
LESSON 1 FIBRES: THEIR CLASSIFICATION AND CHARACTERISTICS

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1. FIBRES: THEIR CLASSIFICATION AND CHARACTERISTICS

The basic component of textiles is the Fibre which significantly influences the structure, appearance, nature and property of a textile. Since there are different types of fibres present around us, a variety of textiles can be produced from them.

This first lesson of the unit and the course is introductory in nature and is concerned with the classification and characteristics of fibres. The next lesson will describe briefly the properties of fibres. The third and final lesson of this unit will deal with tests for identification of fibres.

1.0 Objectives

After going through this lesson you will be able to

- Define a fibre.
- Understand the difference between a fibre and a filament.
- Classify the fibres according to their origin as natural and man made fibres.
- Know how cotton, wool and silk are formed.
- Describe how man-made fibres and filaments are manufactured.

1.1 Introduction

Food, clothing and shelter are the three basic needs of human beings. The fibres, which form the subject matter of this lesson, are the basis of clothing and therefore their importance cannot be overemphasized. Textile fibres are hair-like substances with a high degree of fineness, outstanding flexibility, reasonable strength, a minimum level of length and cohesiveness (ability to hold to one another, when placed side by side). They may be short with a length at least 500 times (but commonly 1000 to 3000 times) their diameter or thickness or may be very long with the length to diameter ratio being almost infinity. The short fibres are called staple fibres while those with very long length are called filaments. However, this distinction is generally not made and both short fibres and continuous filaments are called fibres. In this lesson the fibres will first be classified according to their origin. This will be followed by a description of the growth of natural fibres and manufacture of man-made fibres. Some of the important characteristics will also be briefly considered.

1.2 Classification of Fibres

Based on their origin, the fibres may be classified as belonging to one of the following two categories: Natural and Man-made. Natural fibres can be further classified according to their origin into the following three groups:

- i) *Vegetable Fibres*: Most of these are cellulose fibres and include cotton, linen, jute, flax, ramie, coir, sisal and hemp. Besides their use as textiles, cellulose fibres are also used in the manufacture of paper and other useful products like ropes, cords, coir mats, industrial fabrics, etc.
- ii) *Animal Fibres*: They are mostly protein fibres and include wool and silk.
- iii) *Mineral Fibres*: Asbestos is the only naturally occurring mineral fibre that was used extensively for making industrial products but is now being gradually phased out due to its suspected carcinogenic effect.

Fibres in the second category, as the name implies, are made by man and are therefore sometimes called artificial fibres or manufactured fibres. Like natural fibres they may also be divided into the following three categories:

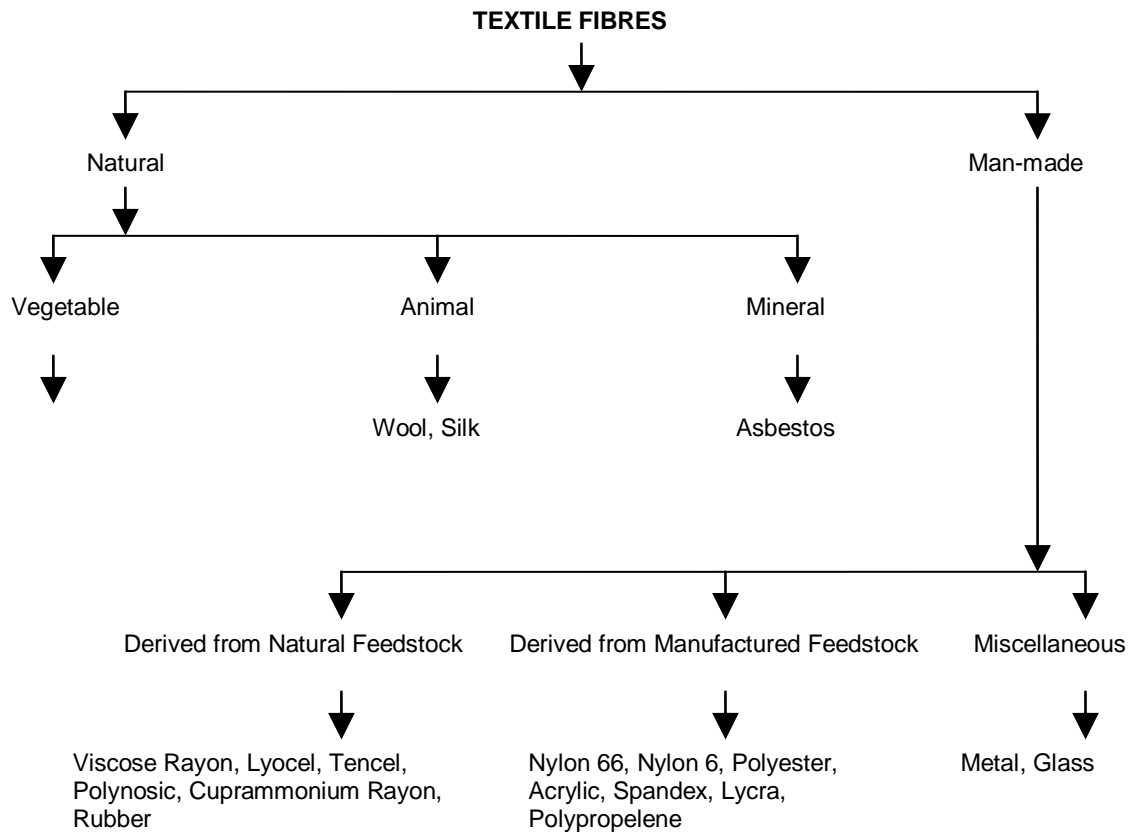
- i) *Derived from natural feedstock*: Most of the fibres in this category are derived from cellulose which is obtained from bamboo, wood or cotton linters. The most important fibre in this category is viscose rayon. For a long time rayon was made by a complex route in which cellulose was first converted to cellulose xanthate and then dissolved and made into a fibre which was then regenerated into pure cellulose fibre called viscose rayon. However, more recently solvents for cellulose have been found and the cellulose fibres are made directly from a solution of cellulose—these are available under the trade names Lyocell and Tencel. Small quantities of chemically modified cellulose fibres are also made—they are cellulose dilacerate and cellulose triacetate fibres.

Rubber latex, which comes out from rubber trees, is another natural feedstock from which rubber fibres are made for use by the Textile and other industries.

- ii) *Derived from manufactured feedstock*: The petrochemical industry is the main source of fibres in this category with coal and natural gas also contributing a bit. Low molecular weight chemicals are first produced and these are converted into fibre forming polymers through polymerization. Synthetic fibres like polyamides (Nylon 66, Nylon 6), polyesters, acrylics and polypropylene are obtained through this route. Elastomeric fibres— Spandex and Lycra are also similarly made.
- iii) *Miscellaneous fibres*: Glass fibres obtained from silica and metallic fibres like silver and gold are man-made fibres which are best put under this category.

Fibres and filaments belonging to these different categories are given in chart format (Chart 1.1) for getting a bird's eye view of all the textile fibres.

Chart 1.1
Classification of Fibres and Filaments



Cotton, Kapok: Seed

Jute, Hemp, Ramie: Flax

Sisal, Pineapple, Banana: Leaf

Coir: Fruit

Activity

1. You are given some samples of fibres. Examine them and state to which category they belong.

Self-check Questions

1. State whether the following statements are True / False:

i) Cotton is a man-made fibre.	True / False
ii) Viscose rayon was the first truly man-made fibre.	True / False
iii) Coir is a cellulosic fibre.	True / False
iv) A staple fibre is of infinite length.	True / False
v) Viscose rayon is a protein fibre.	True / False
vi) Silk is a natural fibre.	True / False
2. Define the following terms: Staple fibre, Filament.

1.3 Natural Fibres

Cotton, wool and silk are the major natural fibres and will be briefly described here. In north India cotton is sown in mid-May and 5 to 6 months later, the cotton boll, which contains the fibres growing on seeds, bursts open to atmosphere (Fig. 1.1) and after the fibres have dried, they are harvested. India was perhaps the first country to grow cotton; there is evidence that it was grown 5000 years ago. The quality of the fibre has improved significantly in the past 50 years - from the short, coarse fibre that was available then, today very fine, long fibres are grown. This has been possible through extensive breeding programmes and production of hybrids. In the year 2000, a total of 50 million tons of fibres were produced in the world, out of which cotton stood at 20 million tons. The corresponding figures for India were: total 4 million tons, cotton 2 million tons. Thus in India 50% of the total fibre produced is cotton.



Fig. 1.1 Cotton boll

Wool is the second important natural textile fibre. It is a hair growing on some animals like sheep, goats, rabbits and camels with the sheep providing almost 90% of the total wool produced. This protein fibre grows at the rate of about 1.25 cm. per month on some sheep. After it has fully grown, the thick coat of wool is sheared (Fig. 1.2); this is followed by cleaning after which it is sent for use. In 1996 there were more than 12 crore sheep in the world out of which India had 4.5 crore. However, India's share of world's wool production was much lower than its share of sheep.



Fig. 1.2 Wool sheared from sheep

Silk is another protein fibre and is produced by the silkworm using a process which is very close to the process of fibre production used for making man-made fibres. The silkworm secretes a viscous fluid from its glands located somewhere below its jaw and then wraps itself with the filament so extruded to form a cocoon. The rate at which it produces a 1 to 2 kilometer long filament is close to 50 cm. per hour. The cocoon is subjected to stoving (steaming) — the silkworm dies inside the cocoon and the filament is collected.

1.4 Polymeric Nature of Fibres

Though natural fibres have been with us for a long time, their structures were characterized only when techniques became available to study them. Extensive studies on cotton led scientists to believe that the fibre had very large molecules. The polymeric nature of fibres explained a number of their properties, e.g. the ability of the fibre to extend significantly on application of load and its recovery on removal of the load. As shown in Fig. 1.3, this was possible because long molecules were not always in well-aligned position, the departure from the oriented state could thus account for finite extension. On release of load, they were back to their original state which was their equilibrium state.

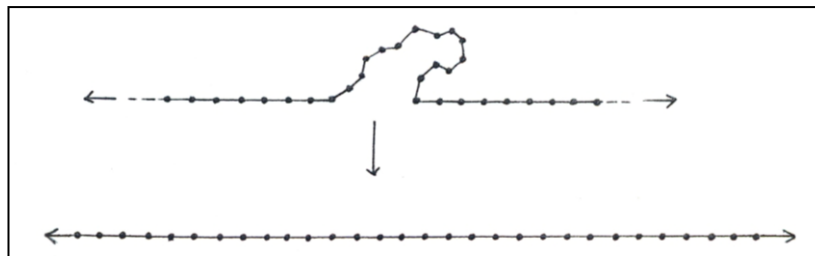


Fig. 1.3 Schematic representation of the extension of a molecule on application of load

All the man-made fibres that followed - viscose rayon, (the first truly man-made fibre was discovered more than 100 years ago), polyamides (before 1940), and polyesters, acrylic and polypropylene (after 1940) - were based on polymers. The two Polyamide fibres, which are produced in large quantities, are nylon 66 and nylon 6. They find considerable use as industrial fibres. Acrylic fibres are widely used as artificial wool. Polyester filaments and fibres find extensive use as dress materials.

1.5 Man - Made Fibres

All man-made fibres, as noted above, are polymeric in nature and are made up of many (poly) units (mers) joined together by chemical bonding forming long chains with high molecular weight. They are produced by polymerizing low molecular weight chemical substances, usually at high pressures and temperatures in the presence of catalysts. Once the polymer is produced, it can be made into a filament by converting the polymer to a fluid and then extruding the molten or dissolved polymer through narrow holes to give fine filaments. The filaments so produced are generally stretched in a drawing machine so that the molecules orient along the fibre length and strengthen the fibre.

As stated above, fibre manufacture requires the conversion of the polymer to a melt or a solution after which the technique used by the spider or the silk worm for centuries to make fibres may be used. This involves the squirting (shooting out like a jet of fluid) the fluid under pressure through a spinneret (a metal disk with a large number of very narrow holes). The threads which come out are pulled rapidly and hardened in the form of continuous filaments.

Melt spinning is possible with those polymers which give a stable melt like nylon 66, nylon 6, polyester, polypropylene, etc. Polymers which do not melt (like cellulose) or those which do not give a stable melt (like polyacrylonitrile) are converted into fibres by solution spinning.

A typical melt spinning line is shown in Fig.1.4. Polymer chips (or granules) are fed into the chip hopper and melted in the extruder. The melt passes through a pre-filter and then through another filter fitted in the spinning head before entering the spinneret. As they come out of the narrow holes of the spinneret, they are solidified by cooling in the quench chamber. After applying a spin finish/lubricant, they are wound on winders provided at the bottom of the unit in the form of single filaments or more commonly in the form multifilament yarns. They are then sent for further processing which may involve drawing and twisting them or draw-texturing them.

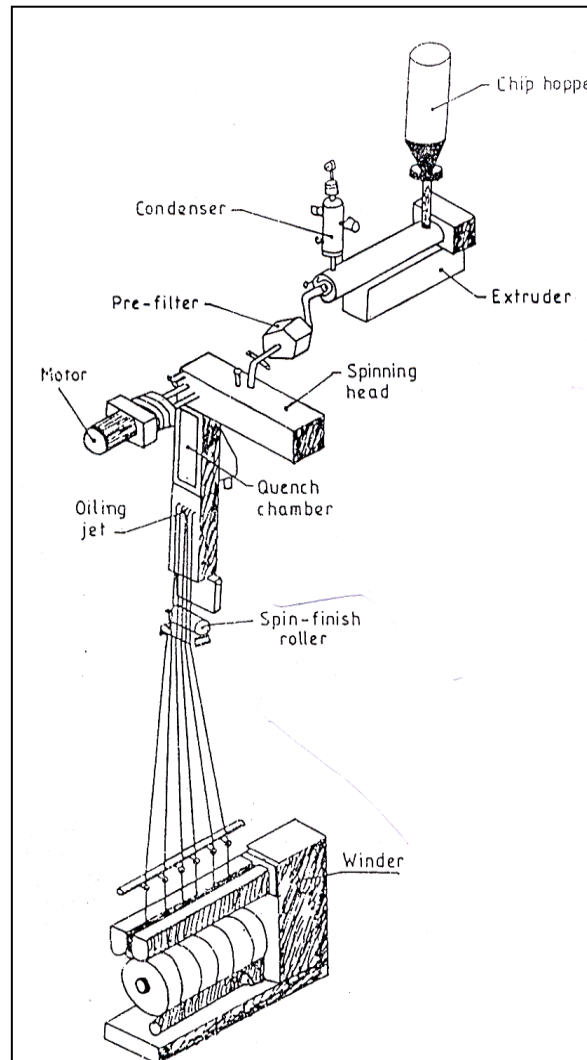


Fig. 1.4 A Melt Spinning Unit

Solution spinning may be classified as wet spinning when the solidification is achieved by precipitation or coagulation of the polymeric filament or as dry spinning when the solidification is achieved by boiling off the solvent in a drying chamber. The basic method of solution spinning is similar to that used for melt spinning.

A wet spinning line is shown in Fig.1.5. The polymer is dissolved in the solvent and filtered. Then a metered quantity of the solution is fed to a spinneret dipped in the coagulation bath. As the fluid filaments are squirted out under pressure, precipitation occurs. The solid filaments are then washed, drawn in two stages, dried and wound. It may be noted that this is an integrated process in which drawing is integrated with spinning, Viscose rayon and polyacrylonitrile fibres are produced by wet spinning.

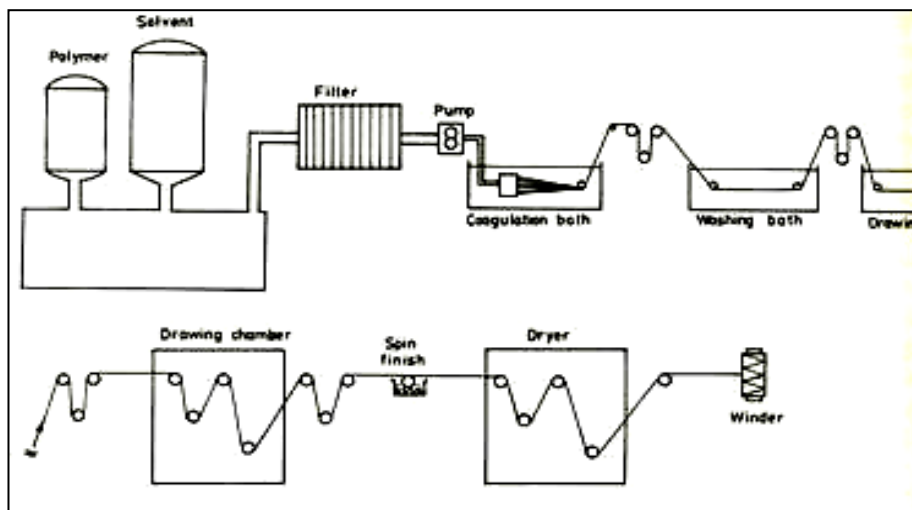


Fig. 1.5 A Wet Spinning Set-up

A Dry spinning line is shown in Fig.1.6. The filtered polymer solution is fed at the top of the set-up and a metered quantity of the solution after passing through a candle filter, enters the spinneret. The filament bundle falls into a drying chamber where the solvent is made to evaporate and the solidified filament are then wound. The drawing is done separately.

Polyacrylonitrile, cellulose acetate, Spandex and viscose rayon fibres can be produced both by dry spinning and wet spinning.

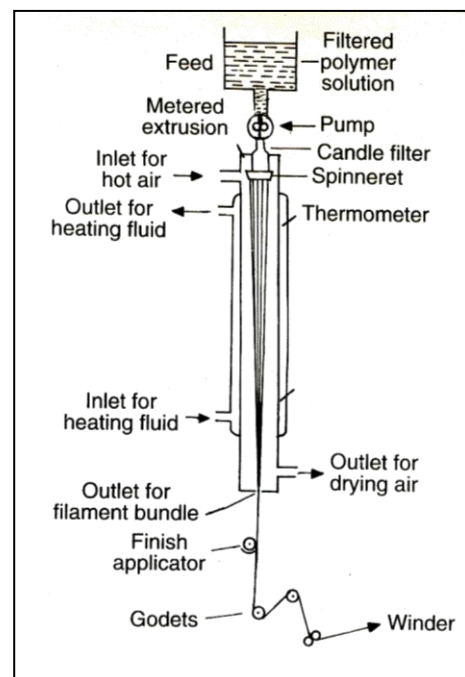


Fig.1.6. A Dry Spinning Set-up

1.6 Natural Fibres Vs. Man-Made Fibres

Though there are major differences in fibre structure between natural and man-made fibres, the long molecules are oriented in both cases and show the presence of both order and disorder in the way molecules are organized (Fig. 1.5). The ordered molecules (which may form crystalline regions) contribute to durability, strength, stability and recovery while the disordered regions (which may form the amorphous phase) make a contribution to elongation, dye and moisture absorption and toughness.

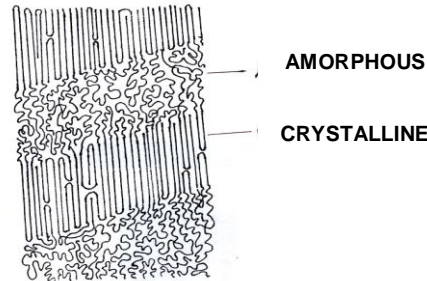


Fig. 1.7 Schematic sketch showing how molecules aggregate in a fibre

There are a number of differences too. The natural fibres show much greater non-uniformity than man-made fibres. Thus testing of natural fibres requires the testing of a very large number of samples before quoting an average value. Another important difference is the complex morphology of natural fibres as opposed to the rather simpler morphology of man-made fibres. A third important difference is that natural fibres absorb a greater amount of moisture because they contain more water absorbing groups than the synthetic fibres. Of course, viscose rayon, a man-made fibre, absorbs a significant amount of moisture because of its cellulosic structure. This makes natural fibres and viscose rayon more comfortable in the form of apparel wear, particularly in tropical and hot climates.

Self-check Questions

3. Give the basic differences between natural and synthetic fibres.
4. State whether the statements are True / False:
 - i) Synthetic fibres are very comfortable. True / False
 - ii) Synthetic fibres are more uniform than natural fibres. True / False
 - iii) Polymers have high molecular weight. True / False
 - iv) Polymers are the only right materials for making textile fibres. True / False

Activity

1. Prepare a chart giving classification of natural fibres. Try to get pictures of the sources of those fibres, wherever possible.
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1.7 Assignments

1.7.1 Class assignments

- i) Paste at least five samples of fabric of each major fibre in your work book and name them.

1.7.2 Home assignments

- i) Collect some samples of natural fibres and synthetic fibres and paste them in a file along with their description.

1.8 Summing Up

This lesson briefly describes the various fibres which are used for textile applications. A scheme of classifying these fibres according to their origin is given. A brief description of the growth of natural fibres and production of man-made fibres is included. The most important characteristics of fibres are also given.

1.9 Possible Answers to Self-check Questions

1. State whether True/False

- i) False
- ii) True
- iii) True
- iv) False
- v) False
- vi) True

2. Staple fibre and Filament: Short fibres are called staple fibres while those which are continuous are called filaments.

3. There are major differences between natural and synthetic fibres. The natural fibres show much greater non-uniformity than man-made fibres. Natural fibres are generally more comfortable than synthetic fibres. Natural fibres absorb a greater amount of moisture because they have a much greater number of water absorbing groups compared to the synthetic fibres.

4. State whether True / False:

- i) False
- ii) True
- iii) True
- iv) False

1.10 Terminal Questions

1. How are filaments produced from synthetic polymers?
2. Write a brief note on cotton fibre.
3. What are the desirable characteristics of a successful textile fibre? Briefly describe them (State why they are desirable)?

1.11 References

1. Bajaj, P. and Gupta, V. B. 2004. Rui Se Nylon Tak (in Hindi). NCERT, New Delhi.
2. Collier, B.J. and Tortora, P.G. 2001. Understanding Textiles. 6th Ed. Prentice Hall Inc., New York.

1.12 Suggested Further Reading

1. Gohl, E.P.G. and Vilensky, L.D. 2005. Textile Science. CBS Publishers & Distributors, New Delhi.
2. Sreenivasa Murthy, H.V. 1987. Introduction to Textile Fibres. The Textile Association (India), Mumbai.

1.13 Glossary

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| 1. Ramie | A fine, silky and strong natural bast fibre |
| 2. Asbestos | The only mineral fibre which occurs in nature |
| 3. Carcinogenic | Causing or tending to cause cancer |
| 4. Precipitation | Coagulation |
| 5. Cellulose Xanthate | Obtained by treating cellulose with caustic soda and carbon disulphide |
| 6. Elastomeric yarn | A rubber like yarn which can be stretched like rubber and has excellent recovery |
| 7. Tropical | Pertaining to tropics |