LESSON 2    PROPERTIES OF FIBRES

STRUCTURE

2.0   OBJECTIVES

2.1   INTRODUCTION

2.2   A PARAMETER TO CHARACTERIZE QUALITY AND SIZE OF FIBRES

2.3   PROPERTIES OF FIBRES
   2.3.1   PHYSICAL PROPERTIES
   2.3.2   CHEMICAL, BIOLOGICAL AND OTHER PROPERTIES

2.4   ASSIGNMENTS
   2.4.1   CLASS ASSIGNMENTS
   2.4.2   HOME ASSIGNMENTS

2.5   SUMMING UP

2.6   POSSIBLE ANSWERS TO SELF-CHECK QUESTIONS

2.7   TERMINAL QUESTIONS

2.8   REFERENCES

2.9   SUGGESTED FURTHER READING

2.10  GLOSSARY


2. PROPERTIES OF FIBRES

In the previous lesson, you were introduced to textile fibres and filaments. In this lesson the various properties of fibres will be described. In the third and final lesson of this unit, you will learn how to identify different fibres.

2.0 Objectives

After going through this lesson, you will be able to:

- Understand why fibre properties are important
- Know about the parameters such as “Denier”, “Count” etc., which are related to the size of fibres.
- Understand the various physical (including mechanical) properties of different fibres.
- Gain an understanding of some biological and chemical properties of fibres.

2.1 Introduction

Knowledge about the properties of fibres, yarns and fabrics is essential as it not only helps the manufacturers make appropriate fabrics for specific applications but also helps the consumer choose the right fabric to suit specific needs. A fabric must ultimately satisfy the needs of the consumer. The consumer is not concerned with what goes into or how a fabric is made. He is concerned primarily with durability, comfort and aesthetic appeal of the fabric. The fabric producer, however, must be aware of the consumers’ requirements.

Fabrics are made mostly from yarns and sometimes from fibres directly. In any case, the yarn characteristics are determined mainly by the characteristics of the fibres, for example, the finer the fibre, the more flexible it would be, resulting in higher yarn flexibility.

Cotton fibres are available in different staple lengths. Yarns are produced from these staple fibres by putting them parallel to each other and then twisting them to form a continuous yarn. This process is known as spinning and forms the subject matter of Lesson 4. The term spinning was used earlier in Lesson 1 for the process used for manufacturing filaments. This must be kept in mind whenever one comes across the term and if the context in which it is used is kept in mind, there would be no room for confusion. The fibres of long staple lengths (2.5 to 6.00 cms) produce smoother and stronger fabrics as cotton fibres of long staple lengths are finer, stronger and also more flexible than fibres of short staple length. These fabrics are of course more expensive than those produced from yarns made from short staple length cotton fibres (1 to 2.5 cms).
In the case of wool, the situation is different. The length of wool fibres is about 5 cms for finest wool and 35 cms for the longest and coarsest wool. Wool fibres also vary greatly in their fibre diameter, ranging from about 14 \( \mu \text{m} \) (micrometer) for the finest wool to more than 45\( \mu \text{m} \) for the coarsest wool. Silk is available in the form of continuous filaments that are about 1.0 km in length.

All man-made fibres like viscose rayon, nylon, polyester and acrylic are produced in continuous lengths. However, when these fibres are to be blended with cotton or wool fibres or when spun yarns are to be produced from man-made fibres, they are cut into shorter lengths which may be 3 to 6 cm, when required for blending with cotton and 7 cm to 24 cm when required to be blended with wool.

### 2.2 A Parameter to Characterize Quality and Size of Fibres

Materials are generally sold by weight, volume or length. In the case of textile fibres, these parameters are considered inadequate as a composite measure of quality and size. We have already seen that while long cotton fibres have superior properties, the reverse is the case with wool fibres. However, it has been observed that generally the finer the fibre, the better its properties. This suggests that a composite measure for fibres must include fineness or coarseness as a factor.

Many years ago, silk traders in Italy devised a unique measure for textile fibres which they named as ‘Denier’. Denier is a number which is equal to the weight in grams of 9000 metre long filament. For example, if a 9000 metre long filament weighs 5 grams, then its denier is 5. It may be noted that this is a direct measure as thin fibres will have low denier and thick fibres will have high denier. The measure is now extensively used for man-made fibres also. Fine silk and fine cotton have deniers close to 1 while fine wool has a denier of 4. The coarser varieties of these fibres sold have deniers of 6 for silk, 4 for cotton and 20 for wool.

Cotton traders have traditionally used a different measure which is known as ‘count’. Like denier, it is also a number but unlike denier, count represents the number of 840 yard hanks of cotton yarn in one pound of cotton. For example, if 20 hanks weigh 1 lb., then the yarn count will be 20. If the yarn is thin, the count will be more and thus it is an indirect measure. A single yarn of 20 count will be 20s (20 single) and if 2 or 3 yarns each of 20 count are twisted together to form a 2 or 3 ply yarn, it will be called 2/20 or 3/20. For wool, a similar measure is used but the hanks are of 256 yards each while for worsted, the hanks are 560 yards long.

It would be obvious from the above discussion that count and denier will be related. For example, it may be easily shown that cotton count \( \times \) Denier = 5315. We will see later on that denier is a very useful number and is of particular assistance in characterizing mechanical behaviour. It is worth recalling that denier represents linear density (gram/9000 metre) and this must be kept in mind when using this parameter.

**Self-check Questions**
1. State whether the following statements are true or false:
   i) All man-made fibres are short length fibres. True / False
   ii) Silk is the only natural fibre having a continuous length. True / False
   iii) Finer the fibre, higher is its Denier. True / False
   iv) If the yarn is thick, the count will be high. True / False
   v) Fibres of short length produce smoother fabric. True / False

2. What is the basic difference between staple fibres and filaments?

**Activity**

1. Collect 10 different types of sewing threads and characterize them in terms of ply, count etc.

---

**2.3 Properties of Fibres**

The properties of textile fibres can be classified into two categories:

1. Physical properties, which are further classified as under:
   i) Mechanical properties
   ii) Moisture absorption characteristics
   iii) Electrical properties
   iv) Thermal characteristics and
   v) Optical characteristics

2. Chemical/biological properties

Optimum levels of properties are essential not only during the service life of the textile product but also to meet processing requirements, particularly during spinning, fabric manufacturing and chemical processing.

---

**2.3.1 Physical properties**

Let us now take up the physical properties one by one.

i) **Mechanical Properties:** From the service and utility point of view and also from the processing point of view, mechanical properties are perhaps the most
relevant, because they include important parameters like breaking strength, breaking elongation, elastic recovery and toughness. One of the most-performed tests on textile fibres, yarns and fabrics is the tensile stress-strain test and in view of its importance, it will be briefly described.

To study the stress-strain behaviour of a textile fibre, the fibre is held between two jaws in a tensile tester and is extended by moving one of the jaws at a controlled rate and the load required to extent the sample is recorded on a chart paper along with its elongation as the sample elongates till it breaks. The load elongation curve so generated has to be converted to a stress-strain curve so that the data is independent of sample dimensions. Since the cross-sections of a number of fibres may not be circular, the most convenient way to do this is to divide the load by the fibre denier and quote the stress in gram force per denier, which is termed specific stress.

The stress-strain curves of the three major natural fibres are of the man-made fibres are shown in Figs. 2.1a and 2.1b respectively. The end points of the curves indicate the breaking stress and the breaking strain. Among natural fibres, wool shows considerable extension before breaking while cotton extends much less. Wool has low breaking strength compared to silk and cotton. Amongst the manmade fibres, polyester (PET) and nylon 66 fibres have high breaking strength compared to acrylic and rayon fibres.

Another useful mechanical parameter that can be obtained from the stress strain curve is the initial modulus which is estimated from the initial slope of the stress-strain curve. Initial modulus or stiffness is the resistance offered by the fibre to initial deformation and is defined as initial modulus = stress/strain at very low strain. In table 2, a summary of the mechanical parameters for different fibres is given. The values cover a range rather than a single value.

<table>
<thead>
<tr>
<th>Fibre</th>
<th>Initial Modulus (gf/denier)</th>
<th>Breaking Stress (gf/denier)</th>
<th>Breaking Extension (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cotton</td>
<td>45 — 75</td>
<td>2.0 — 5.0</td>
<td>5.6 — 7.1</td>
</tr>
<tr>
<td>Wool</td>
<td>25 — 35</td>
<td>1.2 — 1.5</td>
<td>29 — 43</td>
</tr>
<tr>
<td>Silk</td>
<td>35 — 135</td>
<td>2.0 — 5.0</td>
<td>10 — 40</td>
</tr>
<tr>
<td>Viscose Rayon</td>
<td>15 — 40</td>
<td>1.5 — 3.3</td>
<td>15 — 30</td>
</tr>
</tbody>
</table>

Fig. 2.1a Stress-strain curves for natural fibres

Fig. 2.1b Stress-strain curves for man-made fibres

Table 2.1
Mechanical Properties of Major Fibres
Nylon 66  |  22 — 40 |  3.3 – 6.7 |  20 – 30
Nylon 6   |  17 — 40 |  3.3 – 6.7 |  20 – 40
Polyester (PET) |  55 — 90 |  3.0 – 7.2 |  15 – 55
Acrylic   |  20 — 50 |  2.2 – 4.0 |  30 – 65
Polypropylene |  25 — 55 |  3.0 – 7.0 |  25 – 60

It is noteworthy that both natural and man-made fibres have a wide range of mechanical properties. Some interesting points worth noting are:

i) Acrylic fibres have mechanical properties close to those of wool and are in fact used as artificial wool

ii) The initial modulus (stiffness) and breaking stress (tenacity) values for cotton and polyester fibres are quite close so they can be blended

iii) Amongst natural fibres, silk is closest to the man-made fibres in its mechanical properties.

The present discussion has been limited to textile fibres used for apparel wear and at home. For industrial uses, fibres with much superior mechanical properties are made by using high molecular weights and greater molecular orientation.

Elasticity is another mechanical property of fibres that is of practical utility. Elasticity is a measure of the fabric’s ability to return to its original form after being stretched or squeezed. The recovery of the fabric to its original form is time-dependent and may be 100% at lower force. However, as the force increases, recovery may become less. If the recovery is not complete, the fabric remains in the deformed state. That means the material has poor dimensional stability. Nylon 66, wool and polyester fibres show good elastic recovery even while undergoing quite large extensions. Silk, viscose rayon and cotton show poor recovery.

Another term used to quantify elasticity and elastic recovery is resilience. When we walk on carpets, the fibres get compressed and when we step out, the fibres are expected to regain their original size and shape. This ability to recover after the fibre has undergone compression is known as resilience. Nylon 66 and wool are the two most important carpet fibres (polypropylene is also used in cheaper carpets) and they possess high resilience.

Durability is another property that can be considered here. Many mechanical parameters may contribute to durability and these include modulus, breaking strength, breaking elongation, abrasion resistance, etc. Man-made fibres are more durable than natural fibres. In the scale of durability, nylon and polyester are on the top and linen and silk at the bottom.

2. Moisture Absorption: In hot and humid weather one can feel very uncomfortable if the clothes do not absorb perspiration and moisture. If the cloth can absorb perspiration and moisture and maintain some sort of equilibrium with the outside atmosphere, this discomfort is reduced. An understanding of the moisture absorbing capacity of textile is therefore important.

Natural fibres absorb moisture better than man-made fibres (an exception is viscose rayon). It is for these reasons, undergarments, which are in direct contact with the body, are mostly made of cotton.
The amount of water in a specimen is generally expressed in terms of moisture regain which is defined as —

\[
\text{Percentage Moisture Regain} = \frac{\text{Mass of absorbed water in specimen}}{\text{Mass of dry specimen}} \times 100
\]

The moisture regain data for the major natural and man-made fibres is given in Table 2.1. It is noteworthy that its moisture regain is the highest of all fibres, cellulosic and protein fibres absorb much greater amount of moisture than the other classes of fibres mainly because of the presence of moisture absorbing groups in their chemical structures. We will see later that the water absorbing fibres are also easy to dye. In the case of wool, besides a large number of water absorbing group, the disordered or the amorphons phase is much greater (about 75%) and since the water molecules are absorb by this phase, its moisture regain is the highest of all fibres.

<table>
<thead>
<tr>
<th>Fibre</th>
<th>Moisture Regain (%) at 20°C and 65% relative humidity</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cotton</td>
<td>7 – 8</td>
</tr>
<tr>
<td>Mercerized Cotton</td>
<td>12</td>
</tr>
<tr>
<td>Viscose Rayon</td>
<td>12 – 14</td>
</tr>
<tr>
<td>Silk</td>
<td>10</td>
</tr>
<tr>
<td>Wool</td>
<td>14 – 18</td>
</tr>
<tr>
<td>Nylon</td>
<td>4.1</td>
</tr>
<tr>
<td>Polyester</td>
<td>0.4</td>
</tr>
<tr>
<td>Acrylic</td>
<td>1.2</td>
</tr>
</tbody>
</table>

3. Electrical Properties: Textile fibres are generally good insulators of electricity. Their electrical resistance is very high. Unlike metals they do not contain free electrons and therefore do not conduct electricity.

When yarns are being processed or are being woven or knitted into fabrics, the rubbing of the fibres on the machine surfaces generates electrostatic charges which accumulate because the fibre does not conduct or dissipate the charge. This static charge can be troublesome. Since water is a superior conductor of electricity, the presence of moisture avoids accumulation of static charge. For this reason in cotton mills, a high level of humidity is maintained.

Since synthetic fibres have low moisture regain, the problem of static is quite severe with them and flying sparks can sometimes be seen when handling polyester fabrics.

iv) Thermal characteristics: Textile fibres are visco-elastic materials, which means that they combine the ‘elastic’ behaviour shown by conventional solids with the viscous characteristics shown by liquids. Thus heat has considerable effect on fibre properties.

On heating, the fabrics show significant softening. A trouser made of polyester fabric, for example, could be given permanent pleats that can be set at 230°C. This confers dimensional stability to the product up to the temperature of heat setting.
Fabrics made from natural fibres, on the other hand, do not show the typical softening behaviour shown by synthetic fibres. Therefore, chemical processing is used to treat fabrics made from cotton, wool and silk.

**v) Optical Characteristics:** When light falls on a fibre, it may be partly transmitted, absorbed or reflected. The lustre of a fabric and the total visual appearance are related to the intensity of reflected light. Circular filaments arranged parallel to each other in the fabric will enhance the intensity because of specular reflection and thus make the fabric lustrous. That is why mercerized cotton fabrics have more lustre.

Synthetic fibres are generally circular in crosssection and are like smooth circular cylinders. This gives them such high degree of lustre that dulling agents like titanium dioxide are used to reduce the lustre.

### Self-check Questions

3. Name two mechanical properties which can be obtained from a stress-strain curve.

4. Define resiliency and name the two fibres having maximum resiliency.

5. Why is acrylic used as artificial wool?

6. Name the most and the least durable fibres.

7. Why are the synthetic fibres more lustrous?

### 2.3.2 Chemical, biological and other properties

The chemical and biological properties common to all the following three classes of fibres are given in table format for better understanding. The tables also include some other properties of interest.

---

**Table 2.3**

*Basic Features Common to Cellulosic Fibres*
<table>
<thead>
<tr>
<th>S. No.</th>
<th>Property</th>
<th>Significance</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td>Good conductor of heat</td>
<td>Fabrics are cool for summer wear</td>
</tr>
<tr>
<td>2.</td>
<td>Low in elastic recovery</td>
<td>Fabrics wrinkle badly unless finished for recovery.</td>
</tr>
<tr>
<td>3.</td>
<td>Absorbent</td>
<td>Absorb moisture, suitable for summer wear. Good for towels, diapers and handkerchiefs</td>
</tr>
<tr>
<td>4.</td>
<td>Not attacked by moths.</td>
<td>Simplifies problems of storage</td>
</tr>
<tr>
<td>5.</td>
<td>Can withstand high temperature</td>
<td>Fabrics can be boiled to sterilize. Special precautions in ironing are not needed</td>
</tr>
<tr>
<td>6.</td>
<td>Not greatly harmed by alkali.</td>
<td>Fabrics can be bleached, washed with strong soaps; not greatly damaged by perspiration.</td>
</tr>
<tr>
<td>7.</td>
<td>Harmed by acids</td>
<td>Fruit stains must be removed immediately</td>
</tr>
<tr>
<td>8.</td>
<td>Attacked by mildew</td>
<td>Avoid putting away soiled damp garments</td>
</tr>
<tr>
<td>9.</td>
<td>Inflammable</td>
<td>Loosely constructed garments should not be worn near an open flame.</td>
</tr>
<tr>
<td>10.</td>
<td>Packs well into compact yarns</td>
<td>Yarns can be creped.</td>
</tr>
</tbody>
</table>

Table 2.4
Basic Features Common to Protein Fibres

<table>
<thead>
<tr>
<th>S. No.</th>
<th>Property</th>
<th>Significance</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td>Elastic Recovery</td>
<td>Hold their shape better than cellulosic fibres</td>
</tr>
<tr>
<td>2.</td>
<td>Weaker when wet</td>
<td>Wool loses about 40% of its strength when wet, silk about 15%. Handle carefully during washing</td>
</tr>
<tr>
<td>3.</td>
<td>Harmed by oxidizing agents</td>
<td>Chlorine bleach damages fibres. Sunlight causes white fabrics to turn yellow</td>
</tr>
<tr>
<td>4.</td>
<td>Poor conductors of electricity</td>
<td>Good electrical insulation</td>
</tr>
<tr>
<td>5.</td>
<td>High absorbency</td>
<td>Comfortable in cool, damp climate; absorbs odours</td>
</tr>
<tr>
<td>6.</td>
<td>Weakened by alkalies</td>
<td>Perspiration weakens the fabric; Use neutral or mild soap or detergent</td>
</tr>
<tr>
<td>7.</td>
<td>Harmed by dry heat</td>
<td>Wool becomes harsh and brittle and scorches easily with dry heat. Silk yellows with heat</td>
</tr>
<tr>
<td>8.</td>
<td>Do not support combustion</td>
<td>Protein fibres tend to stop burning when the flame is removed. Burning protein fibre smells like burning feathers.</td>
</tr>
<tr>
<td>9.</td>
<td>Attacked by moths</td>
<td>Store goods along with naphthalene balls</td>
</tr>
</tbody>
</table>

Table 2.5
Basic Features Common to Most Thermoplastic Fibres
<table>
<thead>
<tr>
<th>S. No.</th>
<th>Property</th>
<th>Significance</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td>Wet strength is comparable to dry strength.</td>
<td>Little change due to agitation or abrasion during washing or wear</td>
</tr>
<tr>
<td>2.</td>
<td>Good elasticity and elongation</td>
<td>Maintains air space for warmth; Regains shape after stretching.</td>
</tr>
<tr>
<td>3.</td>
<td>Low moisture absorption</td>
<td><strong>Advantages:</strong> 1. Easy to remove stains. 2. Easily washable. 3. Dries quickly. <strong>Disadvantages:</strong> 1. Difficult to dye. 2. Builds up static electricity charges 3. Uncomfortable to wear</td>
</tr>
<tr>
<td>4.</td>
<td>High tensile strength and abrasion resistance</td>
<td>High durability to pulling and rubbing during wear.</td>
</tr>
<tr>
<td>5.</td>
<td>High chemical resistance</td>
<td>Not rapidly destroyed by acids, alkalis, bleaches, detergents. Non-hazardous as skin irritant.</td>
</tr>
<tr>
<td>6.</td>
<td>Heat sensitive</td>
<td>Melts when it comes in contact with 1. hot iron 2. hot tobacco ashes 3. any hot object</td>
</tr>
<tr>
<td>8.</td>
<td>Good elastic recovery</td>
<td>Loses wrinkles easily</td>
</tr>
<tr>
<td>9.</td>
<td>High resistance to moth, mildew, insects, mould, etc.</td>
<td>Simplifies storage problems. Economy of little loss from these causes</td>
</tr>
</tbody>
</table>

**Self-check Questions**

8. Fill in the blanks:
   
i) Wool loses about ______% of strength when wet, while wet silk loses about ______% of strength.
   
ii) ______ fibres have maximum moisture absorption and ____ have the minimum.
   
iii) Burning protein fibres smell like _____.
   
iv) ______ fibre becomes yellow when heated.

**2.4 Assignments**
2.4.1 Class assignments

i) Collect 5 samples of natural fabric and 5 of synthetic fabrics. Test their tensile strength and elastic recovery properties in a Testing Laboratory.

2.4.2 Home assignments

i) Based on different wash and care features and chemical properties, prepare a list of Detergent bleaches and other reagents available in the market for different types of fibres.

2.5 Summing Up

The physical and chemical/biological properties of fibres have been described in this lesson. The factors which control comfort, moisture absorption, electrical and other properties of fibres have been discussed. It is shown that the fibres have a wide range of mechanical properties. The optical and thermal characteristics of fibres have also been discussed.

2.6 Possible Answers to Self-check Questions

1. State whether the following statements are True/False
   
i) False    ii) True    iii) False    iv) False    v) False
2. Filaments are of much longer length and are continuous.
3. The end points of the stress-strain curves indicate the breaking stress & the breaking strain.
4. Ability to recover after the fibre has undergone compression is known as resilience. Nylon66 & wool possess maximum resiliency.
5. Acrylic fibre can be produced with properties very close to those of wool like high extensibility, low strength, etc. and is used as artificial wool.
6. Nylon and Polyester are the most & Linen and Silk are the least durable fibres.
7. Synthetic fibres are generally circular in cross section and are like smooth circular cylinders. This gives them high degree of lustre.
8. Fill in the blanks:
   
i) 40%, 15%    ii) Wool, Polyester    iii) Feathers    iv) Silk

2.7 Terminal Questions
1. Define moisture regain.
2. Why is the moisture regain of natural fibres more than that of synthetic fibres?
3. How is comfort related to moisture absorption?
4. What is permanent pleating and how is it achieved in polyester garment?
5. Why are synthetic fabrics heat set?
6. What is meant by the breaking strength of a textile fibre?

2.8 References

2.9 Suggested Further Reading

2.9 Glossary
1. Coarsest Thick, not fine
2. Resiliency Recovery from compression
3. Modulus Resistance to initial deformation
4. Squeeze To press from all sides
5. Discomfiture Uncomfortable
6. Dissipate Disperse, scatter
7. Visco-elastic Combined viscous and elastic behaviour