LESSON 14 TESTING OF TEXTILE FIBRES AND YARNS

STRUCTURE

14.0 OBJECTIVES
14.1 INTRODUCTION
14.2 CONDITIONING AND SAMPLING
14.3 TESTS ON FIBRES
  14.3.1 LENGTH DISTRIBUTION OF COTTON FIBRES
  14.3.2 FINENESS OF FIBRES
  14.3.3 LONGITUDINAL SECTIONS AND CROSS SECTIONS OF FIBRES
  14.3.4 MOISTURE REGAIN OF FIBRES
14.4 TESTING OF YARNS
  14.4.1 MEASUREMENT OF LINEAR DENSITY AND COUNT
  14.4.2 TWIST MEASUREMENT
  14.4.3 MEASUREMENT OF YARN TENACITY
14.5 ASSIGNMENTS
  14.5.1 CLASS ASSIGNMENTS
  14.5.2 HOME ASSIGNMENTS
14.6 SUMMING UP
14.7 POSSIBLE ANSWERS TO SELF-CHECK QUESTIONS
14.8 TERMINAL QUESTIONS
14.9 REFERENCES
14.10 SUGGESTED FURTHER READING
14.11 GLOSSARY
14. TESTING OF TEXTILE FIBERS AND YARNS

The starting material for making any textile product is a fibre or a yarn. It is therefore necessary to characterize them and to know their properties. In this lesson, the instruments used for this purpose and the information obtained from them will be described. Fabrics will form the subject matter of the next and final lesson of the unit.

14.0 Objectives

After going through this lesson, you will be able to

- Characterize cotton for its length distribution.
- Characterize fibres for their fineness.
- Examine at low magnification the longitudinal section and cross section of fibres.
- Determine the moisture regain of fibres.
- Measure tensile properties of fibres and yarns.
- Measure linear density and count of yarns.
- Measure the amount of twist in yarns.
- Measure evenness of yarns.

14.1 Introduction

In Lesson 1 of Unit 1 of this course we learnt that cotton and wool grow as short fibres and these are called staple fibres. Silk and man-made fibrous structures, on the other hand, have much greater length and these continuous fibrous entities are called filaments. We also learnt in this lesson how fibres are classified on the basis of their origin. In subsequent lessons 2 and 3, we learnt about their properties and identification methods.

We have now reached the final unit of this course. We have already learnt in lesson 13 the meaning of quality and the need for testing fibres, so that total quality management can be achieved.

Fibres, yarns and fabrics are the three important forms in which textile materials are available. Hence methods have been found to study the characteristics and properties of textiles in their different forms. Fibres and yarns will be dealt with in this lesson while fabrics will form the subject matter of study in the next lesson.

But before going to the actual tests and testing instruments, a few words about conditioning and sampling of textile materials would be in order.
14.2 Conditioning and Sampling

We saw in Lesson 2 of this course that the properties of textile materials are quite sensitive to atmospheric temperature and humidity. Thus to get meaningful results, the materials to be tested must be conditioned in a standard atmosphere and the tests must also be performed in a laboratory in which the temperature and humidity are controlled at a temperature of 25°C± 2°C and relative humidity of 65±2 percent.

The variability in dimensions and properties in natural fibres is much more than in man-made fibres. Therefore in the case of natural fibres, the number of samples for a particular test must be large enough to get a meaningful average. The number of samples may be less when testing man-made fibres for a specific property.

14.3 Tests on Fibres

In this lesson, we will describe some of the more important tests that are generally done on fibres, these are: Length distribution of cotton fibre, Fibre fineness, examination under low magnification of longitudinal sections and cross-sections of fibres, moisture regain of fibres and fibre tensile properties. The identification of textile fibres with the help of burning and solubility tests has already been dealt with in lesson 3 and will therefore not be described here.

14.3.1 Length Distribution of Cotton Fibres

Cotton fibres have a distribution of lengths which must be taken into account when spinning the fibres and also when analyzing their properties. These staple fibre diagrams require a fibre sorter of which different versions are available. We will describe the Baer sorter (Fig.14.1). This instrument is provided with 12 bottom combs and 3 top combs which are used to prepare the fibre arrays.

About 20 mg of the cotton fibre to be tested is taken. The fibres are separated with the help of combs into tufts of fibres starting with a tuft of long fibres and small tufts of successively shorter fibres. The tufts are laid side by side on the velvet pad such that the free ends of the tufts lie along a straight base line.
Fig. 14.2 is a typical Baer diagram for cotton and it is obvious that the curve represents the probability that any fibres taken at random will be longer than any given length, \( l \). Note that the probability of having fibres of lengths greater than \( l_{\text{max}} \) in Fig. 14.2 is zero. Also the probability of having fibres of length greater than \( l_{\text{min}} \) is 1. From the diagram, useful information can be extracted like effective length, percentage short fibres, coefficient of variation of length, etc. The Indian Standard (IS) 233 (part 2): 1978 gives the methods for estimating those parameters.

**Self-check Questions**

1. Textile fibres should be tested under standard atmospheric conditions. What should be the relative humidity and the temperature?

2. The dimensional variability in natural fibres is greater than in man-made fibres. Why?

3. In typical staple fibre diagram, what do the two axes represent?

**14.3.2 Fineness of Fibres**

Fineness is a relative measure of size, diameter, linear density or weight per unit length. The importance of fineness in determining the quality and commercial value of fibres has been recognized in the worsted section of textile industry, where short fine wool is known to be much more valuable than a long coarse one. In cotton fibre, since long fibres are fine and since length has been considered as the prime factor, fineness has taken a back seat. With the advent of microfine polyester fibres and the combination of properties that they possess, there is revival of interest in the transverse dimensions of fibres.

The airflow instruments, which are generally used for measuring fineness, operate on the principle that the fineness of cotton fibre is related to the rate of airflow through a plug of cotton fibre of fixed weight contained in a container of definite dimensions and subjected to a constant pressure head.

A fibre fineness tester (Fig. 14.3) is first calibrated by three calibration cottons and if found to be in order, two specimens of cotton each of 5 mg weight are tested. The air is allowed to flow through the specimen. The finer the fibres, greater is the surface area and so the drag to airflow is greater. Thus the flow will be lesser through the finer fibres. In some instruments, the scale is graduated in micronaire units while in others the direct reading of airflow has to be converted to micronaire value.

The instrument can also be used for testing wool in which case the standard mass of the sample is 5.9 grams and the air pressure is 4.5 lbs/cm\(^2\).

**14.3.3 Longitudinal Sections and Cross Sections of fibres**

As stated previously in lesson 3 of this course, cross sections of fibres are of particular interest in the identification of fibres. The longitudinal sections and cross
sections of a number of major fibres, both natural and man-made, were shown in Figures 3.1 and 3.2 in which their unique features were quite evident.

These studies are made at relatively low magnification. The photographs shown in fig.3.1 were taken on a scanning electron microscope but a projection microscope (Fig.14.4) or optical microscopes (Fig.14.5) are quite adequate for this purpose.

The technique of sample preparation is described in section 3.3 of Lesson 3 of Unit 1 of this course.

The photographs of cross sections can also be used for getting an idea about the extent of dye or stain penetration in a fibre. An interesting example of this can be seen in Fig.14.6 which shows the cross section of a grey jute fibre which has been stained with a reagent. It is interesting to note that the grey jute sample develops the magenta colour quite extensively with the inter-cellular and the middle lamella regions having the deepest colour. Such studies help in development work.

14.3.4 Moisture Regain of Fibres

The moisture absorbed by a fibre can be measured gravimetrically. For this an empty weighing bottle, an analytical balance and a hot air oven are required. The empty weighing bottle is first accurately weighed with the help of a precision balance. A sample of the fibre is placed in the bottle and it is weighed again with the fibre sample in it.
The bottle with its contents is dried in an oven (Fig. 14.7) at 105 ± 3 °C with its stopper removed for about 30 minutes. After this, it is removed and cooled with the stopper replaced.

This procedure is repeated until almost complete drying takes place when the weight becomes almost constant. The percentage regain is obtained by first calculating (the mass of original sample) – (oven-dry mass of dried sample) and then dividing by the (oven-dry) mass of the sample and finally multiplying this by 100. The moisture regain values for the major fibres are given in Table 2.2 of Lesson 2.

14.4 Testing of Yarns

Some important characteristics of yarns are:

- their linear density and count,
- twist level,
- evenness and
- tenacity (strength).

In this section we will see how these can be measured.

14.4.1 Measurement of linear density and count

Linear density is used to indicate the fineness of the yarns. There are 2 systems of yarn numbering as described below –

- Direct system – uses mass per unit length as a measure of fineness and expresses it as Tex or Denier.
  - Tex: The Tex is mass in grams of 1000 m of the yarn. It is expressed as a number.
  - Denier: The Denier of the yarn is the mass in grams of 9000 meters of the yarn. It is expressed as a number.

- Indirect system – uses the length per unit mass as a measure of fineness and expresses it as yarn number or count.
  - Cotton (English) count (Ne): The cotton count of any yarn is the number of 840 yard lengths (hanks) which weigh one pound.
  - Wool (American cut) count (Nac): The wool count of any yarn is the number of 300 yard lengths (hanks) which weigh one pound.
  - Worsted count (Nw): The worsted count of any yarn is the number of 560 yard lengths (hanks) which weigh one pound.
  - Metric count (Nm): The metric count is the number of 1000 m lengths (hanks) which weigh one kilogram.
We will first deal with length measurement which will be considered for two cases viz. yarn in package form and yarn in short lengths.

- **Yarn in package form:** Where the yarn is in package form such as ring bobbins or cones, it is usual to wind a number of hanks by means of a wrap reel (Fig. 14.8). It is essential that the tension at which the yarn is wrapped, is kept constant. A gauge can be used to check that the reeling tension is constant. If very high accuracy is desired the yarn should first be wound into a hank form and stored in a conditioned atmosphere for three hours and then wrapped on the reel for count measurement. This allows the yarn to relax and contract during conditioning and errors due to contraction are avoided.

![Fig.14.8 Wrap Reel](image)

- **Yarn in short lengths:** Sometimes only short lengths of yarns are available. These should be conditioned for 24 hours before making measurement.

We will now consider weight measurement. The analytical balances and any other special yarn balances used in the determination of count must be accurate and must be levelled and checked before measurement. It is necessary to account for presence of moisture in the sample. This can be done either by drying the sample in an oven and taking the oven dry weight or by allowing the sample to condition in the testing atmosphere long enough to reach equilibrium and then weighing it in the same atmosphere. The results of the two tests might not necessarily agree.

We will first describe the measurement of linear density.

For determination of Tex and Denier the conditioned yarn may be used and a hundred meter length wrapped on the wrap reel and taken out in the form of a hank. It is then weighed on a sensitive balance. Knowing the length of the sample and its weight, the linear density can be estimated. For example if 100 m weighs 2.5 grams the linear density is 25 Tex or 225 Denier.

For measuring the count or yarn number, a hundred & twenty yard of conditioned hank made from cotton yarn is weighed. From this measurement one can find out the number of hanks of 840 yards that will weigh one pound and this gives the English count of the cotton yarn.

A number of special yarn balances are available which are designed to furnish a quick estimate of the count especially when only small samples are at
hand. One such balance is the Beesley balance shown in Fig. 14.9. This instrument consists of a simple beam with a sample hook at one end and a pointer at the other as shown in Fig. 14.10. The beam is initially leveled to bring the pointer opposite a datum line.

A standard weight is hung in a notch on the beam arm on the pointer side of the pivot. (See fig. 14.10). A template is used to cut short lengths of the yarn, the length depending on the count system required. These short lengths are added on the hook until the pointer is opposite the datum line. The count is the number of short lengths to balance the beam. When used in the analysis of small samples of fabrics a rough estimate of the crimp should be made and the count corrected.

Self-check Questions

4. What is the relation between Denier and Tex?

5. What is meant by English cotton count?

Activity

1. Two common filaments of polyester yarn in common use are:
   a) 76 Denier, 24 filaments, 0 twist
   b) 80 Denier, 34 filaments, 0 twist

Assuming that the filaments are circular and that the density of polyester is 1.4 gram/cm³, calculate the diameters of the fibres in the above two cases and comment.

14.4.2 Twist measurement

Several methods of twist measurement are available. We will describe two methods which are applicable to the more common type of yarns - first for single yarn and the second for double or multi ply yarns.

Twist tester for single yarn: We will describe a single yarn twist tester based on the twist contraction method. (Fig. 14.11) The yarn is first gripped in the left hand clamp which is mounted on the pivot & carries a pointer. After being led through the rotating jaw, the yarn is pulled through until the pointer lies opposite a zero line on a small quadrant scale; the jaw is then closed. At this stage the specimen is under a small tension and a nominal length of 10” (or any other chosen test length). As the twist is removed the specimen extends and the pointer assumes a vertical position. Eventually all the twist is taken out but the jaw is kept rotating in the same direction until sufficient twist has been inserted to bring the pointer back to zero mark again. The total number of turns registered on the revolution counter is divided by two i.e. twice the number of inches on the test
length. This gives the total twist in the yarn. To get the twist level per inch of the yarn, this number is again divided by ten.

Twist tester for double or multiple plied yarns (Fig. 14.12): In fig. 14.12 a hand operated twist tester to determine the level of twist in double or multiple plied yarn is shown. The unit has a pre-settable five digit counter to register the number of twists in the yarn. There is provision in the unit to provide required tension in the yarn while untwisting. A viewing plate and a magnifying glass are provided to enable easy untwisting and determining the end point of the open yarn. There is provision for tension load adjustment so that tension in the yarn during untwisting is maintained at a constant level.

In this instrument the stage when untwisting just stops can be easily identified. The two jaws are generally at a distance of 10", the left side is tensioned by a means of hanging weight, the right side can be tensioned by means of a handle. There is a horizontal disc which directly reads the number of revolutions of the jaw. The scale will move in either direction depending on the direction of the rotation of the handle. There is a mirror lens arrangement on a ply which helps in accurate observation of the yarn being untwisted. For S twist the handle is moved clockwise whereas for Z twist the handle is moved anticlockwise. The untwisting is stopped when two parallel yarns are visible. At this stage a pin is able to pass freely from the left jaw to the right jaw. The number of revolutions on the outer scale is read for S twist and on the inner scale for Z twist. When the number of revolutions is divided by ten then we get the twist per inch.

Self check Questions

5. Why does a yarn become longer on untwisting?
Activity

2. Try to explain why the same twist tester cannot be used for single and double yarn.

14.4.3 Yarn evenness test

Variation in fineness of textile fibres and yarns arises due to a variety of reasons, most of which are related to the production process. The irregularity can adversely affect many properties of textile materials, the most obvious being the variation in strength along the yarn. If the average mass per unit length is equal, but one yarn is less regular than others, the more even yarn will be stronger of the two. An irregular yarn breaks relatively more easily during spinning, winding, weaving, knitting or any other process where stress is applied in comparison to any other yarn. Another characteristic of uneven yarn is that it leads to the presence of visible faults on the surface of the fabric and variation in fineness can be easily detected in the finished fabric.

A number of other fabric properties such as abrasion or pill resistance, soil retention, drape, absorbency, reflectance and luster may also be affected by yarn evenness.

A number of methods are available for determining yarn evenness, the simplest method consists of cutting a fixed length and then weighing many specimens of yarn. However this method is tedious, lacks precision and is of limited use. The most common method of continuously monitoring the evenness of the yarn is based on passing the yarn through a parallel plate (Fig. 14.13) (condenser) continuously and monitoring the capacity electronically. A change in the mass of the dielectric (which in this case is the non conducting yarn), in the condenser changes its capacitance, the change being proportional to the mass of the material present. USTER company of Switzerland is one of the major manufacturers of evenness testers which are extensively used. The variation of mass per unit length is recorded on a chart which is known as a diagram. A diagram for a 78 d Tex / 20 filament yarn is shown in fig. 14.14. Besides showing the variability in evenness a missing filament in this yarn can be easily identified from this diagram.
The appearance of the yarn can also be observed on a board on which yarn is wound with the help of a yarn appearance board winder. (Fig. 14.15) A traversing guide ensures that the yarn is wound with regular spacing on the board. The yarn is then graded by visual observation and compared with the standard grading which gives the appearance index value as 130 for A grade and 60 for D grade.

**Fig. 14.15 A Yarn Appearance Board Winder**

**Self-check Questions**

6. What types of non-uniformity are present in a yarn?

**Activity**

3. A few filaments in a multifilament yarn have thick places along the length. How will they affect strength of the yarn and why?
14.4.4 Measurement of yarn tenacity

The strength of a yarn is one of its most important characteristics. It is generally measured by a tensile testing machine.

The basic principles of tensile testing have been explained in lesson 2 of this course. The tensile testers are designed to test a single yarn (Fig. 14.16) or a lea (Hank) (Fig. 14.17). In a single yarn tester a yarn of 20 cm. length is secured between the upper and the lower jaw and on switching the machine, the lower jaw moves at a fixed rate till the yarn breaks. The load elongation curve can be plotted on a graph paper and the various parameters obtained from the tensile test can be evaluated as had been explained in lesson 2. These include the initial modulus of the yarn, the elongation at break and the breaking stress i.e. the tenacity of the yarn. In the Lea strength tester either 100 meters of the yarn or 120 yards of the yarn are converted to a lea using a wrap reel having a circumference of 1 m. or 1.5 yards. The Lea is first conditioned and then is fixed between two hooks of the upper and lower jaw. In some machines pulleys are provided. The machine is started and the test continues till the Lea breaks. The load elongation curve can be obtained in this case also. In both cases 25 samples are examined and the average values are taken as the characteristic of this sample.

Activity

4. Two single polyester filaments (one of denier 5 and the other of denier 10) having the same, production history are tested in a tensile tester. Assuming that their mechanical properties are the same, draw the load elongation curves that you will expect from these two filaments. Also draw in another figure the corresponding stress-strain curves for these two filaments.
14.5 Assignments

14.5.1 Class assignments

i) How will you proceed to trace the cross section of a cotton fibre?

ii) What is the principle of the instrument which measures evenness of a yarn?

14.5.2 Home assignments

i) Describe a method of measuring moisture regain of a fibre?

ii) How will you determine the Lea strength of a yarn?

14.6 Summing Up

In this lesson the tests performed on fibres and yarns to characterize them and to study some important properties have been described. These include characterizing cotton for its length distribution, examining the longitudinal section and cross section of a fibre and determining their moisture regain. In the case of yarn measurement of linear density and count, amount of twist, evenness and load elongation behaviour have been considered.

14.7 Possible Answers to Self-check Questions

1. Relative humidity: 65±2%, Temperature 25±2°C.

2. Man-made fibres are machine made and the variability in their dimensions arises from the variability in i) materials used, ii) machine related variability and iii) process related variability. Since all these three can be controlled to within very narrow limits the product is uniform. Natural fibres are relatively more variable in dimensions because the growth of fibres is dependent on environmental and other factors which show large variations.

3. Length and probability.

4. Denier is nine times Tex.

5. The English cotton count of a yarn is the number of 840 yard lengths which weigh one pound.

6. When a yarn is twisted the inclination of the filament to the yarn axis increases with the result that the filament contracts. Therefore on untwisting the yarn becomes longer.

7. The yarn may contain non uniformities arising from heterogeneity of the raw material, variability related to machine parameters and variability related to process. As a result there are thick and thin portions in the filament, impurities like degraded material in the form of broken filaments etc.

14.8 Terminal Questions
1. What are the major fiber characteristics & properties that need to be determined? Describe a measurement of one of these in detail?

2. What are the important characteristic and properties of yarns that have to be determined? Describe one of them in detail.

14.9 References


14.10 Suggested Further Reading


14.11 Glossary

1. Regain Amount absorbed.

2. Tufts A Cluster yarn drawn through a fabric to project from the surface in the form of cut threads or loops.

3. Coefficient A constant number that serves as a measure of some property or characteristic.

4. Worsted A fine smooth yarn spun from combed wool fibres.

5. Middle lamella Thin plate, a thin membrane.

6. Hanks Loops

7. Pivot A short shaft that supports something that turns.