similar to rotor spinning, the input strand in air-jet spinning is a drawn sliver, which may be carded or combed. Drafting is achieved using multiple zone roller drafting. The consolidation mechanism in air-jet spinning is achieved by blowing out compressed air through air nozzle holes of about 0.4mm diameter to form an air vortex. The air revolves at high speed (more than 3 million rpm). Thus, the rotating element in air-jet spinning is air. This results in a rotation of the fiber bundle at a rate typically ranging from 200,000 to 300,000 rpm.

The figures shows the air-jet spinning system produced by Murata. Two air nozzles are used: nozzle 1 may be called the "end-opening" nozzle, and nozzle 2 may be called "the twisting nozzle". These names imply the specific functions of these two nozzles as explained below.
The Principle of Air-Jet Spinning

To simplify the principle of the consolidation mechanism, suppose that only nozzle 2 is at work and that air is rotating in a clockwise direction. This action will result in twisting the fibers fed to the nozzle to form a yarn. When the yarn leaves the nozzle, untwisting takes place. Thus, with one air nozzle, a case of pure false twisting is achieved. In the actual machine, another nozzle (nozzle 1) is positioned between the nip of the front roller and nozzle 2, with air rotating in a counterclockwise direction. Thus, the two nozzles apply air rotation in two opposite directions. However, the air in nozzle 2 has a higher rotational speed than nozzle 1 to avoid complete false twisting. The fiber strand, coming out of the delivery roll, forms a spinning triangle similar to that in ring spinning. However, fibers in this triangle are under much less tension than those in ring spinning. In other words, the fibers in the triangle are comparatively loose. The air rotation of the fiber strand in the two nozzles results in ballooning the fiber bundle between the front roller and nozzle 1, and in turning the balloon in nozzle 2. This balloon has no significant tension, which results in some fibers being raised from the bundle surface and move freely. This process is called "the end-opening" action. Thus, the opposite rotation of air in nozzle 1 assists in detaching some fibers from the input strand.
Main Parameters affecting Air Jet Spinning

The main spinning parameters in air-jet spinning are as follows:

• The main draft ratio \( \left( \frac{V_{\text{Front Roller}}}{V_{\text{Second or Apron roller}}} \right) \); this varies from 15 to 50, but generally runs from 30 to 40.

• Distance between the first nozzle and the nip of the front roller, \( k \).

• The feed ratio \( \left( \frac{V_{\text{Front Roller}}}{V_{\text{Delivery}}} \right) \); this ranges from 0.98 to 0.99

• Spinning speed (up to 300 m/min)

• Air pressure in nozzle 1 (typically, 2-5 kg/cm²)

• Air pressure in nozzle 2 (typically, 2-5 kg/cm²)
Developments in Air-Jet Spinning

Air-jet spinning machinery may be divided into two main types: single end spinners, and twin spinners.

In the twin-spinner, two slivers are fed to the same drafting system where they are drafted. The drafted strands are then fed to two different spinning units (air nozzles) to produce two single yarns. These two yarns are then doubled together onto a take-up package suitable for two-for-one twisting system. The twin spinner is therefore suitable for applications where plied yarns are required. In comparison with ring spinning, the twin spinner eliminates roving, winding, and doubling machinery.
Murata Vortex system
Details
The Murata Vortex Spinning (MVS) system was introduced in 1998 under the commercial name “MVS851”. This system uses the principle of air vortex to produce a yarn similar in structure to that of the ring-spun yarn. The idea of this development is to improve two important features of the jet-spinning system: (i) the number of wrapper fibers, and (ii) the length of wrapper fibers. Accordingly, MVS should be considered as an inevitable and natural evolution of the MJS system. The driving force of MVS development was to produce 100% cotton yarns on jet spinning.

As in the conventional MJS, a finished drawn sliver is directly fed to a roller drafting system, similar to that used on the MJS system. The drafted fibers are passed through an air-jet nozzle and hollow spindle. Fibers exiting the nip of the front rollers are sucked into a spiral orifice at the entrance of the air nozzle, and they are then held together more firmly as they move towards the tip of a needle protruding from the orifice. At this stage, the force of the air stream twists the fibers. This twisting motion tends to flow upwards. The needle protruding from the orifice prevents this upward propagation (twist penetration). Therefore, the upper portions of some fibers are separated from the nip point of the front rollers but they are kept open.
Comparison between MJS and MVS

changing the system from "two dimensional" to "three dimensional" offers the possibility of dramatically increasing the number of edge fibers and hence the number of wrapper fibers. There is non twisting section, twist of certain level are given to the entire yarn from the center to the surface of the yarn. The yarn thickness is uneven. Twisting is concentrated at the finer section, with twisting is loose at the thicker section and hairiness tends to come out.
As indicated earlier, the twisting mechanism in friction spinning is achieved by feeding the fibers into the nip of two spinning (friction) drums, which rotate them to form the yarn. The resulting twist, however, does not correspond to the ratio of yarn diameter to drum diameter because of the slippage effect, which can lead to a loss of up to 60%. The problem associated with fiber landing discussed above adds to the problem of twist loss by introducing a great deal of twist variability.

DREF 3000, the only spinning system to offer the production of special high-tech, core and multi-component yarn constructions in the NM 0.5 - NM 25 (cc 0.3 - cc 14.5) yarn count ranges in a single, straightforward working process.
Yarn Unevenness and Yarn Faults
Yarn Cleaning
Yarn Irregularity and Faults

- Yarn irregularity affect twist distribution in yarn (thick places have less twist)

- Yarn irregularity mainly affect fabric appearance and many other properties. Uster evenness tester is the most popular instrument used for evaluation of irregularity characteristics.

- Irregularity can be defined as the continuous variation in mass per unit length and expressed as coefficient of variation CV, where faults are discrete function and are expressed as number of faults per unit length. Faults may occur frequently and known as imperfections (thick, thin places and neps), or occur seldom. These have longer length (slubs, fly, piecing, long thick or thin places, snarls and loops …)

- Analysis of yarn irregularity can be provided on the base of descriptive statistics methods (CV% values) or on the basis of time series and signal analysis principles.
Mass evenness, capacitive measuring principle

A high-frequency electric field is generated in the sensor slot between a pair of capacitor plates. If the mass between the capacitor plates changes, the electrical signal is altered and the output signal of the sensor changes accordingly. The result is an electrical signal variation proportional to the mass variation of the test material passing through. This analog signal is then converted into a digital signal, stored and processed directly by the USTER® TESTER computer. The capacitive measuring principle is very reliable and has a good signal stability. With this measuring principle not only yarns, but also rovings and slivers can be tested. The output contains a large amount of information which cannot be provided by the spectrogram, by the U/CV-value or by the counting of imperfections. The diagram is especially valuable for the detection of the following faults: Seldom-occurring events, and long-term variations.
Mass diagram of different cut lengths

Normal diagram: The mass diagram directly shows the mass variation of the test material in graphical form. A normal diagram contains the entire information from which the other test results (CV, Spectrogram, IPI, etc.) are derived.

1 cm cut length diagram, scale ± 100%

10 m cut length diagram, scale ± 20%

1 m cut length diagram, scale ± 20%
Determination of frequently occurring yarn faults

- Yarns spun from staple fibers contain "imperfections" which can be subdivided into three groups: **Thin places, Thick places, Neps**
- Faults are due to: a) **raw material** or b) **an imperfect processing**
- Thick places and thin places, referring to those, which can be classified under the term "imperfections", exceed -30% or +35% with respect to the mean value of yarn cross-sectional size, "neps" can overstep the ± 100% limit.
Imperfection Indicator IPI
Thin, thick and neps

- **Thin places:** The USTER® 4 allows the following sensitivity thresholds for thin places: -30% / -40% / -50% / -60%. Every time the selected limit is exceeded, a thin place is counted.

- **Thick places** The USTER® 4 allows the following sensitivity thresholds for thick places: +35% / +50% / +70% / +100%. Every time the selected limit is exceeded, a thick place is counted.

- **Definition of neps:** The USTER® 4 allows the following sensitivity thresholds for neps: +140% / 200% / +280% / +400%, reference length of 1 mm. Every time the selected limit is exceeded, a nep is counted.
Huberty’s index of irregularity:

\[ I = \frac{CV_{\text{eff}}}{CV_{\text{lim}}} \]

- \(CV_{\text{eff}}\): measured (actual) value of unevenness
- \(CV_{\text{lim}}\): calculated ("limit") value of unevenness
Theoretical background:

Cutting and weighting
Total length $L_c$, divided to $N$ portions. In each portion of length $L$ are created local elements of length $L_{ij}$.
Each portions and elements are weighted.
Weights are denoted $W$, $W_i$, $W_{ij}$.
Theoretical background:

Variance within portion

Total variance division

\[ s^2_c = \frac{1}{N} \sum_{i=1}^{N} \left( \frac{1}{N_i} \sum_{j=1}^{N_i} [W_{ij} - \bar{W}]^2 \right) \]

\[ \frac{1}{N_i} \sum_{j=1}^{N_i} [W_{ij} - \bar{W}]^2 = \frac{1}{N_i} \sum_{j=1}^{N_i} [W_{ij} - \bar{W}_i + \bar{W}_i - \bar{W}]^2 = s^2_{V_i} + (\bar{W}_i - \bar{W})^2 \]

\[ \frac{1}{N} \sum_{i=1}^{N} [s^2_{V_i} + (\bar{W}_i - \bar{W})^2] = \frac{1}{N} \sum_{i=1}^{N} s^2_{V_i} + s^2_B = s^2_V + s^2_B \]

\[ s^2_V = \frac{1}{N} \sum_{i=1}^{N} s^2_{V_i} \]

Variance within portion

Total variance is sum of external (between portions) and internal (within portions) Variances

\[ s^2_C = s^2_V (L) + s^2_B (L) \]
Effect of tarb mass irregularity on the fabric appearance

Mass unevenness

CVm = 11.5%  CVm = 14.7%  CVm = 22.6%
Measurements of Mass unevenness

- Normal test
- Inert test (larger cut lengths – virtual extension of electrodes length)
- Modern apparatus: – variance length curve. $CV_B(L)$ vs. $L$. 
- Deviation rate curve
Uster Statistics

Cumulative frequency (portion of companies producing yarns with CV less or equal to a given value (here 50%)
The approach based on the percentage of mass deviation exceeding or falls below a certain limit is used for characterization of yarn unevenness. The deviation rate $DR(b)$ expresses a portion of the length of yarn that is not within the limits.

The $DR(b)$ has the form:

$$D(i) = 0 \quad \text{if } \bar{y} - b < y(i) < \bar{y} + b$$

$$DR(b) = \frac{\sum_{i=1}^{N} D(i)}{N} \times 100 \quad \text{elsewhere}$$

The $\text{DR-plott}$ is then dependence of $DR(b)$ on $b$.
The DR(b) is closely connected with probability for which is random process y(i) exceeding of value b
Alternatively, the deviation rate

\( DRR(b) \) corresponding to the portion of the length

of yarn that is above limit and deviation rate

\( DRL(b) \)

expressing a portion of the length of yarn that is below limit can be computed. From \( DRR(b) \) and \( DRL(b) \) the DR -mass histogram in logarithmic scale of \( DR \) can be created. Into this graph the histogram of normal distribution is superimposed.

This graph is useful for comparison of unevenness at various cut lengths \( L \). Standard selection is \( L = 0.01 \) m, 1.5 m and 10 m.
The Fast Fourier Transformation is used to transform from time domain to frequency domain and back again. There are many types of spectrum analysis, Power spectrum, Amplitude spectrum, Auto regressive frequency spectrum, moving average frequency spectrum, ARMA spectrum.
Autocorrelation R(1)

Autocorrelation coefficient of first order R(1) can be evaluated as

\[ R(1) = \frac{\sum_{j=1}^{N-1} (y(j) - \bar{y})(y(j+1) - \bar{y})}{s^2(N-1)} \]

Roughly, if R(1) is in interval

\[-2/\sqrt{N} \leq R(1) \leq 2/\sqrt{N}\]

Simply the Autocorrelation function is a comparison of a signal with itself as a function of time shift. Also could be considered as the correlation between y(x) and y(x+u), where u is the lag (distance)
Practical Uster Unevenness

Irregularity: Continuous variation in mass expressed in CV% or U%.

Count Variation: Variation in mass over length measured by weighing 100 m or 120 yards.

Imperfection: Sporadic thin or thick places or neps. Measured as a number per 1000 m of yarn

Seldom occurring defects: infrequent large thick places or long thin places, measured on Uster classimat system and expressed in number/ 100000 m.
Practical Uster Unevenness

Ideal Spectrum: Spectrum calculated from fiber distribution. It was found that maximum amplitude is given at about 2.5 to 3 (2.8) * mean fiber length

Mechanical fault caused by machine

Draft waves due to bad setting Of the draft arrangement
Types of faults in short spinning process

Foreign matter: This type of fault is easy to explain. In most cases it refers to non textile material which is already available in the bales or is colored at some during further processing.

Fiber Entanglement:
These entanglements are found primarily in yarn containing mad-made fibers. They consist of fibers which are bonded together and in many cases are combined with collection of finishing agents.

Synthetic un-drawn fibers: These are fibers which are stuck together in the form of single fibers or fiber groups.
Effect of mechanical faults of fabric

Cotton yarn: An eccentric front roller caused a periodic fault identical in length with circumference of roller
Yarn Faults Classification
USTER® CLASSIMAT QUANTUM, is used for checking cleared and un-cleared yarn, providing perfect classification of thick and thin places, as well as checking infrequently occurring yarn defects and, recently, foreign fibers in the yarn. You can determine the optimal setting parameters for yarn clearing, analyze new material and competitors’ products – and improve the quality and value of your yarns. Also, recognition and classification of foreign fibers and vegetable matter • Direct comparison with production data of the USTER® QUANTUM • Compatible with USTER® CLASSIMAT 2 and 3
The introduction of the USTER® CLASSIMAT 1 in 1968 revolutionized the checking and determining of yarn quality in production and commerce. The later models CLASSIMAT 2 and CLASSIMAT 3 optimized and extended the application possibilities. Today, the USTER® CLASSIMAT is used in yarn classification system which is accepted worldwide.
Fully equipped system with pre-installation of all required software applications, consisting of capacitive basic measuring head, foreign fiber sensor (optional), control unit, PC, color printer, flat screen, keyboard and mouse.

**USTER CAY® (Computer Aided Yarn clearing)**
Graphic classification of all yarn defects in the thick and thin place matrix and of foreign fibers in the foreign fiber classification.
Simulation of all yarn defects and their effect, either in yarn (such as USTER® Simulation of all yarn defects and their effect, either in yarn (such as USTER GRADES), in woven or in knitted fabric according to choice.
GRADES), in woven or in knitted fabric according to choice.
Yarn cleaning System

Elder systems of Classimat, require installing the cleaning limits using the so called Correlator find the optimized yarn faults to be cleaned due to Winding. The newer systems find automatically the optimized cleaning limits.
Dual light beams perpendicular to each other, is used. This design reduces shape error caused by irregular yarn cross-sections. The variation in yarn diameter is measured by the fluctuation of the light intensity or shadow on the sensor caused by the beam of light passing across the yarn cross-section.
The system operates with the principle of absolute optical measurement using infra-red light beam. The measuring system compares the yarn diameter with the constant reference mean and records variations in length and diameter. The yarn testing module uses an infrared light sensor operating with a precision of 1/100 mm over a measuring field length of 2 mm. The speed of measurement may be selected on a graduated scale between 100 and 400 m/min.
Keisokki KET-80 and Laserspot LST-V [4] are two types of evenness testers based on capacitive and optical measurement principles, respectively. The Laserspot evenness and hairiness instrument uses laser beam and is based on the Fresnel diffraction principle. With this principle the yarn core is separated from hairs, allowing yarn diameter and hairiness to be measured at the same time.
QQM-3 yarn quality analyzer

1- Measuring head  2- PSION work about terminal,  3- Battery charger  
4- TTL – RS232 converter, 5- RJ-6 Cable

- 2 Optical sensors of 2mm width, equipped with infra diodes and transistors positioned in the direction of yarn delivery, 10 mm apart, sampling rate is limited to 300 m/min (capability 600 m/min) because “hand held” TTL is slower.
The yarn diameter is measured optically while the yarn is passing between an optical sensing head and a light source. For simplicity, we will call the Optical Sensing Head as the “Camera”. The camera has 2048 light receiving elements, which we refer to as Pixels.

Light is projected on one side of the yarn and is either blocked by the yarn or received by a pixel in the CCD array. The pixels that receive light are considered Light Pixels while the ones that are not receiving light are called Dark Pixels.

The computer calculates the yarn diameter as the distance between the first dark pixel and the last dark pixel, the figure.

The maximum value of D is 6 mm, which is also the maximum yarn diameter that can be measured by this system.

The YAS software reports the yarn diameter value in millimeter, and 1 mm = 308 pixels.
Yarn winding