GOVERNMENT POLYTECHNIC,BHADRAK

BRANCH-TEXTILE ENGINEERING DEPT.

SEM-3RD

SUBJECT- TH-1 FIBER SCIENCE

PREPARED BY- SMT. RASHMI REKHA PATEL,

SR. LECT. GD&DM

PAGES- 1-13

MODULE-1

1.1 Basic concept on Polymer and classification

What Are Polymers?

A **polymer** is a large molecule or a macromolecule, which essentially is a combination of many subunits. The term polymer in Greek means 'many parts'. Polymers can be found all around us, from the strand of our DNA, which is a naturally occurring biopolymer, to polypropylene which is used throughout the world as plastic.

Polymers can be naturally found in plants and animals (**natural polymers**) or can be human-made (**synthetic polymers**). Different polymers have a number of unique physical and chemical properties, due to which they find usage in everyday life.

Classification of Polymers

Polymers cannot be classified under one category because of their complex structures, different behaviours and vast applications. We can, therefore, classify polymers based on the following norms.

Classification of Polymers Based on the Source of Availability

There are **three types of classification** under this category, namely, natural, synthetic, and semi-synthetic polymers.

Natural Polymers

They occur naturally and are found in plants and animals. For example, proteins, starch, cellulose and rubber. To add up, we also have biodegradable polymers called biopolymers.

Semi-synthetic Polymers

They are derived from naturally occurring polymers and undergo further chemical modification. For example, cellulose nitrate and cellulose acetate.

Synthetic Polymers

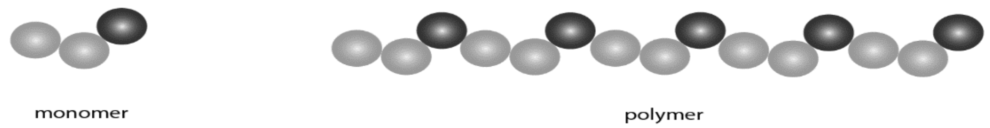
These are human-made polymers. Plastic is the most common and widely used synthetic polymer. It is used in industries and various dairy products. For example, nylon-6, 6, polyether, etc.

Monomer Definition and Examples

A monomer is a molecule that forms the basic unit for polymers, which are the building blocks of proteins. Monomers bind to other monomers to form repeating chain molecules through a process known as polymerization. Monomers may be either natural or synthetic in origin.

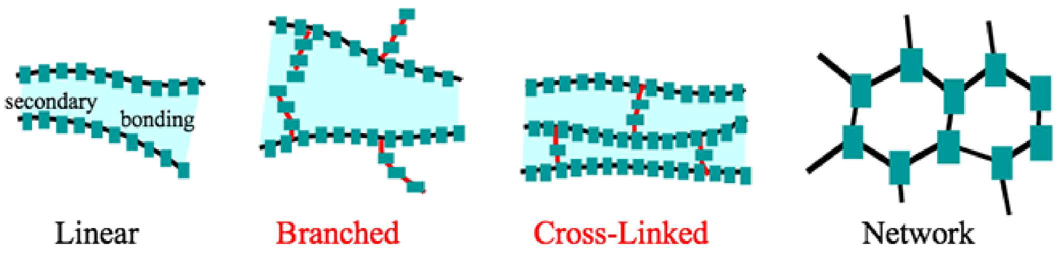
Examples of Monomers

Glucose, vinyl chloride, amino acids, and ethylene are examples of monomers. Each monomer may link in different ways to form a variety of polymers. In the case of glucose, for example, glycosidic bonds may link sugar monomers to form such polymers as glycogen, starch, and cellulose.



Classification of Polymers Based on the Structure of the Monomer Chain

This category has the following classifications:



Linear Polymers

The structure of polymers containing long and straight chains falls into this category. PVC, i.e., polyvinyl chloride, is largely used for making pipes, and an electric cable is an example of a linear polymer.

Branched-chain Polymers

When linear chains of a polymer form branches, then such polymers are categorised as branched chain polymers. For example, low-density polythene.

Cross-linked Polymers

They are composed of bifunctional and trifunctional monomers. They have a stronger covalent bond in comparison to other linear polymers. Bakelite and melamine are examples of cross-linked polymers.

Other Ways to Classify Polymers

Classification Based on Polymerization

- **Addition Polymerization:** For example, poly ethane, Teflon, polyvinyl chloride (PVC), etc.
- **Condensation Polymerization:** Examples include nylon -6, 6, perylene, polyesters, etc.

Classification Based on Monomers

- **Homomer:** In this type, a single type of monomer unit is present. For example, polyethene.
- **Heteropolymer or co-polymer:** It consists of different types of monomer units. For example, nylon -6, 6.

Classification Based on Molecular Forces

- **Elastomers:** These are rubber-like solids, and weak interaction forces are present in them. For example, rubber.
- **Fibres:** Strong, tough, high tensile strength and strong forces of interaction are present. For example, nylon -6, 6.

- **Thermoplastics:** These have intermediate forces of attraction. For example, polyvinyl chloride.
- **Thermosetting polymers:** These polymers greatly improve the material's mechanical properties. It provides enhanced chemical and heat resistance. For example, phenolics, epoxies and silicones.

1.2 Degree of polymerization.

What is polymerization?

A process of making the monomer molecules react together in a chemical reaction and produce three-dimensional networks or polymer chains is called polymerization.

Degree of polymerization (n)

A number of the repeating unit of the monomer is called as the degree of polymerization.

The length of the polymer is most important. All fibres, both man-made and natural, have long to extremely long polymers. The length of a polymer can be obtained by determining its degree of polymerization. This is often abbreviated DP and defined by the following mathematical expression:

$$D.P. = \frac{Average\ molecular\ weight\ of\ polymer}{Molecular\ weight\ of\ the\ repeating\ unit\ in\ the\ polymer}$$

1.3 Brief idea on different polymerization methods

TYPES OF POLYMERISATION:

The process of polymerization is still unknown for natural fibers like cotton, flax, wool and silk. But the polymerization in the case of regenerated and synthetic fiber is well studied. The man-made or regenerated fibers, polymerization is of two types: addition and condensation.

ADDITION POLYMERISATION:

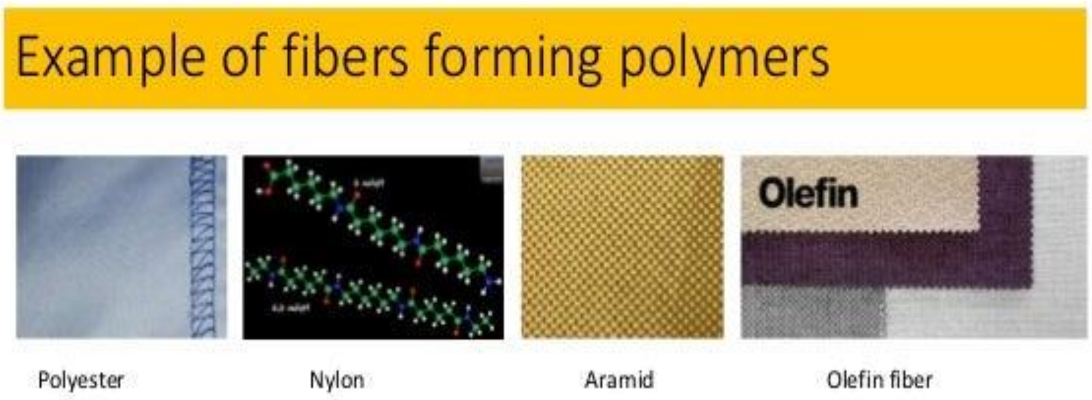
Addition polymerization is also referred to as chain-growth polymer formation. As the name suggests, addition polymerization is a process by which two identical monomers add or combine end-to-end without producing any by-product.

The fibers which undergo addition polymerization are acrylic, modacrylic, polypropylene, polyethylene, and polyvinyl chloride.

CONDENSATION POLYMERISATION:
Condensation polymerization is also referred to as step-growth polymer formation. This type of polymerization involves the end-to-end joining of two different monomers and produces by-product. Water and sometimes hydrogen chloride or ammonia, depending on the monomer involved, are some of the by-products liberated as a result of condensation polymerization.

1.4 Features of fibre forming polymers

- Fiber forming polymers are linear macromolecules that are usually suitable for making man-made fibers.
- The term "Synthetic fiber" will be used to denote all made-made fibers manufactured from non cellulosic raw materials.
- Synthetic fibers are the result of extensive research by scientists to improve on naturally occurring animal and plant fibers.
- Example- Hydrophobic-polymer fibers like nylon and polyester are often blended with cotton, viscose or wool.



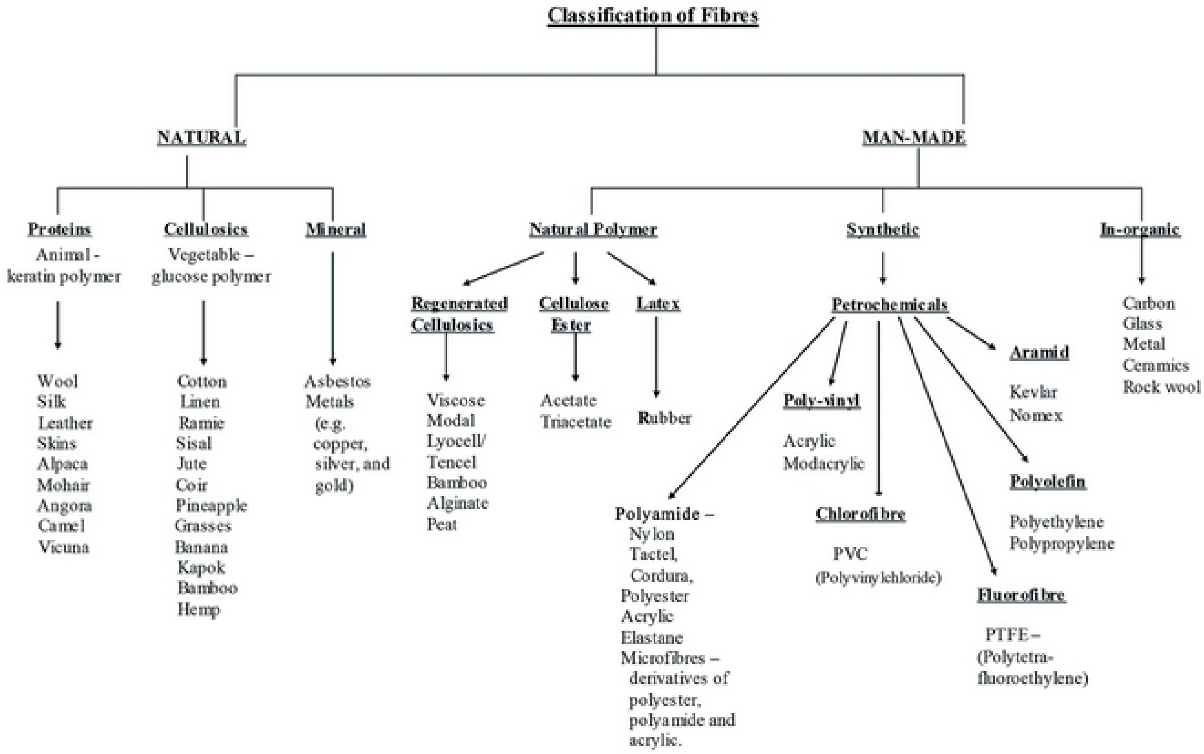
1.5 Concept of fibre & Classification of textile grade fibres.

Definition of Textile Fibre:

A textile fibre is a strand of material that is used to make textiles. Textile fibres are the basic raw materials used to produce **textiles**. They are long, thin strands that can be spun or extruded into yarns or threads and then woven, knitted, or pressed into fabrics. Textile fibres can be natural or synthetic, and each type of fibre has unique properties that determine its suitability for different types of textiles. In this article I will discuss classification of textile fibres.

Classification of Textile Fibres:

Textile fibres classification means to the categorization of fibres based on their origin, chemical composition, and physical properties. The classification of textile fibres can be done in a number of ways.



Textile fibres can be classified into two main categories: natural fibres and synthetic fibres.

Natural fibres:

Natural fibres are fibres that are obtained from plants, animals, and minerals. Examples of natural fibres include cotton, wool, silk, flax, hemp, jute, and ramie. These fibres are used to make a wide range of products, including textiles, paper, and building materials. They are also used in the production of bioplastics and biocomposites. Natural fibres are renewable, biodegradable and are considered as an eco-friendly alternative to synthetic fibres.

Natural fibres can be classified into several categories based on their origin and properties. Some common classifications of natural fibers include:

1. Plant fibres: These fibres are obtained from plants, such as cotton, linen, hemp, and jute.
2. Animal fibres: These fibres are obtained from animals, such as wool, silk, cashmere, and alpaca.
3. Cellulosic fibres: These fibres are derived from plant cell walls, such as cotton, linen, and hemp.
4. Protein fibres: These fibres are derived from animal hair or secretions, such as wool, silk, and cashmere.
5. Bast fibres: These fibres are obtained from the stem of certain plants, such as flax, hemp, and jute.
6. Leaf fibres: These fibres are obtained from leaves of certain plants, such as sisal and abaca.
7. Seed fibres: These fibres are obtained from seeds, such as cotton and kapok.

Some fibres may fit into more than one classification. For example, cotton is a plant fibre and a cellulosic fibre.

Man-made fibres:
Man-made fibers, also known as synthetic fibres are fibres that are artificially created from chemical compounds. These fibres are not naturally occurring and are typically manufactured from petroleum-based products. Examples of synthetic fibres include polyester, nylon, acrylic, and spandex. These fibres are often used to make a wide range of products, including clothing, upholstery, and industrial materials. Synthetic fibres are known for their durability, strength, and resistance to shrinking and wrinkling, which makes them popular for use in clothing and other textiles. They are also less expensive to produce than natural fibres, which makes them more cost-effective for many applications. However, they are not biodegradable and also require a significant amount of energy to produce which makes them environmentally unfriendly.

Synthetic fibres can be classified based on their chemical composition and manufacturing process. Some common classifications include:

1. Polymer fibres: These fibres are created by polymerization of synthetic monomers, such
2. as polyester, nylon, and acrylic.
3. Glass fibres: These fibres are made from glass and are known for their high strength and low thermal expansion.
4. Carbon fibres: These fibres are made from carbon and are known for their high strength, low weight and thermal stability.
5. Metal fibres: These fibres are made from metal, such as stainless steel and are known for their high strength and thermal stability.
6. Aromatic polyamide fibres: These fibres are made from aromatic polyamides and are known for their high strength, thermal stability, and chemical resistance.
7. Viscose rayon fibres: These fibres are made from cellulose and are known for their softness, drapability and ability to absorb moisture.
8. Acetate fibres: These fibres are made from cellulose acetate and are known for their softness, drapability and luster.
9. Modal fibres: These fibres are made from beech tree pulp and are known for their softness, drapability and moisture-wicking properties.

1.6 Concept of staple fibre and filament

Staple fibre is a type of fibre that is relatively short in length and is usually measured in millimetres or inches. Staple fibres are typically used in the textile industry to produce fabrics, clothing, and other textile products. Unlike filament fibres, which are long and continuous, staple fibres are shorter and can be twisted or spun together to form yarn.

Natural Staple Fibres
Natural staple fibres come from plants or animals and are typically more expensive than synthetic staple fibres.

Cotton
Cotton is a natural staple fibre that comes from the cotton plant. It is one of the

most commonly used fibres in the textile industry, thanks to its softness, breathability, and versatility.

Wool
Wool is a natural staple fibre that comes from sheep or other animals such as alpacas, llamas, or goats. It is used in a variety of applications, including clothing, carpets, and blankets.

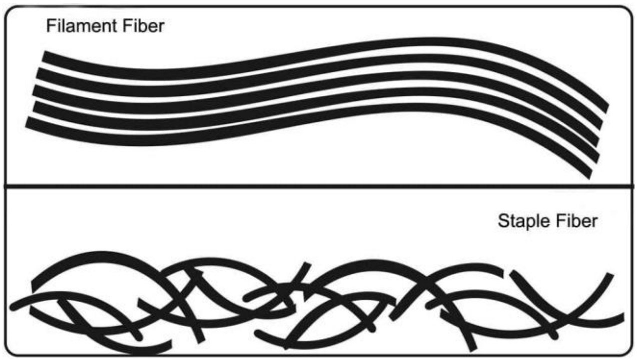
Silk
Silk is a natural staple fibre that comes from the cocoons of silkworms. It is prized for its softness, lustre, and strength and is often used in high-end clothing and accessories.

Synthetic Staple Fibres
Synthetic staple fibres are made from chemical substances and are typically less expensive than natural staple fibres.

Polyester
Polyester is a synthetic staple fibre that is commonly used in the textile industry. It is known for its durability, resistance to wrinkles, and low cost.

Nylon
Nylon is another synthetic staple fibre that is widely used in the textile industry. It is known for its strength, elasticity, and resistance to abrasion.

Rayon
Rayon is a synthetic staple fibre that is made from cellulose. It is often used as a substitute for silk or cotton in clothing and other textiles.



What is filament fiber in textile?

All fibers that have a practically unlimited length are considered filaments. In other words, filament fibers are continuous fiber. Natural filament fibers are rare, but the silk is a good example: as a material in filament form, silk is reeled from cocoons.

Examples of filament fibres & staple fibres. Most natural fibres, such as cotton and wool, are staple fibres and this is what gives polo shirt fabric its texture.

Synthetic fibres, such as nylon and polyester are filament fibres, which is why these fabrics tend to be smoother.

1.7 State the essential & desirable properties of Textile grade fibre.

What is Textile Fibre?

Generally textile fibre is a raw materials for textile finished products. If we define textile fibre then we can say, a textile fibre is a fine single filament which is used in making of yarns and thread which comprise of the basic component of all textile items- such as fabrics, mats, strings, cords, twines and ropes. It is defined as a fine strand of tissue of plant, animal or any synthetic material drawn out into filament and subsequently cut into required length. Many fibrous materials are not suitable to make into fabrics, e.g., corn silk or wood slivers.

Properties / Characteristics of a Good Textile Fibre:

Textile fibres are perhaps most obviously characterised by their fineness; they are long and very thin. There are numerous fibrous structures in nature, but only those that can be converted into yarns are suitable for constructing textile fabrics. Textile fibers are used for a wide range of applications, but in order for them to be useful, they must possess adequate properties in various categories. To be designated as a textile fiber any material should satisfy two important characteristics, namely, the essential or the primary properties and the desirable or the secondary properties.

Essential / Primary Properties of Textile Fibres:

1. Fibre Length
2. Fibre Strength and related properties
3. Fibre Flexibility
4. Fibre Cohesiveness

Desirable / Secondary Properties of Textile Fibres:

1. Fineness
2. Resiliency
3. Colour
4. Uniformity
5. Porosity
6. Lustre
7. Durability
8. Commercial availability
9. Trash Content

Essential / Primary properties of textile fibres:

Fibre length, strength, cohesiveness and flexibility are the four essential textile fibres properties.

1. Fibre Length: This is the most important property, along with its strength. Most natural textile fibres exist as staple fibres and their length varies considerably. For example, the lengths of cotton fibres range from 12 to 36 mm (depending on the quality), whilst those of wool fibres range from 50 to 400 mm. If a fibre is to be spun into yarn, there needs to be a minimum fibre length of 5 mm. It is because with the traditional spinning methods, it is not possible to spin the yarn below this length. The length alone does not suffice the purpose. In addition, its relation to fibre thickness is equally important. The length to diameter (thickness) ratio needs to be at least a hundred times. Many a time, another indicator called "uniformity ratio" is also used. It is the ratio of the mean length of the fibre (50% span length) to its upper half mean length (2.5% span length), expressed as percentage.

The characteristics of yarns depend on the staple fibre length. A fluffy, spongy yarn with a soft handle is obtained from shorter fibres, where many loose ends remain disoriented in the yarn. Fibres with longer staple lengths give smoother, finer yarns with a higher lustre and higher strength.

2. Fibre Strength: Strength of any material is derived from the load it supports at break and is thus a measure of its limiting load bearing capacity. Normally strength of a textile fibre is measured in tension when the fibre is loaded along its long axis and is designated as Tensile strength.

Mechanical properties have an important bearing on the end uses to which fibres can be put. Strength gives the fibre the ability to withstand the stress-strain caused during its conversion to yarn and fabrics. Certain fibres such as Kapok not only have very short length but also lack adequate strength. The strength is measured as force per unit cross-section when fiber breaks and is expressed as g/d, g/tex or cN/tex. When the two different fibres are to be blended, it is very important to select the components so that they have matching stress-strain curves. When the yarns are spun with this criterion, the two component fibres share the load almost equally.

3. Fibre Flexibility: One of the most important operations in yarn forming is twisting. It binds the fibres together to form a yarn having worthwhile strength. During twisting operations, the fibres are strained. The ability of the fibre to try to spring back is flexibility. It makes the fibre pliable.

4. Fibre Cohesiveness: The fibres as a bundle finally make the yarn. The ability of the fibres to form the yarn depends upon their cohesive action to hold on to each other. In fact, it is the surface characteristics which give the frictional property to the fibres with which they are able to hold on to the other fibres. The cohesiveness appears in a different form. In cotton, it is due to natural convolutions during their growth. The crimp in the woollen fibres gives them this ability. In man-made fibres, however, this needs to be specially imparted. Viscose is manufactured with serrated cross-section, while polyester fibre is crimped. This is because uncrimped synthetic fibres, as it is, are quite smooth and rod-like structures. In this form, it is very difficult to make them hold together even when twisted.

Desirable / Secondary properties of textile fibres:

Apart from these essential properties, a fibre becomes more useful if it also has some desirable properties. Therefore, even when a yarn can be made with a fibre only having essential properties, a still better yarn can be made when it also possesses some of the following desirable properties.

1. Fineness: The fineness of fibres also has an important bearing on the properties of yarns and fabrics made from them. There are various ways of representing fineness (the count). It is a measure of both the diametric size and linear density of the fibres. In the case of artificially manufactured fibres, the diameter of the fibre is proportional to linear density, except in the case of "hollow" fibres. With natural fibres, the fibre maturity governs the linear density, hence it is customary to define the fibre fineness in terms of weight per unit length with such fibres. The following are some of the units of measure: Micron: 10–4 cm, especially used in the case of wool fibres to specify diameter. Micronaire: It is another measure of judging both the fineness and maturity of the fibres. Micro-grammes per inch: 10–6 grammes per inch for expressing linear density. Tex or Denier – grammes per 1000 m or 9000 m, respectively. This unit is specially used for fibres and filaments There is a lot of variation in diameter (20–30% for wool or silk) in the case of natural fibres, whereas man-made fibres can be manufactured more precisely (3–5% variation only).

2. Resiliency: Fibres exhibit a beautiful property called resiliency. This is disclosed when a fibre is stressed. Here, they try to yield; and when the stress is removed, they try to spring back, i.e. recover their shape and size. Fibres like wool show excellent resilience. During the twisting operation, this property of resiliency becomes very useful when fibres try to regain their original state. Under this condition, a constant pressure is experienced by the inner mass of the fibres, and it helps in holding the inner mass and the peripheral fibres together.

3. Colour: The colour of the cotton is judged by two parameters – Degree of Reflectance (Rd) and Yellowness (+b). While degree of reflectance shows the brightness, yellowness depicts the degree of cotton pigmentation. The colour gets affected by atmospheric conditions, impact of insects, fungi, type of soil and storage conditions. There are five recognized groups – White, Gray, Spotted, Tinged and Yellow-stained.

4. Uniformity: The artificial fibres can be very precisely manufactured as for their weight per unit length and length itself. But, it is not so with natural fibres. Therefore, in spite of the same growing conditions, natural fibres greatly vary in their size and length. Silk, when formed during cocoon formation, greatly varies in its size. Fibres like cotton have large variation, both in terms of linear density and length. **Flax fiber** and jute fibres are much stronger natural fibres, but the fibre dimensions greatly vary, thus producing uneven yarn and fabric.

5. Porosity: The property of absorbing moisture or any liquid within the fibre arises owing to its porous nature. With the natural fibres, the amorphous and crystalline regions vary in their dimensions. It is the amorphous regions that give the fibre property of absorption. With man-made fibres, the drawing operation improves the crystalline regions, thus imparting strength. However, their absorption capacity is much limited.

6. Lustre: Among the natural fibre, silk is probably the one having maximum lustre. Egyptian cotton has natural silky lustre. Lustre as such is not essential, but when a fibre possesses pleasing lustre, it adds to the appearance. The process of mercerization helps in imparting round shape to the cotton yarns and in improving its lustre. Almost all man made fibers show far better lustre than many of the natural fibres. However, the glittering reflection of light is not very pleasant. In fact, for this, in some cases, the fibre-dulling process is followed during the manufacture of some man-made fibres.

7. Durability: As mentioned earlier, during the conversion of fibre to finished fabric, the fibre, the yarn and subsequently the fabric have to undergo pro-cessing, which puts a lot of strain on them. The fibres and their subsequent forms, therefore, should possess durability to sustain these stresses. Even the normal washing/laundering processes or exposure to light and heat require some resistance. The adverse effects of chemicals like alkalis/acids/bleaching agents and bacterial attacks have to be fought against. Fibre durability counts in all such cases.

8. Commercial Availability: The supply of regular raw material in the form of fibres is another important criterion. When a particular variety of raw material is not available in plenty, the fibre-processors are forced to switch over to another variety to continue manufacture of the same variety of the goods. The commercial availability is thus another desirable characteristic.

9. Trash Content: It is the non-lint material in the bale cotton and is required to be removed before spinning the yarn. Similarly, in all other natural fibres, there is useless and unwanted content. The higher trash content in cotton or in other natural fibres is, therefore, always a problem. Especially in better grade cottons, the high trash content is a huge problem. The trash content in cotton is highly related to leafy vegetable matter, dirt and dust. Normally, the trash content in the different types of cotton varies greatly from 1% to 6–8%.

Prepared by-Smt. Rashmi Rekha Patel, Sr. lect. G.D.& D.M
Reference & sources- Textile journals & internet