BASIC OF TEXTILES

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Directorate of Distance Education

SWAMI VIVEKANAND SUBHARTI UNIVERSITY

MEERUT 250005

UTTAR PRADESH

SIM MOUDLE DEVELOPED BY:

Reviewed by the study Material Assessment Committed Comprising:

1. Dr. N.K.Ahuja, Vice Chancellor

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UNIT

1

FIBER STUDY

STRUCTURE

1.1 LEARNING OBJECTIVE

After studying this unit you should be able to:

- Describe the Natural Fiber.
- Explain the meaning and significance of Monomer.
- Explain the procedure of Polymerization.
- Describe the technology for Degree of Polymerization.
- Explain the Basic Textile Fiber Properties.
- Explain the meaning and significance of Properties of Textile Fibers.
- Explain the Classification of Textile Fibers.

1.2 INTRODUCTION

Fabric surface properties are important because of their psychological and physical effects on a person's appreciation of a fabric. The sensations perceived from the contact of clothing with the skin can greatly influence the overall feeling of comfort. The subjective feeling of fabric is a complex result of psychological and physiological responses of the human body and physical properties of the fabric. Fabric characteristics such as fiber type, thread linear density, thread density, weave type and yarn twist affect how a fabric feels to the touch. Surface properties also help in perception of the smoothness and crispness of the fabric. Geometrical roughness is another important factor affecting perceived softness of a fabric.

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In the determination of fabric handle, fabric smoothness/roughness plays an important role. This is evaluated by friction and surface unevenness measurements. The physical parameters taken into account to estimate the fabric handle are coefficient of friction and geometrical roughness of the fabric surface. These two parameters influence fabric abrasion resistance. Abrasion is basically the wearing away of any part of a material by rubbing against another surface. Textile materials become unserviceable due to abrasive wear. Abrasive wear is caused mainly due to friction between the fabric and solid objects in contact with fabric, the wearer's body and environmental particles such as dust and grit. It is important to consider abrasion and friction characteristics from a mechanical damage point of view which subsequently results in the loss of aesthetic and physical fabric quality.

- **Materials:** Materials refer to the basic components of textile production, the source components of the fabric.
- **Natural Fiber -** These are textiles created from raw materials found in nature. While humans may alter these materials through treatments and dyes, they originate in the natural world. Examples include wool, cotton, leather, silk, jute, and even asbestos which comes from a mineral.
- **Synthetic Fiber -** These are textiles that are woven from man-made materials, often from a petroleum and plastic base. They include common fabrics like polyester and rayon.

Natural and Synthetic Sources

- **Components:** From the production materials, textile producers create components of fabric.
- **Fibers -** This is the basic component of any textile. Fibers are small, hair-like strands of natural or synthetic material that is bound together to create yarns thick enough to weave.
- **Yarn -** Yarn is not just the skeins you buy in the craft store. In textile design and production, yarn refers to any long strand of fibers bound together for the purpose of weaving or knitting into cloth.
- **Blend -** Blends are yarns made from fibers of two or more different materials and may include both natural and synthetic fibers.

- **Selvage -** When weaving the cloth, manufacturers use a stronger yarn, more tightly woven to avoid unraveling of the finished fabric. This is usually a very narrow band that is discarded when cutting pattern pieces.

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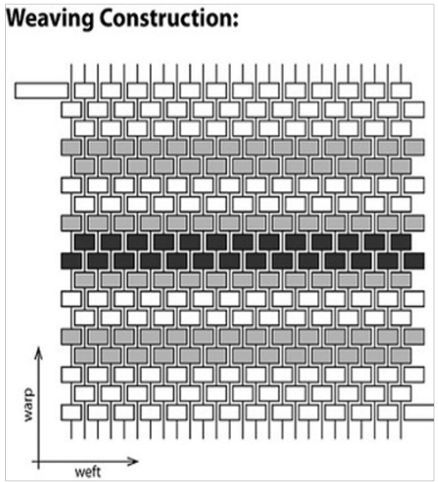
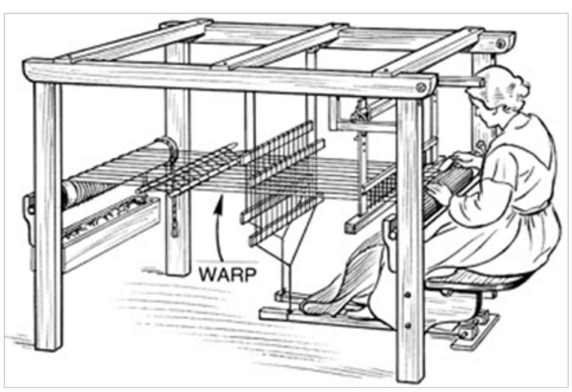


Warp and Weft Strands

- **Warp -** In a basic weave, yarns are interlaced in a horizontal and vertical pattern. The warp includes all the yarn strands running the length of the fabric, parallel to the selvage. These are stronger and more prominent than the weft yarns.
- **Weft -** In a woven fabric, these strands of yarn run the width of the cloth, perpendicular to the warp strands and the selvage. These are usually weaker yarns than the warp strands.
- **Yardage -** This term refers to the length of any piece of fabric.

Production: This section introduces terms necessary to understanding how a textile is produced from the parts of fibers and yarns.

- **Weave -** This refers to both the process of combining yarns by intertwining warp and weft strands as well as the pattern used to intertwine them. There are three basic patterns (plain, satin, and twill) which we will define later.



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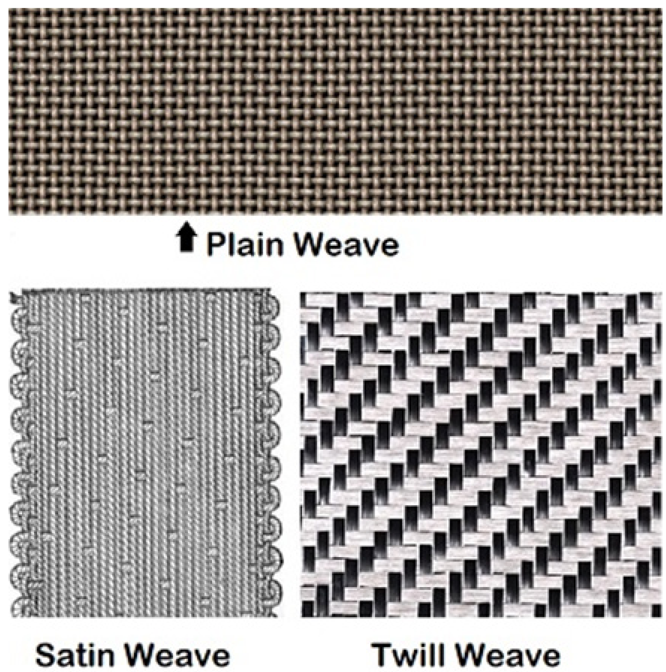
Loom

- **Loom -** This is the device used to weave fabrics, holding the warp strands of yarn while interlacing the weft strands using a shuttle. For a manual loom, people physically move the weft strands in place, but most fabric production today uses mechanical looms.
- **Beating-**Up - This is the final step of loom production where the last strand is beaten into position to create a tightly woven end.
- **Greige Fabric (pronounced greyzh) -** This is a fabric fresh off the loom before subjected to any finishing processes of treating or dying.

Weaves: As promised, we will now address the three main types of weaves, known as plain, satin, and twill.



- **Plain Weave -** This is the most basic weave pattern in which weft strands alternate passing over a warp strand, then under the next warp strand.

1.3 MONOMER, POLYMER, DEGREE OF POLYMERIZATION

Functionally monomer plays a good role to form by the monomer. The size of polymer is also related to monomer. If many monomers add with each other they produce a big polymer. The molecular weight of

1. Polymer is forming by the adding of monomer.

2. Monomer gives the size of a polymer.

3. Molecular weight of a polymer is related to monomer.

Monomer

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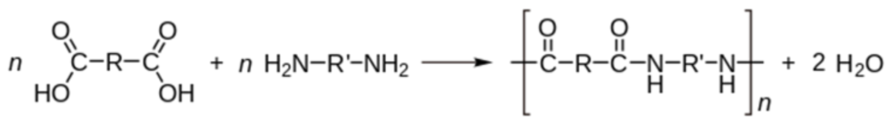
A monomer is a molecule that can react together with other monomer molecules to form a larger polymer chain or three-dimensional network in a process called polymerization.

- **Monomer molecule:** A molecule which can undergo polymerization, thereby contributing constitutional units to the essential structure of a macromolecule.

Classification

Monomers can be classified in many ways. They can be subdivided into two broad classes, depending on the kind of the polymer that they form. Monomers that participate in condensation polymerization have a different stoichiometry than monomers that participate in addition polymerization:



This nylon is formed by condensation polymerization of two monomers, yielding water.

Other classifications include:

- natural vs synthetic monomers, e.g. glycine vs caprolactam, respectively
- polar vs nonpolar monomers, e.g. vinyl acetate vs ethylene, respectively
- cyclic vs linear, e.g. ethylene oxide vs ethylene glycol, respectively

The polymerization of one kind of monomer gives a homopolymer. Many polymers are copolymers, meaning that they are derived from two different monomers. In the case of condensation polymerizations, the ratio of comonomers is usually 1:1. For example, the formation of many nylons requires equal amounts of a dicarboxylic acid and diamine. In the case of addition polymerizations, the comonomer content is often only a few percent. For example, small amounts of 1-octene monomer are copolymerized with ethylene to give specialized polyethylene.

Synthetic monomers

- thylene gas ($H_2C=CH_2$) is the monomer for polyethylene.
- Other modified ethylene derivatives include:
- tetrafluoroethylene ($F_2C=CF_2$) which leads to Teflon
- vinyl chloride ($H_2C=CHC_l$) which leads to PVC
- styrene ($C_6H_5CH=CH_2$) which leads to polystyrene
- Epoxide monomers may be cross linked with themselves, or with the addition of a co-reactant, to form epoxy

- BPA is the monomer precursor for polycarbonate
- Terephthalic acid is a comonomer that, with ethylene glycol, forms polyethylene terephthalate.
- Dimethylsilicon dichloride is a monomer that, upon hydrolysis, gives polydimethylsiloxane.
- Ethyl methacrylate is an acrylic monomer that, when combined with an acrylic polymer, catalyzes and forms an acrylate plastic used to create artificial nail extensions

Biopolymers

The term "monomeric protein" may also be used to describe one of the proteins making up a multiprotein complex.

Natural monomers

Some of the main biopolymers are listed below:

Amino acids

For proteins, the monomers are amino acids. Polymerization occurs at ribosomes. Usually about 20 types of amino acid monomers are used to produce proteins. Hence proteins are not homopolymers.

Nucleotides

For polynucleic acids (DNA/RNA), the monomers are nucleotides, each of which is made of a pentose sugar, a nitrogenous base and a phosphate group. Nucleotide monomers are found in the cell nucleus. Four types of nucleotide monomers are precursors to DNA and four different nucleotide monomers are precursors to RNA.

Glucose and related sugars

For carbohydrates, the monomers are monosaccharides. The most abundant natural monomer is glucose, which is linked by glycosidic bonds into the polymers cellulose, starch, and glycogen.

Isoprene

Isoprene is a natural monomer that polymerizes to form natural rubber, most often cis-1,4-polyisoprene, but also trans-1,4-polymer. Synthetic rubbers are often based on butadiene, which is structurally related to isoprene.

Monomer Definition and Examples

The Building Block of Polymers

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.

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Oligomers are polymers consisting of a small number (typically under 100) of monomer subunits. Monomeric proteins are protein molecules that combine to form multi-protein complexes. Biopolymers are polymers consisting of organic monomers found in living organisms.

Because monomers represent a huge class of molecules, they are commonly categorized into various subgroups such as sugars, alcohols, amines, acrylics, and epoxides. The term "monomer" combines the prefix mono-, which means "one," and the suffix -mer, which means "part."

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.

Names for Small Monomers

When only a few monomers combine to form a polymer, the compounds have names:

- **Dimer:** Polymer consisting of two monomers
- **Trimer:** Three monomer units
- **Tetramer:** Four monomer units
- **Pentamer:** Five monomer units
- **Hexamer:** Six monomer units
- **Heptamer:** Seven monomer units
- **Octamer:** Eight monomer units
- **Nonamer:** Nine monomer units
- **Decamer:** 10 monomer units
- **Dodecamer:** 12 monomer units
- **Eicosamer:** 20 monomer units

Monomers and Polymers in Chemistry

A monomer is a type of molecule that has the ability to chemically bond with other molecules in a long chain; a polymer is a chain of an unspecified number of monomers. Essentially, monomers are the building blocks of polymers, which are more complex type of molecules. Monomers—repeating molecular units—are connected into polymers by covalent bonds.

Monomers

The word monomer comes from mono- (one) and -mer (part). Monomers are small molecules which may be joined together in a repeating fashion to form more complex molecules called polymers. Monomers form polymers by forming chemical bonds or binding supramolecularly through a process called polymerization.

Sometimes polymers are made from bound groups of monomer subunits (up to a few dozen monomers) called oligomers. To qualify as an oligomer, the properties of the molecule need to change significantly if one or a few subunits are added or removed. Examples of oligomers include collagen and liquid paraffin.

A related term is "monomeric protein," which is a protein that bonds to make a multiprotein complex. Monomers are not just building blocks of polymers, but are important molecules in their own right, which do not necessarily form polymers unless the conditions are right.

Examples of Monomers

Examples of monomers include vinyl chloride (which polymerizes into polyvinyl chloride or PVC), glucose (which polymerizes into starch, cellulose, laminarin, and glucans), and amino acids (which polymerize into peptides, polypeptides, and proteins). Glucose is the most abundant natural monomer, which polymerizes by forming glycosidic bonds.

Polymers

The word polymer comes from poly- (many) and -mer (part). A polymer may be a natural or synthetic macromolecule comprised of repeating units of a smaller molecule (monomers). While many people use the term 'polymer' and 'plastic' interchangeably, polymers are a much larger class of molecules which includes plastics, plus many other materials, such as cellulose, amber, and natural rubber.

Lower molecular weight compounds may be distinguished by the number of monomeric subunits they contain. The terms dimer, trimer, tetramer, pentamer, hexamer, heptamer, octamer, nonamer, decamer, dodecamer, eicosamer reflects molecules containing 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, and 20 monomer units.

Examples of Polymers

Examples of polymers include plastics such as polyethylene, silicones such as silly putty, biopolymers such as cellulose and DNA, natural polymers such as rubber and shellac, and many other important macromolecules.

Groups of Monomers and Polymers

The classes of biological molecules may be grouped into the types of polymers they form and the monomers that act as subunits:

- **Lipids -** polymers called diglycerides, triglycerides; monomers are glycerol and fatty acids
- **Proteins -** polymers are known as polypeptides; monomers are amino acids
- **Nucleic Acids -** polymers are DNA and RNA; monomers are nucleotides, which are in turn consist of a nitrogenous base, pentose sugar, and phosphate group
- **Carbohydrates -** polymers are polysaccharides and disaccharides*; monomers

are monosaccharides (simple sugars)

*Technically, diglycerides, and triglycerides are not true polymers because they form via dehydration synthesis of smaller molecules, not from the end-to-end linkage of monomers that characterizes true polymerization.

How Polymers Form

Polymerization is the process of covalently bonding the smaller monomers into the polymer. During polymerization, chemical groups are lost from the monomers so that they may join together. In the case of biopolymers of carbohydrates, this is a dehydration reaction in which water is formed.

Polymers are made up of various molecules that combine together to form long chains. Polymers usually have high melting and boiling points like PVC (poly vinyl chloride), polystyrene, cellulose. These simple molecules which bind to form polymers are known as monomers.

Monomers are the building blocks of more complex molecules, called polymers. Therefore, we can say that a monomer is a molecule that forms the basic unit for polymers and they bind with other monomers to form a repeating chain molecule. Like glucose, vinyl chloride, amino acids, etc.

Characteristics of polymers are:

a) They are made, by addition or by condensation.

b) They are homopolymers or heteropolymers (co-polymers).

c) They are thermoplastics, thermosets, elastomers or fibres.

d) Have a steric structure.

Important Synthetic fibers

List of Some common man-made Polymers and their Uses:

S. No.	**Polymer**	**Use**
1.	Polythene	Packaging, material, carry bags, bottles.
2.	Teflon	Nonstick Kitchen ware
3.	Polypropene	Bottles, Crates
4.	Melamine	Crockery
5.	Polyvinyl chloride (PVC)	Pipes Insulation
6.	Lexan	Bullet proof glass
7.	Vinyl rubber	Rubber erasers
8.	Bakelite	Electrical insulation buttons
9.	Polystyrene	Foam Thermocole
10.	Poly (Styrene butadiene)	Rubber bubble gum

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11.	Nylon (Polyester)	Fibres, ropes
12.	Luminous Paints	Glow when exposed to light. They are applied on a surface to protect it from corrosion and weathering.
13.	Antimicrobial polymers (polymeric biocide)	The ability to inhibit the growth of microorganisms
14.	Antigen	Substance capable of stimulating formation of antibodies.
15.	Antipyretie	A substance used to lower body temperature.
16.	Pesticides	Used to kill animals
17.	Para-aramid fibre (Kevlar)	Manufacturing armour, sports and musical equipment. Used in the field of cryogenics.
18.	Polyacrylonitrile (PAN) (Orlon)	Used for making clothes and fabrics like sweaters, hats,rugs, etc
19.	Copolyamid (Technora)	Used for manufacturing optical fiber cables, drumheads, automotive industry, ropes, wire ropes and cables.
20.	Polytetrafluoroethylene (PTFE)(Viton)	Viton B is used in chemical process plants and gaskets. As it depends upon the grade of the polymer.

We have seen the list of polymers with their uses. **But one question arises in my mind that how polymers are formed**.

They are formed with the help of a process known as **polymerization**. It is the process of binding smaller monomers into the polymers by a covalent bond. During polymerization, chemical groups are lost from the monomers so that they may join together. In the case of biopolymers of carbohydrates, this is a dehydration reaction in which water is formed.

Polyester and Our Health

Polyester is a very popular fabric choice – it is, in fact, the most popular of all the synthetics. Because it can often have a synthetic feel, it is often blended with natural fibers, to get the benefit of natural fibers which breathe and feel good next to the skin, coupled with polyester's durability, water repellence and wrinkle resistance. Most sheets sold in the United States, for instance, are cotton/poly blends.

It is also used in the manufacture of all kinds of clothing and sportswear – not to mention diapers, sanitary pads, mattresses, upholstery, curtains and carpet. If you look at labels, you might be surprised just how many products in your life are made from polyester fibers.

So what is this polyester that we live intimately with each day?

At this point, I think it would be good to have a basic primer on polyester production, and I've unabashedly lifted a great discussion from Marc Pehkonen and Lori Taylor, writing in their website diaperpin.com:

Basic polymer chemistry isn't too complicated, but for most people the manufacture of the plastics that surround us is a mystery, which no doubt suits the chemical producers very well. A working knowledge of the principles involved here will make us more informed users.

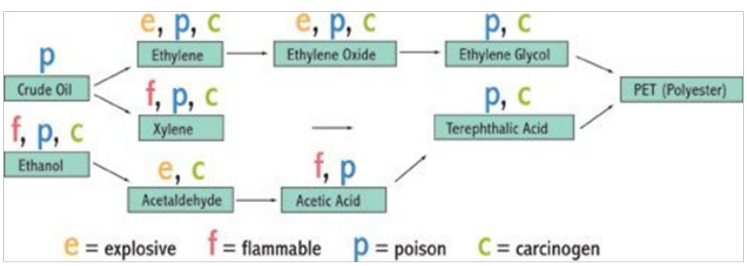
Polyester is only one compound in a class of petroleum-derived substances known as polymers. Thus, polyester (in common with most polymers) begins its life in our time as crude oil. Crude oil is a cocktail of components that can be separated by industrial distillation. Gasoline is one of these components, and the precursors of polymers such as polyethylene are also present.

Polymers are made by chemically reacting a lot of little molecules together to make one long molecule, like a string of beads. The little molecules are called monomers and the long molecules are called polymers.

Like this:

O + O + O + . . . makes OOOOOOOOOOOOOOOO

Depending on which polymer is required, different monomers are chosen. Ethylene, the monomer for polyethylene, is obtained directly from the distillation of crude oil; other monomers have to be synthesized from more complex petroleum derivatives, and the path to these monomers can be several steps long. The path for polyester, which is made by reacting ethylene glycol and terephthalic acid, is shown below. Key properties of the intermediate materials are also shown.



The polymers themselves are theoretically quite unreactive and therefore not particularly harmful, but this is most certainly not true of the monomers. Chemical companies usually make a big deal of how stable and unreactive the polymers are, but that's not what we should be interested in. We need to ask, what about the monomers? How unreactive are they?

We need to ask these questions because a small proportion of the monomer will never be converted into polymer. It just gets trapped in between the polymer chains, like peas in spaghetti. Over time this unreacted monomer can escape, either by off-gassing into the atmosphere if the initial monomers were volatile, or by

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dissolving into water if the monomers were soluble. Because these monomers are so toxic, it takes very small quantities to be harmful to humans, so it is important to know about the monomers before you put the polymers next to your skin or in your home. Since your skin is usually moist, any water-borne monomers will find an easy route into your body.

Polyester is the terminal product in a chain of very reactive and toxic precursors. Most are carcinogens; all are poisonous. And even if none of these chemicals remain entrapped in the final polyester structure (which they most likely do), the manufacturing process requires workers and our environment to be exposed to some or all of the chemicals shown in the flowchart above. There is no doubt that the manufacture of polyester is an environmental and public health burden that we would be better off without.

What does all of that mean in terms of our health? Just by looking at one type of cancer, we can see how our lives are being changed by plastic use:

- The connection between plastic and breast cancer was first discovered in 1987 at Tufts Medical School in Boston by
- research scientists Dr. Ana Soto and Dr. Carlos Sonnenschein. In the midst of their experiments on cancer cell growth, endocrine-disrupting chemicals leached from plastic test tubes into the researcher's laboratory experiment, causing a rampant proliferation of breast cancer cells. Their findings were published in Environmental Health Perspectives (1991).
- Spanish researchers, Fatima and Nicolas Olea, tested metal food cans that were lined with plastic. The cans were also found to be leaching hormone disrupting chemicals in 50% of the cans tested. The levels of contamination were twenty-seven times more than the amount a Stanford team reported was enough to make breast cancer cells proliferate. Reportedly, 85% of the food cans in the United States are lined with plastic. The Oleas reported their findings in Environmental Health Perspectives (1995).
- Commentary published in Environmental Health Perspectives in April 2010 suggested that PET might yield endocrine disruptors under conditions of common use and recommended research on this topic.

These studies support claims that plastics are simply not good for us – prior to 1940, breast cancer was relatively rare; today it affects 1 in 11 women. We're not saying that plastics alone are responsible for this increase, but to think that they don't contribute to it is, we think, willful denial. After all, gravity existed before Newton's father planted the apple tree and the world was just as round before Columbus was born.

- **Polyester fabric is soft, smooth, supple** – yet still a plastic. It contributes to our body burden in ways that we are just beginning to understand. And because polyester is highly flammable, it is often treated with a flame retardant, increasing the toxic load. So if you think that you've lived this long being exposed to these chemicals and haven't had a problem, remember that the human body can only withstand so much toxic load – and that the endocrine disrupting chemicals which don't seem to bother you may be affecting generations to come.

Agin, this is a blog which is supposed to cover topics in textiles: polyester is by far the most popular fabric in the United States. Even if made of recycled yarns, the toxic monomers are still the building blocks of the fibers. And no mention is ever made of the processing chemicals used to dye and finish the polyester fabrics, which as we know contain some of the chemicals which are most damaging to human health.

Polymerization

An example of **alkene polymerization**, in which each styrene monomer's double bond reforms as a single bond plus a bond to another styrene monomer. The product is polystyrene.

In polymer chemistry, **polymerization** (American English), or **polymerisation** (British English), is a process of reacting monomer molecules together in a chemical reaction to form polymer chains or three-dimensional networks. There are many forms of polymerization and different systems exist to categorize them.

In chemical compounds, polymerization can occur via a variety of reaction mechanisms that vary in complexity due to the functional groups present in the reactants and their inherent steric effects. In more straightforward polymerizations, alkenes form polymers through relatively simple radical reactions; in contrast, reactions involving substitution at a carbonyl group require more complex synthesis due to the way in which reactants polymerize. Alkanes can also be polymerized, but only with the help of strong acids.

As alkenes can polymerize in somewhat straightforward radical reactions, they form useful compounds such as polyethylene and polyvinyl chloride (PVC), which are produced in high tonnages each year due to their usefulness in manufacturing processes of commercial products, such as piping, insulation and packaging. In general, polymers such as PVC are referred to as "**homopolymers**," as they consist of repeated long chains or structures of the same monomer unit, whereas polymers that consist of more than one monomer unit are referred to as copolymers (or co-polymers).

Other monomer units, such as formaldehyde hydrates or simple aldehydes, are able to polymerize themselves at quite low temperatures (ca. −80 °C) to form trimers; molecules consisting of 3 monomer units, which can cyclize to form ring cyclic structures, or undergo further reactions to form tetramers, or 4 monomer-unit compounds. Such small polymers are referred to as oligomers. Generally, because formaldehyde is an exceptionally reactive electrophile it allows nucleophilic addition of hemiacetal intermediates, which are in general short-lived and relatively unstable "mid-stage" compounds that react with other molecules present to form more stable polymeric compounds.

Polymerization that is not sufficiently moderated and proceeds at a fast rate can be very hazardous. This phenomenon is known as hazardous polymerization and can cause fires and explosions.

Step-growth v chain growth polymerization

Step-growth and chain-growth are the main classes of polymerization reaction mechanisms. The former is often easier to implement but requires precise control of stoichiometry. The latter more reliably affords high molecular-weight polymers, but only applies to certain monomers.

Step-growth

In step-growth (or step) polymerization, pairs of reactants, of any lengths, combine at each step to form a longer polymer molecule. The average molar mass increases slowly. Long chains form only late in the reaction.

Step-growth polymers are formed by independent reaction steps between functional groups of monomer units, usually containing heteroatoms such as nitrogen or oxygen. Most step-growth polymers are also classified as condensation polymers, since a small molecule such as water is lost when the polymer chain is lengthened. For example, polyester chains grow by reaction of alcohol and carboxylic acid groups to form ester links with loss of water. However, there are exceptions; for example polyurethanes are step-growth polymers formed from isocyanate and alcohol bifunctional monomers) without loss of water or other volatile molecules, and are classified as addition polymers rather than condensation polymers.

Step-growth polymers increase in molecular weight at a very slow rate at lower conversions and reach moderately high molecular weights only at very high conversion (i.e., >95%). **Solid state polymerization** to afford polyamides (e.g., nylons) is an example of step-growth polymerization.

Chain-growth

In chain-growth (or chain) polymerization, the only chain-extension reaction step is the addition of a monomer to a growing chain with an active center such as a free radical, cation, or anion. Once the growth of a chain is initiated by formation of an active center, chain propagation is usually rapid by addition of a sequence of monomers. Long chains are formed from the beginning of the reaction.

Chain-growth polymerization (or addition polymerization) involves the linking together of unsaturated monomers, especially containing carbon-carbon double bonds. The pi-bond is lost by formation of a new sigma bond. Chain-growth polymerization is involved in the manufacture of polymers such as polyethylene, polypropylene, polyvinyl chloride (PVC), acrylate. In these cases, the alkenes $RCH=CH_2$ are converted to high molecular weight alkanes $(-RCHCH_2-)n$ (R = H, CH_3, C_l, CO_2CH_3).

Other forms of chain growth polymerization include cationic addition polymerization and anionic addition polymerization. A special case of chain-growth polymerization leads to living polymerization. Ziegler–Natta polymerization allows considerable control of polymer branching.

Diverse methods are employed to manipulate the initiation, propagation, and termination rates during chain polymerization. A related issue is temperature control, also called heat management, during these reactions, which are often highly exothermic. For example, for the polymerization of ethylene, 93.6 kJ of energy are released per mole of monomer.

The manner in which polymerization is conducted is a highly evolved technology. Methods include emulsion polymerization, solution polymerization, suspension polymerization, and precipitation polymerization. Although the polymer dispersity and molecular weight may be improved, these methods may introduce additional processing requirements to isolate the product from a solvent.

Photopolymerization

Most **photopolymerization** reactions are chain-growth polymerizations which are initiated by the absorption of visible or ultraviolet light. The light may be absorbed either directly by the reactant monomer (direct photopolymerization), or else by a photosensitizer which absorbs the light and then transfers energy to the monomer. In general only the initiation step differs from that of the ordinary thermal polymerization of the same monomer; subsequent propagation, termination and chain transfer steps are unchanged. In step-growth photopolymerization, absorption of light triggers an addition (or condensation) reaction between two comonomers that do not react without light. A propagation cycle is not initiated because each growth step requires the assistance of light.

Photopolymerization can be used as a photographic or printing process, because polymerization only occurs in regions which have been exposed to light. Unreacted monomer can be removed from unexposed regions, leaving a relief polymeric image. Several forms of 3D printing—including layer-by-layer stereolithography and two-photon absorption 3D photopolymerization—use photopolymerization.

Multiphoton polymerization using single pulses have also been demonstrated for fabrication of complex structures using a digital micromirror device.

Polymer ratio

In a given formulation or recipe of a polymer compound, the total amount/parts per hundred of polymer added to prepare certain compound is called **polymer ratio**. It basically refers to the aggregated amount of polymer content within the formulation that may undergo any physical or chemical change during the course of post polymerization or physical heat treatment.

Degree of Polymerization

Degree of polymerization means the number of repeat unit of a polymer molecule for instance if there are 1000 repeat units in polymer molecule. So the degree of **polymerization** (D.P) is 1000.

- **Function of Degree of polymerization:** Degree of polymerization plays a good role in forming a polymer. Because the size of a polymer molecule depends on the number of repeat unit which represent the degree of polymerization so a polymers behavior is also depends on degree of polymerization, the polymer

D.P. is high, its luster, dyeing, and strength as cross degree of polymerization is 2500-3000. So its physical and chemical properly is no good.

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1.4 STUDENT ACTIVITY

1. What is Monomer? Explain the Natural monomers and Synthetic monomers?

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....

2. **What is** Polyester and Our Health? **Explain the** Polymerization?

....
....
....

1.5 PROPERTIES OF FIBER: PRIMARY & SECONDARY

Basic Textile Fiber Properties

There are several primary properties necessary for a polymeric material to make an adequate fiber. Certain other fiber properties increase its value and desirability in its intended end-use but are not necessary properties essential to make a fiber. Such secondary properties include moisture absorption characteristics, fiber resiliency, abrasion resistance, density, luster, chemical resistance, thermal characteristics, and flammability.

Some Primary Properties of Textile Fibers are:

- Fiber length to width ratio,
- Fiber uniformity,
- Fiber strength and flexibility,
- Fiber extensibility and elasticity, and
- Fiber cohesiveness.

How heat affects Textile Fiber's properties

Examples of Fiber Shapes

Heat helps the fiber /fabric to gain certain special qualities at certain times and are also harmful at other times. But under special guidance, heat helps fiber acquire the following characteristics

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- Softening, melting, or decomposition temperatures
- The tendency of the fiber and fabric to shrink when heat-relaxed, or stretch when heated and under tension
- The ability of the fabric to heat set
- The ability of the fabric to function properly at elevated temperatures at one time or repeated use
- The ability of the fabric to function properly at room temperature (or some other lower temperature) after exposure at high temperature for a given period of time

Thermal Properties of Common Fibers

Fiber	Melting Point		Softening Sticking Point		Safe Ironing Temperature	
	°F	°C	°F	°C	°F	°C
Natural Fibers						
Cotton	Nonmelting				425	218
Flax	Nonmelting				450	232
Silk	Nonmelting				300	149
Wool	Nonmelting				300	149
Manmade Fibers						

NOTES

Acetate	446	230	364	184	350	177
Arnel Triacetate	575	302	482	250	464	240

Fiber	**Melting Point**		**Softening Sticking Point**		**Safe Ironing Temperature**	
	°F	**°C**	**°F**	**°C**	**°F**	**°C**
Acrylic			400-490	204-254	300-350	149-176
Aramid	Does not melt, carbonizes above 800F					
Glass			1400-3033			
Modacrylic	410	210	300	149	200-250	93-121
Novoloid	Nonmelting					
Nylon6	414	212	340	171	300	149
Nylon66	482	250	445	229	350	177
Olefin	275	135	260	127	150	66

NOTES

Fiber	Melting Point		Softening Sticking Point		Safe Ironing Temperature	
	°F	°C	°F	°C	°F	°C
Polyester PET	480	249	460	238	325	163
Polyester PCDT	550	311	490	254	350	177
Rayon	Nonmelting				375	191
Saran	350	177	300	149	Do not iron	
Spandex	446	230	347	175	300	149
Vinyon	285	140	200	93	Do not iron	

Density and Moisture Regain of Fibers

Fiber	Density (g/cc)	Moisture Regain
Density: Ratio of weight of a given volume of fiber to an equal volume of water.		
Natural Fibers		

NOTES

Cotton	1.52	7-11
Flax	1.52	12
Silk	1.25	11
Wool	1.32	13-18
Man-made Fibers		
Acetate	1.32	6.0
Arnel Triacrylic	–	3.2

Fiber	**Density (g/cc)**	**Moisture Regain**
Acrylic	1.17-1.18	1.3-2.5
Aramid	1.38-1.44	4.5
Fluorocarbon	2.20	0
Glass	2.49-2.73	0-0.3

NOTES

Modacrylic	1.30-1.37	0.4-4.0
Nylon	1.14	4.0-4.5
Nylon Qiana	1.03	2.5
Olefin	0.91	0.01-0.1
Polyester	1.22/1.38	0.4-0.8

Fiber	**Density (g/cc)**	**Moisture Regain**
Rayon	1.50-1.52	15
Rayon HWM	–	11.5-13
Spandex	1.20-1.22	0.75-1.3

The chemical composition of some common fibers

Type of fiber	**Cellulose**	**Lignin**	**Pentosan**	**Ash**
Seed flax	43-47	21-23	24-26	5

NOTES

Jute (Bast)	45-63	21-26	18-21	0.5-2
Hemp	57-77	9-13	14-17	0.8
Ramie	87-91	–	5-8	–

Type of fiber	**Cellulose**	**Lignin**	**Pentosan**	**Ash**
Kenaf (Core)	37-49	15-21	18-24	0.8
Jute (Core)	41-48	21-24	18-22	–
Abaca	56-63	7-9	15-17	1-3
Sisal	43-62	7-9	21-24	0.6-1
Cotton	85-96	0.7-1.6	1-3	0.8-2

The diameter of Natural and Meltblown Fibers

Material	**Diameter Mean Value (microns)**	**Coeff Variation(%)**
Spider silk	3.57	14.8

NOTES

B. mori Silk	12.90	24.8
Merino Wool	25.50	25.6

Material	**Diameter Mean Value (microns)**	**Coeff Variation(%)**
Polyester	13.30	2.4
Nylon 6 Filament	16.20	3.1
Kevlar 29	13.80	6.1

Effects of Acidds on Common Fibers - Camparison

Fiber	**Effects of Acids**
Acrylic	Resistant to most acids
Modacrylic	Resistant to most acids
Polyester	Resistant to most mineral acids disintegrated by 96% sulphuric
Rayon	Disintegrates in hot dilute and cold concentrated acids

NOTES

Acetate	Soluble in acetic acid, decomposed by strong acids

Fiber	**Effects of Acids**
Triacetate	Similar to acetate
Nylon 66	Decomposed by strong mineral acids, resistant to weak acids
Olefin	Very resistant
Glass	Resists most acids. Etched by hydrofluoric acid and hot phosphoric acid
Cotton	Similar to rayon
Wool	Destroyed by hot sulfuric, otherwise unaffected by acids

Effects to Alkalies on Common Fibers – Camparison

Fiber	**Effects of Alkalies**
Acrylic	Destroyed by strong alkalies at a boil, resists weak alkalies
Modacrylic	Resistant to alkalies

Fiber	Effects of Alkalies
Polyester	Resistant to cold alkalies, slowly decomposed at a boil by strong alkalies
Rayon	No effect by cold, weak alkalies, swells and loses strength in concentrated alkalies
Acetate	Saponified, little effect from cold weak alkalies
Triacetate	Not effected up to pH 9.8,205□ F; better than acetate
Nylon 66	Little or no effect
Olefin	Very resistant
Glass	Attacked by hot weak alkalies and concentrated alkalies
Cotton	Swells when treated with caustic soda but is not damaged
Wool	Attacked by weak alkalies, destroyed by strong alkalies

Effects of Organic Solvents on Common Fibers – Camparison

Fiber	Effects of Organic Solvents
Acrylic	Unaffected

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Modacrylic	Soluble in warm acetone, otherwise unaffected
Polyester	Soluble in some phenolic compounds, otherwise unaffected
Rayon	Unaffected
Acetate	Soluble in acetone, dissolved or swollen by many others
Triacetate	Soluble in acetone, chloroform and swollen by others
Nylon 66	Generally unaffected, soluble in some phenolic compounds
Olefin	Soluble in chlorinated hydrocarbons above 160□
Glass	Unaffected

Fiber	**Effects of Organic Solvents**
Cotton	Resistant
Wool	Generally resistant

Effects of Sunlight on Common Fibers - Camparison

Fiber	**Effects of Sunlight**

NOTES

Acrylic	Little or no effect
Modacrylic	Highly resistant, some loss of strength and discoloration after constant exposure
Polyester	Some loss of strength, no discoloration, very resistant behind glass
Rayon	Generally resistant loses strength after long exposure

Fiber	**Effects of Sunlight**
Acetate	Approximately same as rayon
Triacetate	Resistant loses strength after long exposure
Nylon 66	No discoloration, strength loss after long exposure
Olefin	Very resistant retains 95% strength after 6 months exposure
Glass	None
Cotton	Strength loss on long exposure
Wool	Strength loss, dyeing is affected

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Primary Properties of Textile Fibers

Each fibers has particular properties with help us to decided which particular fiber should be used to suite a particular requirement. Certain fiber properties increase its value and desireability in its intended end-use but are not necessary properties essential to know the individual aspect and specific properties of each kind of fiber.

Fig: Various synthetic fibers

There are several primary properties necessary for a polymeric material to make an adequate fiber.Certain other fiber properties increase its value and desirability in its intended end-use but are not necessary properties essential to make a fiber. Such secondary properties include moisture absorption characteristics, fiber resiliency, abrasion resistance, density, luster, chemical resistance, thermal characteristics, and flammability.

Some Primary Properties of Textile Fibers are:

- Fiber length to width ratio,
- Fiber uniformity,
- Fiber strength and flexibility,
- Fiber extensibility and elasticity, and
- Fiber cohesiveness.

Properties of different fibers:

Properties of Nylon Fiber:

- **Fiber Type :** Nylon
- **Heat :** Melts at 419F to430F.
- **Bleaches & Solvents :** Will bleach.Degrades in mineral acids & oxidizing agents.
- **Acids & Alkalis :** Insoluble in organic solvents Resists weak acids, inert to alkalis. Hydrolyzed by strong acids

- **Abrasion :** Excellent
- **Mildew, Aging & Sunlight :** Excellent resistance to mildew and aging. Prolonged sun exposure can cause degradation.

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Polyethylene Fiber Properties

- **Fiber Type :** Polyethylene
- **Heat :** Melts at 525F
- **Bleaches &Solvents :** Excellent
- **Acids & Alkalis :** Excellent
- **Abrasion :** Good to Poor
- **Mildew, Aging &Sunlight :** Excellent resistance to mildew.

Spandex Fiber Properties / Lycra Properties

- **Fiber Type :** Spandez® / Lycra®
- **Heat :** Sticks at 350-390F. Melts above 500F.
- **Bleaches & Solvents :** Good resistance to oxidizing agents. Poor resistance to bleaches.
- **Acids & Alkalis :** Good
- **Abrasion :** Good in diluted (weak), but degrades in strong acids & bases.
- **Mildew, Aging & Sunlight :** Excellent aging and mildew resistance. Good resistance to sunlight.

Polyester Fiber Properties

- **Fiber Type :** Polyester
- **Heat :** Melts at 500F.
- **Bleaches & Solvents :** ExcellentAcids & Alkalis : Good resistance to weak alkalis & weak acids. Moderate resistance to strong acids & alkali.
- **Abrasion resistance:** Excellent
- **Mildew, Aging & Sunlight :** Excellent resistance to mildew, good aging. Degrades after prolonged exposure to sunlight.

Fiberglass Properties

- **Fiber Type :** Fiberglass
- **Heat :** Does not burn or melt
- **Bleaches & Solvents :** Excellent solvent & bleach resistance.
- **Acids & Alkalis :** Fair
- **Abrasion :** Good
- **Mildew, Aging & Sunlight :** Excellent

Aramid Properties / Kelvar Properties / Nomex Properties / Tarwon

Properties / Technora Properties

- **Fiber Type :** Aramid (Kelvar®, Nomex®, Tarwon®, Technora®)
- **Heat :** Difficult to ignite. Does not burn or melt. Decomposes at 800F to 932F.
- **Bleaches & Solvents :** Poor in bleach.Excellent solvent resistance.
- **Acids & Alkalis :** Good in dilute acids & bases. Poor in strong acids & bases.
- **Abrasion :** Fair to Good
- **Mildew, Aging & Sunlight :** Excellent resistance to mildew & aging. Degrades when exposed to sunlight.

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Flurocarbon Fiber Properties / Teflon Fiber Properties

- **Fiber Type :** Fluorocarbon -Teflon® (PTFE)
- **Heat :** Very heat resistant -350F to 550F. Melts at 620F.
- **Bleaches & Solvents :** Essentially inert to bleaches & solvents
- **Acids & Alkalis :** Excellent but effected by acids & alkali at high temperatures.
- **Abrasion :** Good
- **Mildew, Aging & Sunlight :** Excellent

Fiber Type : Nylon

- **Density (g/cc) :** 1.14
- **Moisture Regain (%) :** 2.8 to 5.0
- **Elongation at Break (%) :** 17 to 45
- **Breaking Tenacity (g/Denier) :** 4.0 to 7.2
- **Initial Modulus (CN/tex) :** 400
- **Thermal Shrinkage (@ 177 C) :** N/A
- **Melting Point (C/F) :** 216/419

Fiber Type : Polyester (PET)

- **Density (g/cc) :** 1.38
- **Moisture Regain (%) :** 0.4
- **Elongation at Break (%) :** 15.3
- **Breaking Tenacity (g/Denier) :** 9.2
- **Initial Modulus (CN/tex) :** 998
- **Thermal Shrinkage (@ 177 C) :** 11.6
- **Melting Point (C/F) :** 256/493

Kevlar Fiber Properties

- **Fiber Type :** Kevlar 29®
- **Density (g/cc) :** 1.44
- **Moisture Regain (%) :** 7

- Elongation at Break (%) : 3.6
- Breaking Tenacity (g/Denier) : 23
- **Initial Modulus (CN/tex) :** 4,900
- **Thermal Shrinkage (@ 177 C) :** < 0.1
- L.O.I. : 28
- **Melting Point (C/F) :** 427/800 T

Fiber Type : Kevlar 49®

- **Density (g/cc) :** 1.44
- **Moisture Regain (%) :** 3.5
- **Elongation at Break (%) :** 2.4
- **Breaking Tenacity (g/Denier) :** 23.6
- **Initial Modulus (CN/tex) :** 7,814
- **Thermal Shrinkage (@ 177 C) :** < 0.1
- **L.O.I. :** 28
- **Melting Point (C/F) :** 427/800 T

Fiber Type : Nomex®

- **Density (g/cc) :** 1.38
- **Moisture Regain(%) :** 4.5
- **Elongationat Break(%) :** 28
- **BreakingTenacity(g/Denier) :** 4.9
- **InitialModulus(CN/tex) :** 839
- **ThermalShrinkage(@ 177 C) :** 0.4
- **L.O.I. :** 29-30
- **MeltingPoint (C/F) :** 371/700 T

Vectran Fiber Properties

- **Fiber Type :** Vectran®
- Density (g/cc) : 1.41
- **Moisture Regain (%) :** < 0.1
- **Elongation at Break (%) :** 3.3
- **Breaking Tenacity (g/Denier) :** 23
- **Initial Modulus (CN/tex) :** 4,635
- **Thermal Shrinkage (@ 177 C) :** < 0.5
- **L.O.I.:** 35
- **Melting Point (C/F) :** 330/625

Fiber Type : Technora®

- **Density (g/cc) :** 1.39
- **Moisture Regain(%) :** 2
- **Elongation at Break(%) :** 4.6

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- **Breaking Tenacity(g/Denier) :** 28
- **Initial Modulus(CN/tex) :** 5,209

Thermal Shrinkage(@ 177 C) : < 0.5

- **L.O.I. :** 35
- **Melting Point (C/F) :** 330/625

Fiber Type : Twaron®

- **Density (g/cc) :** 1.44
- **Moisture Regain (%) :** 6.5
- **Elongation at Break (%) :** 3.6
- **Breaking Tenacity (g/Denier) :** 22.3
- **Initial Modulus (CN/tex) :** 4,900
- **Thermal Shrinkage (@ 177 C) :** < 0.1
- **L.O.I. :** 25
- **Melting Point (C/F) :** 500/932 T

Carbon Fiber Properties / Graphite Properties

- **Fiber Type :** Carbon / Graphite
- **Density (g/cc) :** 1.77 **Moisture Regain(%) :** None
- **Elongation at Break(%) :** 1
- **Breaking Tenacity (g/Denier) :** 21.3
- **Initial Modulus (CN/tex) :** ----
- **Thermal Shrinkage (@ 177 C) :** < 0.1
- **Melting Point (C/F) :** 315/600 T

Fiber Type : Fiberglass E-glass

- **Density (g/cc) :** 2.54
- **Moisture Regain (%) :** None
- **Elongation at Break (%) :** 4.8
- **Breaking Tenacity (g/Denier) :** 15.3
- **Initial Modulus (CN/tex) :** 2,900
- **Thermal Shrinkage (@ 177 C) :** < 0.1
- **Melting Point (C/F) :** 1121/2050

Fiber Type : Fiber Glass S-Glass

- **Density (g/cc) :** 2.48
- **Moisture Regain(%) :** None
- **Elongation at Break (%) :** 5.7
- **Breaking Tenacity (g/Denier) :** 19.8
- **Initial Modulus (CN/tex) :** 3,500
- **Thermal Shrinkage (@ 177 C) :** < 0.1
- **MeltingPoint (C/F) :** 1493/2719

Fiber Type : PBI

- **Density (g/cc) :** 1.43
- **Moisture Regain(%) :** 15
- **Elongationat Break(%) :** 28.5
- **BreakingTenacity(g/Denier) :** 2.7
- InitialModulus(CN/tex) : 280
- **ThermalShrinkage(@ 177 C) :** < 0.1
- **L.O.I. :** 41
- **MeltingPoint (C/F) :** 460/860 T

Fiber Type : PTFE (Teflon)

- **Density (g/cc) :** 2.1
- **Moisture Regain (%) :** None
- **Elongation at Break (%) :** 35
- **Breaking Tenacity (g/Denier) :** 1.7
- **Initial Modulus (CN/tex) :** 110
- **Thermal Shrinkage (@ 177 C) :** 7
- **L.O.I. :** N/A
- **MeltingPoint (C/F) :** 327/621 TT

Fiber Type : Spectra® / Dyneema®PBI

- **Density (g/cc) :** 0.97
- **Moisture Regain(% :** < 0.1
- **Elongationat Break(%) :** 2.7-3.5
- **BreakingTenacity(g/Denier) :** 26 to 34
- **InitialModulus(CN/tex) :** 10,595
- **ThermalShrinkage(@ 177 C) :** N/A
- **MeltingPoint (C/F) :** 147/297

Properties of Textile Fiber

Before learning about properties of fiber, you should know about what is textile

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fiber? We can define fiber as; Any substance, natural or manufactured, with a high length to width ratio and with suitable characteristics for being processed into fabric; the smallest component, hair like in nature, that can be separated from a fabric. I have also published a complete post on textile fiber.

To be a textile fiber it has some properties. The **properties of textile fiber** are given below:

Normally properties of textile fiber are three types:

A) Physical Properties

1. Length
2. Fineness
3. Crimp
4. Maturity
5. Lusture
6. Softness
7. Resiliency
8. Work of rupture
9. Density
10. Appearance
11. Flexibility
12. Toughness
13. Elongation

B) Mechanical Properties

1. Strength

2. Elasticity
3. Extensibility
4. Rigidity

C) Chemical Properties

1. Solubility in aqueous salt
2. Solubility in organic salt

Without above that properties, fiber has also

1. Thermal Properties
2. Torsional Properties

We can also textile fiber properties can classify in the following way:

1. Primary properties of textile fibres:

- High length to width ratio
- Tenacity
- Flexibility
- Spinning quality (Cohesiveness)
- Uniformity

2. Secondary properties of textile fibres:

- Physical shape
- Elastic recovery and elongation
- Resiliency
- Flammability and other thermal reactions
- Density
- Lusture
- Colour
- Moisture regain

Classification of Textile Fibers

In a broad sense the word fiber is used for various types of matter – natural or manmade, forming basic elements of textile fabrics and other textile structures. It is defined as one of the delicates, hair-like portion of the tissues of a plant or animal. Fiber is defined by Fabric Link Textile Dictionary as The basic entity, either natural or manufactured, which is twisted into yarns, and then used in the production of a fabric. The physical interpretation of the word fiber is a unit of matter characterized by having a length of at least hundred times its diameter.

Textile fiber

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Technologists have defined the term **Textile fibers** as those fibers which can be spun into a yarn or made into a fabric by interlacing, or interlooping in a variety of machines including weaving, knitting, braiding, felting, bonding, etc.

The fabric- and **garment manufacturing industry** is one of the most essential industries. Its raw materials are fibers. So, in making a textile product the parameters of the basic raw material, fiber, are very important.

The use of textiles for clothes and furnishing hinges on an exceptional combination of properties, such as warmth, softness, and pliability. These properties depend upon the raw materials used to make these products. Thus for a fiber to be useful for textile purposes, it should have certain properties: the fiber length must be several hundred times the width, it must be able to be converted into yarn, and it must be strong enough to withstand mechanical action during production. So, a textile fiber must have at least 5 mm of length so that it will be supple, flexible, and strong enough to be spun. Other properties like elasticity, fineness, uniformity, durability, luster, and crimp should also be possessed by a textile fiber.

Classification of Textile Fibres

Fibers for textiles are classified by many systems. In 1960, the Textile Fiber Products Identification Act became effective. One of the basic ways to classify fiber is by its origin, and this is indeed the most commonly employed method. Flow chart-1 gives a general overview of fiber classification.

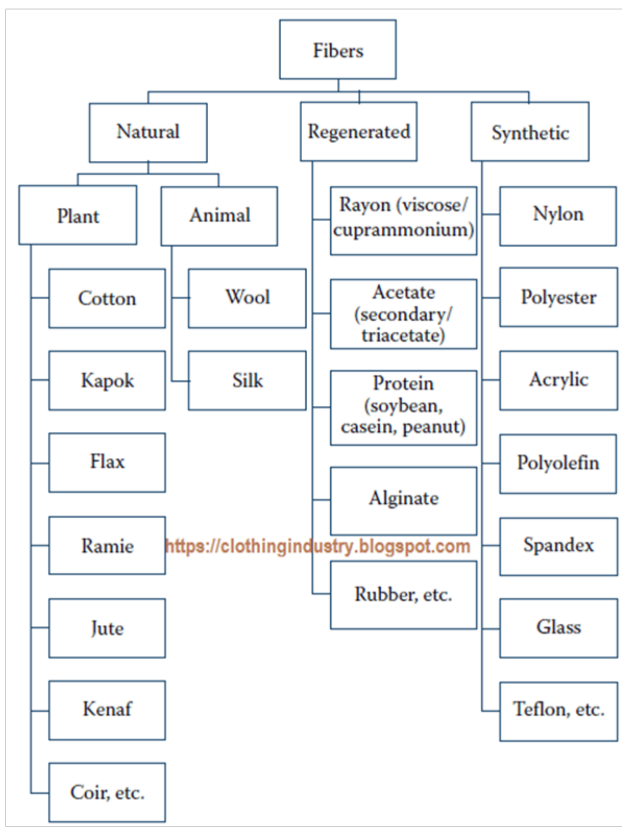

Fig.: Overview of fiber classification

There are various types of fibers used in the textile industry, each having their unique properties. These characteristics are largely dependent upon their origins. Natural fibers are obtained from nature, where the source could be a plant, an animal, or a mineral. Regarding plants, we obtain fibers from seeds (cotton, coir), from leaves (sisal), and from stems (jute, flax, ramie, etc.).

From animals we get wool and silk and from minerals we obtain asbestos. With the increasing population, the demand for textiles is ever increasing and to meet these demands mankind has started to develop fibers commonly classified as manmade fibers. Man made fibers are produced from polymer sources, either from nature **(regenerated fibers)** or from synthetic polymers.

Classification is branching of whole discipline in different categories. Since textile fibers have ceased to be of descriptive discipline and have become a branch of science, the exactness and intricacy has entered into it. Therefore, before selecting any textile fiber for the intended use, the knowledge of the classification of textile fibers is essential.

Classification of textile fibers can be done in many ways. Some of them are as follows:

Classification according to their nature and origin

Flow charts 2–9 show the classification of main natural and manmade fibers used normally in textile applications. The fibers are normally classified as natural and manmade. Among natural subgrouping is made as animal origin, vegetable origin and mineral origin. The manmade fibers are further subgrouped as regenerated fibers and synthetic fibers.

Natural fibers are those fibers which are available from the natural sources, viz. plants, animals, minerals, etc. The mineral fibers are also referred as miscellaneous inorganic fibers.

Manmade fibers are those fibres which are developed by man. Man possesses a natural instinct of imitating nature and its products. Textiles are no exception to it. He does it either using some natural resources and/or chemicals to produce fibres, artificially. Therefore, sometimes back in their earlier development stages, manmade fibres were also called Artificial Fibres.

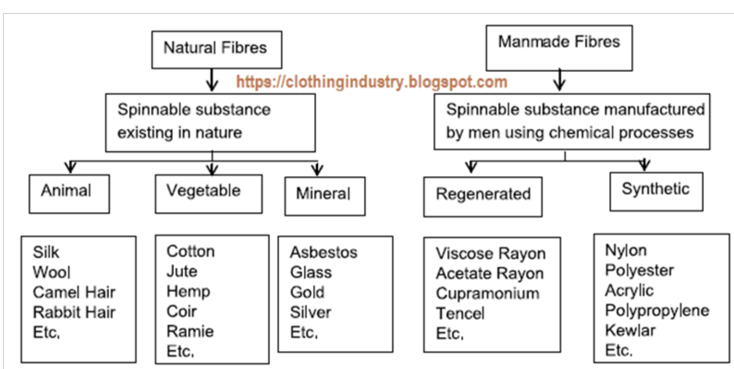

Fig.: Classification of fibers

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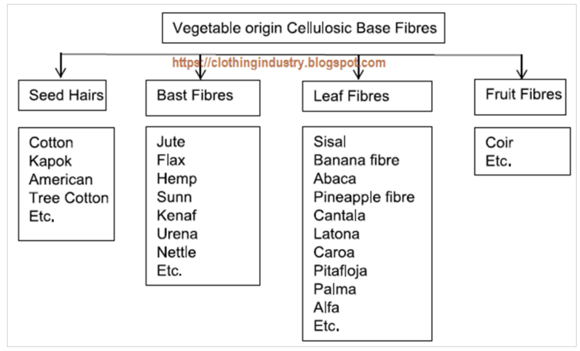

Fig.: Natural vegetable fibers

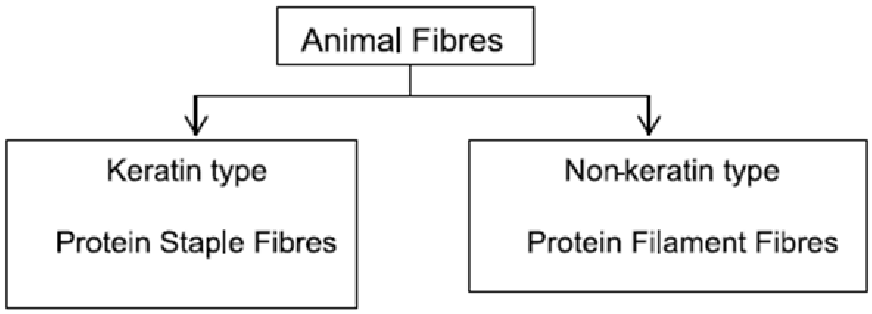

Fig.: Animal fibers

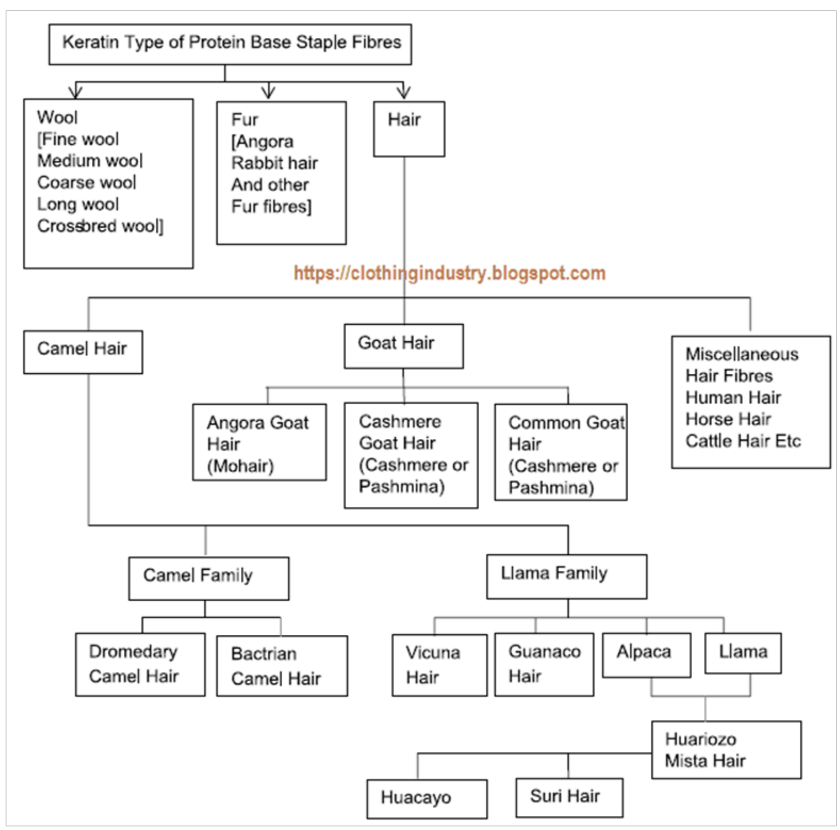

Fig.: Keratin types fiber

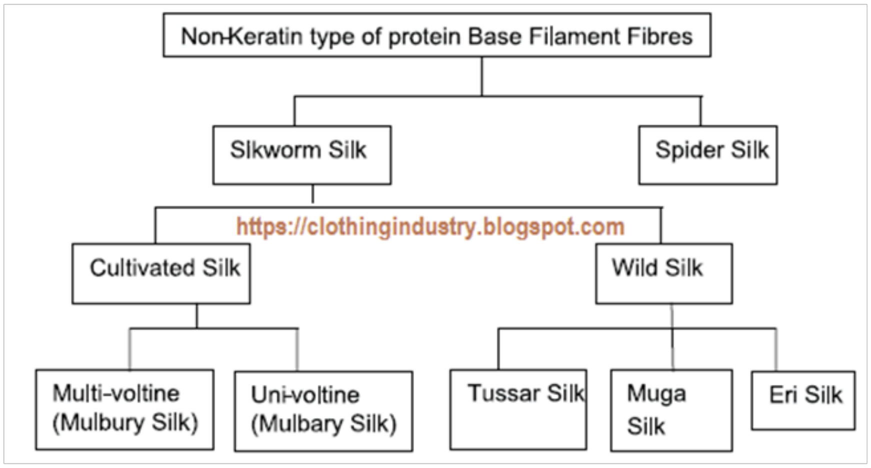

Fig. : Non keratin types fiber

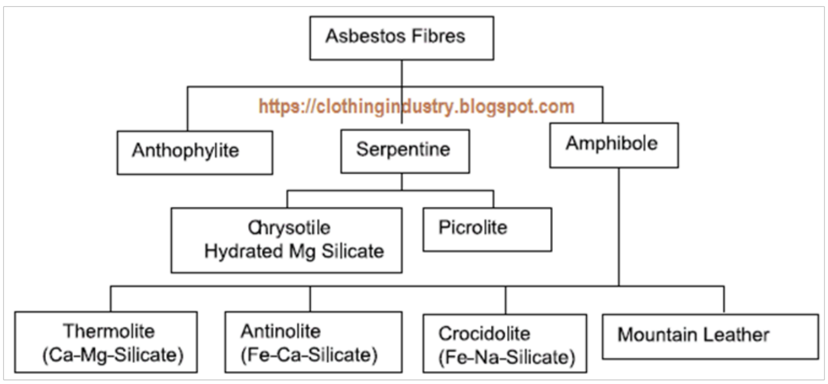

Fig.: Mineral fiber (Asbestos)

If the **manmade fibers** are obtained from cellulosic base material then they are termed as regenerated cellulosic manmade fibers; if they are manufactured from synthesizing using various chemicals like the petroleum products then they are called synthetic manmade fibers.

Manmade fibers can be broadly classified into regenerated fibers, synthetic fibers and miscellaneous inorganic fibers.

Regenerated natural-polymer fibers (polymer is a fiber forming substance) are those fibers which are regenerated by using natural source as a base and are chemically shaped to filament form, e.g. viscose rayon, cuprammonium rayon, acetate rayon, casein ardil, etc.

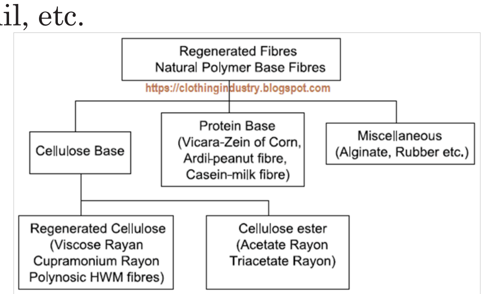

Fig.: Manmade regenerated fibers

Synthetic fibers are those fibers where only chemicals are used in the manufacture of such fibers. They do not require natural raw material as a base for the manufacture, as in the case of regenerated fibres. For example, hexamethylenediamine and adipic acid are used in the manufacture of nylon and dimethyl terephthalate and ethylene glycol in the production of polyester fibre etc.

The chemicals are converted into materials capable of forming fibers and these substances are manipulated into fibrous form.

In another way, synthetic fibers can also be classified in two groups, viz. (a) Heterochain fibers, e.g., polyester, polyamide, polyurethane, polyurea fiber, etc., (b) Carbochain fibers, e.g. polyacrylonitrile, polyvinyl alcohol, polyvinyl chloride, polyolefi n and special purpose fluorine, etc., containing fibres.

The macromolecules of heterochain fibres contain in their main chain carbon atoms and atoms of other elements, such as, oxygen and nitrogen. These polymers are usually obtained by polycondensation or polymerization of cyclic compounds.

The macromolecules of heterochain fibers have a carbon skeletal chain, i.e., they contain only carbon atoms in the main chain. Such polymers are obtained by polymerization.

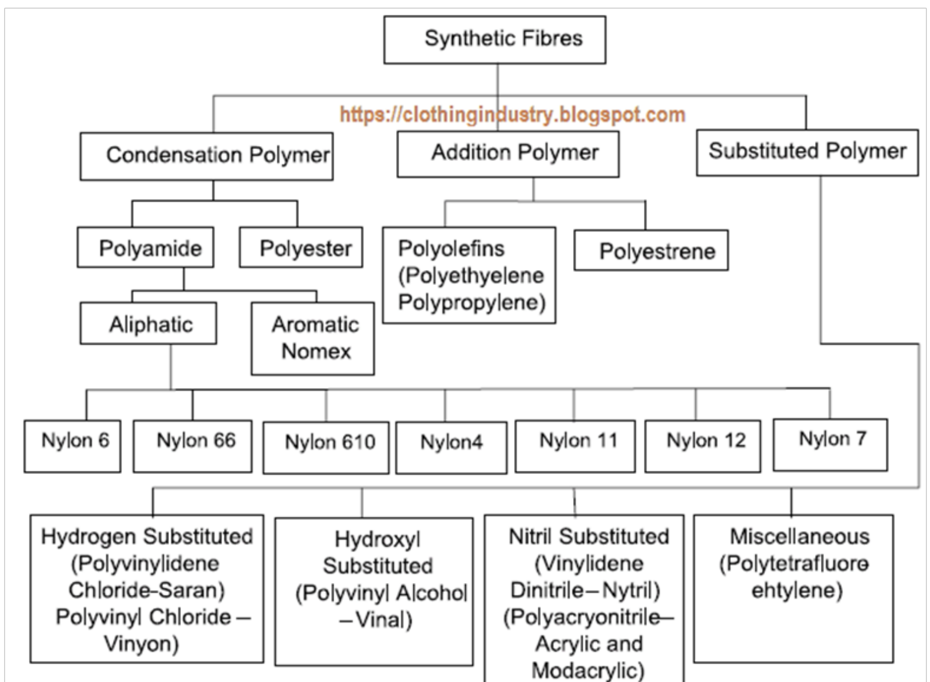

Fig.: Synthetic fibers

Miscellaneous inorganic fibers are those fibers which are made from substances such as metal and glass. Both these materials have been used by man for a long time in forms other than textile fibres. Thus malleable and ductile nature suggested the use as textile fibres long ago, but the cost and technical difficulties hindered its wide use. Modern developments in converting both these materials into textiles have overcome the difficulties to ensure their modest regular use.

The classification of fibres under this category is by no means exhaustive but Flow charts 2–9 do include the main apparel use fibres as well as some of the less well known fibres.

Classification according to their botanical, zoological or chemical name

- Vegetable fibres are grouped under botanical classification. They include cotton, jute, fl ax, etc.
- Animal fibres are grouped under zoological classification. They include wool, silk and hair fibres.
- Chemical name is given to the classification of fibres under manmade fibres. The main constituent chemicals and mode of their production is explained in brief, for example, regenerated cellulose, polyamide linear macromolecules having in their chain the recurring amide functional group, etc.

Detailed classification is given in Table.

Table: Varieties, geographical sources and uses of some important textile fibres:

	Type	Varieties	Major sources	Use
Natural fibres				
Vegetable origin		Botanical name		
1.	Cotton – Seed hair	Gossypium (G)		All grades of textile and cordage
	Upland type		USA, India and China	
	American type	*G. hirsutum*	West Indies and USA	
	Asiatic type	*G. herbaceum*	Egypt and Peru	
	Island type	*G. barbadense*	West Indies and Brazil, Haiti islands	
	Peruvian	*G. peruvianum*	Peru	
	American tree cotton	*G. purpurascend*	Argentina	
	Bast fibres			
2	Jute	*Corchorus olitorius* and *Corchorus capsularis*	India and Bangladesh	Carpets, rope, geotextile, hessian or burlap, sacks
3	Flax	*Linum usitatissimum*	USSR, Germany,	Cordage and coarse textiles

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			France, Holland, America	
4	Hemp	*Cannabis sotiva*	Philippines, North Bomea, etc.	Cordage and coarse textiles, clothing and nutritional products
5	Ramie	*Bohemeria nivea* and *Bohemeria tenacissima*	India, China, etc.	Cordage and coarse textiles, industrial sewing thread, packing materials, fishing nets and filter cloths
6	Abaca – Manila Hemp	Musa	Philippines, North Bomea, etc.	Cordage and coarse textiles
7	Sisal	*Agave sisalana*	Africa, Java, Mexico	Cordage and coarse textiles
8	Sunn	Fibre from the bast of *Crotalaria juncea*	India	Cordage and coarse textiles
9	Henequen	Fibre from the bast of *Agave fourcroydes*	Mexico	Cordage and coarse textiles
10	Maguey or *Agave americana or Century plant*	Fibre from the bast of *Agave cantala*	America, Asia,	Cordage and coarse textiles
11	Broom	*Cytisus scoparius* and/ or *Spartium junceum*	India, Europe	Mattress, bags
12	Kapok – Fibre obtained from the inside of the kapok fruit	Ceiba pentandra	Argentina	Fine textiles
13	Alfa Grass – Fibre obtained from the leaves	*Stipa tenacissima*	Northwest Africa and Spain	Floor coverings, home furnishing
14	Coir	*Cocos nucifera*	India	Cordages, home furnishing
Animal origin				
15	Wool or animal hair	Hair		

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	Sheep	Ovisaries	World over	
	Goat hair (mohair)	Caprahircusan		
	Rabbit hair	Lepus	Europe	
	Alpaca	Aucheniapalo	Europe	
	Llama	*Auchenia llama*	Himalaya	
	Vicuña	*Auchenia vicuña*	South America	
	Camel Hair	Camelidae	Arabia, Sahara	
	Pashm or pashmina	Kashmir or Cashmere goat	Himalayas	Felt, textiles, cordage and coarse textiles
	Angora	Angora goat and Angora Rabbit	Europe	
	Yak	*Bos grunniens*	Himalayas	
	Guanaco	*Llama guanicoe*	South America	
	Beaver	Genus Castor	North America	
	Otter	*Lutra perspicillata*	India, Africa	
16	Silk			
	Cultivated silk	*Bombyx mori*	Japan, China, India	Textiles, apparels
	Wild silk	Eri, Muga, Tussah	India	
Manmade fibres				
	Regenerated fibres			
17	Viscose rayon	Regenerated cellulose fibre obtained by the viscose process for filament and discontinuous fibre	Produced under many trademarks in different countries	Textiles, light apparel, furnishing, interlining, carpets, etc.
18	Polynosic – Modal	Regenerated cellulose having a high breaking force and high wet modulus	Produced under many trademarks in different countries	

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19	Cuprammonium rayon	Regenerated cellulose fibre obtained by the cuprammonium process	Bemberg	
20	Acetate rayon	Cellulose acetate fibre wherein less than 92% but at least 74% of hydroxyl groups are acetylated		
21	Triacetate	Cellulose acetate fibre wherein at least 92% of the hydroxyl groups are acetylated		
22	Alginate – Sea weed	Fibre obtained from metallic salts of alginic acid		
23	Protein	Fibre obtained from natural protein substances regenerated and stabilized through the action of chemical agents		
	Synthetic fibres			
24	Polyamide or nylon	Polyamide linear macromolecules having in their chain the recurring amide functional group	Manufactured in various countries	Technical textiles, floor coverings, sarees

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25	Polyester	Polyester linear macromolecules having in their chain at least 85% (by mass) of an ester of a diol and terephthalic acid		Clothing and industrial purposes
	Acrylic	Fibre formed of linear macromolecules comprising at least 85% (by mass) in the chain of the acrylonitrilic pattern		Blankets, carpets and outerwear garments
	Modacrylic	Fibre formed of linear macromolecules having in their chain more than 50% and less than 85% (by mass) of the acrylonitrilic pattern		
	Chlorofibre	Fibre formed of linear macromolecules having in their chain more than 50% by mass of chlorinated vinyl or chlorinated vinylidene monomeric units		
	Fluorofibre	Fibre formed of linear macromolecules made from fluorocarbon aliphatic monomers		

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	Polyethylene	Fibre formed of un-substituted aliphatic saturated hydrocarbon linear macromolecules		
	Polypropylene	Fibre formed of an aliphatic saturated hydrocarbon linear macromolecule where one carbon atom in two carriers a methyl side chain in an isotactic disposition and without further substitution		Ropes, insulation for electric cable, sanitary products. rugs and mats, under armour clothing, roofing membranes, filter media in water filters
	Polycarbamide	Fibre formed of linear macromolecules having in their chain the recurring ureylene (NH-CO-NH) functional group		
	Polyurethane	Fibre formed of linear macromolecules composed of chains with the recurring urethane functional group		

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	Vinylal (m)	Fibre formed of linear macromolecules whose chain is constituted by poly(vinyl alcohol) with differing levels of acetilization		
	Trivinyl	Fibre formed of acrylonitrile terpolymer, a chlorinated vinyl monomer and a third vinyl monomer, none of which represents as much as 50% of the total mass		
	Elastodiene or spandex	Elastofibre composed of natural or synthetic polyisoprene, or composed of one or more dienes polymerized with or without one or more vinyl monomers, and which, when stretched to three times its original length and released, recovers rapidly and substantially to its initial length		Wide range of garments, especially in skin-tight garments.

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	Elastane	Elastofibre composed of at least 85% (by mass) of a segmented polyurethane, and which, when stretched to three times its original length and released, recovers rapidly and substantially to its initial length		

Classification according to their ability to absorb moisture

From the point of view of wet processing the ability to bleach, mercerize, dye and give different finishes using chemicals to textile materials successfully depends on the ability to absorb moisture. The fi bres which absorb moisture are called Hygroscopic or Hydrophilic fibres.

Hydrophilic fibres are characterized by the presence of hydrophilic groups which attract water. For example, all the natural fibres have groups in their molecules which attract water. Moisture absorption of hydrophilic fibres is higher than hydrophobic fibres.

Hydrophobic fibres are those which do not readily absorb moisture. All synthetic fibres, so far produced, contain very few water attracting groups. Absence of water attracting groups accounts for their low moisture absorption. The fibres which have lower moisture absorption are difficult to dye and bleach. Another disadvantage is that they develop static electricity charges quicker than hydrophilic fibers. This is an important factor which is responsible for some troubles during mechanical processing of fibers.

Classification according to their thermoplasticity

The textile fibres can also be classified into two types, viz.

- Thermoplastic type
- Non-thermoplastic type

Thermoplastic types are those which are deformable by heat and pressure, without accompanying chemical changes. This suggests that the thermoplastic types of fibres can be softened by heat, which means they can be moulded and heat set. The fibres which do not possess the above characteristic are designated as non-thermoplastic.

Most of the synthetic fibres have thermoplastic properties. Regenerated acetate rayon may melt when ironed hot, and polyvinyl chloride (PVC) fibres are most heat sensitive type. Some synthetic fibres have thermoplastic properties which are more pronounced than those of acetate, notably polyamide and polyester.

This property of thermoplasticity is used to heatset fabrics made from them and confer on them the dimensional stability. Also this quality is used to convert these fibres into new type of yarn such as Textured Yarn.

Classification according to their utility

The textile fibres can be broadly classified into two types under this category, viz.

- Major textile fibres
- Minor textile fibres

Major textile fibres are those which are widely used as textiles by the textile industry, e.g., cotton, wool, silk, jute, viscose rayon, acetate rayon, nylon, polyester, etc.

Minor textile fibres are those which are used to a very much less extent as textiles (by the textile industry), e.g. banana fibres, abaca fibres, asbestos fibres, bamboo fibres, soybean fibres, pineapple fibres, metallic fibres, milk fibres, casein fibres, alginate fibres, rubber, etc.

Secondary Properties

Physical Properties

- **Physical Shape:** The physical shape of the fibre is an important factor in determining many of its properties. It includes the surface contour (smooth, rough, serrated), the shape of the cross section and the width and length of the fibre. The shape of the cross section influences certain factors such as lustre, body and hand. The surface contour in turn influences cohesiveness, resiliency, loft and thickness. It contributes to resistance to abrasion, Pilling and comfort factors such as absorbency and warmth. The cross sectional shape can be changed for all artificial fibres unlike natural fibres as the fibres are moulded though spinnerets.
- **Density:** Density is the mass of a unit volume of material. It is expressed as gms/cubic cm or pounds per cubic foot. The specific gravity of a fibre indicates the density relative to that of water at 4oC. All textile fibres are heavier than water except olefin fibres. Only these fibres float on water. Cotton, wool fibres are heavy and nylon is comparatively lighter. The lower the density the more the covering power. A pound of wool and a pound of nylon weigh the same but the fibres are more in nylon than in wool. High density results in heavy fabrics, low density results in light weight fabrics.

A light weight fibre helps a fabric to be warm without being heavy. Acrylic fibres being light comparatively are wool like in appearance and are used extensively instead of wool to produce light weight sweaters & blankets.

- **Lustre:** Lustre is the amount of light reflected from a surface. It is more

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subdued than shine. Light rays are broken up into many short rays unlike the shine in which the light ray is reflected back wholly without any breaks. The lustre is due to smoothness, fibre length, flat or lobal shape. It determines the fibres natural brightness or dullness. The natural fibre silk has the high lustre and cotton is the dullest natural fibre. All man-made fibres are produced with lustre controlled. It is not always desirable to produce bright fabrics. So the lustre is controlled by the addition of pigments such as titanium dioxide in spinning solution. The lustre in natural and man-made fibres can also be improved by various finishing techniques. For example the lustre in cotton is improved by mercerization.

- **Absorbency:** Generally textile fibres have certain amount of water as an integral part of the fibre. All most all textiles fibres are naturally hygroscopic (i.e they pick up moisture from air). But the amount of moisture the fibres absorb may differ. Absorbency in the ability to take in moisture and moisture regain is the percentage of moisture a bone-dry fibre will absorb from the air under the standard conditions of temperature and moisture. Fibres that absorb water easily are known as hydrophilic (water loving) fibres. Natural protein and vegetable fibres, rayon and acetate are hydrophilic fibres. Fibres that have difficulty in absorbing water are known as hydrophobic fibres.

Many synthetic fibres are hydrophobic in nature. The absorbency of glass fibre is '0'. The absorbency of a fibre is due to the hydroxyl groups present within the fibre and the amorphous molecular arrangement. The fibres having crystalline arrangement are generally hydrophobic.

Absorbency is an important factor in all textile fibres especially those which are used for apparels as it influences many other fabric properties such as comfort, warmth, water repellency, static build up, dyeability, shrinkage, wrinkle resistance etc. It is easy to wash a hydrophobic fabric as it does not absorb stains and it dries quickly.

Among the textile fibres the natural protein fibres silk and wool are the most absorbant of all fibres. Next comes the natural and man-made cellulosic fibres.

The absorbency of a textile fabric is controlled by the type of yarn and fabric construction and also by finishing. For example: in cotton, the absorbency is increased by kier boiling, mercerization and napping. Pile construction increases the area of absorption.

- **Elasticity:** Elasticity is defined as the ability of fibres to return back to original shape after being stretched. Elastic recovery is the ability of fibres to return from strain and is expressed in percentage. If a fibre returns to original length after stretching to a specified length, it is said to have 100% elastic recovery.

Elasticity is required in fabrics when subjected to stretch during wear. This property is influenced by the side chains & cross linkages between the molecules. If strong bonds are present in between chains of molecules, the fibre tends to return to its original length. If the bonds are not strong it can't recover to its original length but takes up the new shape. Thus creases appear on the material. Some fibres show immediate elastic recovery, and some fibres may show delayed elastic recovery. For example, the creases on a silk material disappear if hung overnight. Wool, silk, viscose and nylon are having good elasticity. Cotton and acetates have poor elastic recovery. Polyester has moderate elongation but has good elastic recovery. It is apparent that both the elongation and elastic recovery are considered together in evaluating fibres, yarns and fabrics.

- **Abrasion Resistance:** It is the ability of fibres to withstand the rubbing or abrasion it gets in everyday use. All fabrics irrespective of the enduse are subjected to rubbing of some kind during wear. The fabric has to withstand rubbing, otherwise the fabric will show signs of damage and become unsightly. The resistance may be due to the tough outer layer and flexible molecular chains of the fibre. The size of the yarn also influences the abrasion resistance. Thick yarns resist abrasion than thin yarns. Yarn uniformity is also important as irregular yarns are abraded more easily than uniform yarns. Smooth fabrics with compact yarn arrangement are less susceptible to damage by abrasion than those with irregular surface in the low count.

Nylon has excellent resistance and acetate and glass have very poor abrasion resistance when compared to silk & wool. Cotton has better abrasion resistance. This is an important property, as it influences the durability and increases the resistance to splitting.

- **Hand:** Hand is the way a fibre feels. It can be only detected by feeling it in between fingers. The hand varies due to the cross sectional shape, the length and diameter, the flexibility, the compressablity, resilience, surface contour of the fibres, surface friction and thermal characteristics of fibres .

The hand and drape of a fabric are inter dependent. The hand of a fabric may vary from very pliable to very stiff, from very soft to very hard, from very limpy to very springy, from rigid to high degree of stress, form very smooth to very rough, from slippery to harsh, from very cool to very hot and from wet to dry.

The hand of a yarn and fabric should not be confused with the hand of a fibre. It is possible to produce smooth yarns from rough fibres and vice versa.

- **Pilling:** Ball like structures are often observed on polyester and nylon materials after few washes which make the material unsightly. Pilling is nothing but the balling up of fibre ends on the surface of fabrics. It is one of the disadvantages of staple fibre fabrics. In natural fibres the balls cut away from the fabric easily but synthetic fibres are so strong that they do not break away rapidly from the fabric. So the strength of fibres is a basic factor in the problem of pilling. Pills usually occur in areas that are abraded or subjected to abrasion during wear. Usually at the armpits of garments and back and lower edge of sarees, pilling can be seen. It can be made better by removing pills. But it is almost impossible to remove pilling from synthetics unless it is given singeing finish. In this the fabric passes through gas flames, so that the balls are burnt off. In order to inhibit the formation of pills on materials, they are given special finishes known as anti pilling finishes.

To prevent pilling close fabric construction is recommended. Tightly twisted yarns and longer staple fibres are helpful in preventing pilling. Fulling of wool, resin finishes on cotton are anti pilling finishes.

- **Loft and Resiliency:** Loft is the ability of a fibre to spring back to original thickness after being compressed. Resiliency is the ability of a fibre to bounce back to shape following compression, bending or similar deformation. Wool and silk fabrics are more resilient. They can be deformed, crushed or wrinkled during wear but they come to shape upon hanging. Elastic recovery is an important factor while evaluating the resilience of a fibre. Usually good elastic recovery indicates good resiliency.
- **Static Electricity:** This is the electricity produced by the friction of a fabric against itself or some other object. If a fabric is better conductor of electricity, it conducts away the electricity that is produced. But if the material is not a good conductor, the electricity produced cannot be conducted away, but it tends to pile up on the surface of the fabric. It the material comes in contact with a good conductor, a shock or transfer occurs. It may produce sparks, in gaseous atmosphere, it may give explosions. So it is a hazard in places where materials which are highly inflammable are present. So the use of synthetics is prohibited in operation theatres. Static electricity rapidly develops in cold and dry atmospheres. After wearing synthetics for few hours, it is better to wipe the garments with a wet towel. It carries away the electricity produced. Static electricity makes the fabric to cling to the body of the wearer. It attracts more dust and thus gives unsightly appearance. Fabrics cling to the machinery & thus cutting and stitching of garments is made difficult.

Antistatic finishes are given to fabrics in order to inhibit the piling up of static electricity on fabrics. But this is washed off after few washes.

- **Feltability:** It is the ability of fibre to mat together. Using this property, it is possible to produce fabrics without the complicated processing of spinning and weaving. These are termed as non - woven felted materials. Some rug materials, carpet materials and apparels are produced by felting. The ability of wool to coil together, interlock & shrink when subjected to heat, moisture and pressure is responsible for felting of wool fibres. In fact the other fibres are also felted by using a suitable adhesive.

1.6 SUMMARY

The word **textiles** comes from the Latin term Textere, ”Woven”. Today the word textile is more generalized and refers to the product made from fibres.

A **fiber** is defined as any product capable of being woven or otherwise made into a fabric. It may be thought of as the smallest visible unit of textile production or a fiber can be defined as a pliable hair like strand that is very small in diameter in relation to its length. Fibres are the fundamental units or the building blocks used in the making of textile yarns and fabrics.

Where the **yarns** are produced by twisting or spinning of the textile fibers and in turn a **fabric** is a planner structure produced by interlacing or interlooping of yarns.

- **Textile Fiber:** Fiber means any substance that has a high length to width ratio. But textile fiber means any substance which has a high length to width ratio with suitable characteristics for being processed into fabric. For being textile fiber some properties are very important to have i.e.

Primary Properties of Textile Fiber

- High length to width ratio
- Tenacity
- Flexibility
- Spinning quality/ spin ability
- Uniformity

Secondary Properties of Textile Fibers

- Physical Shape
- Resiliency
- Density
- Flammability
- Lusture
- Color
- Moisture regain
- Elastic recovery
- **Classification of Textile:** If we observe then we will find that broadly we can divide textile into four major categories according to the sources of materials from which textile is produced. These are:

1. Animal textile

- Wool, Silk

2. Plant textile

- Cotton, Flax, Jute

3. Mineral textile

- Asbestos, Glass fiber

4. Synthetic textile

- Nylon, Polyester, Acrylic
- **Yarn:** The yarn is a continuous strand which is made by natural or synthetic fiber or material twisted or laid together that can be made into a textile fabric. So, a continuous twisted strand of natural or synthetic fibers used in weaving

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or knitting to produce fabric. The yarn can be different types depending on which types of fiber is using. It is a very important raw material for textile.

- **Fabric:** A cloth of flexible planar substance constructed from solutions, fibers, yarns in any combination. Textile fabrics can also be produced directly from webs of fibers by bonding fusing or interlocking to make non-woven fabrics and felts.

Fig. Ready Fabric for Making Garment

In textile, especially fabric is the fundamental component of a ready-made garment, because it is the basic raw material of a garment. So, to know the manufacturing sequence of fiber to fabric is very important. The present time is the time of a quality product. It is impossible to maintain the quality of a garment without proper knowledge of textile manufacturing i.e. fiber, yarn, and fabrics.

1.7 GLOSSARY

Aramid Fiber : A manufactured fiber in which the fiber-forming material is a long chain synthetic polyamide having at least 85% of its amide linkages (-NH-CO-) attached directly to two aromatic rings.

Autoclave : An apparatus for the carrying out of certain finishing operations, such as pleating and heat setting, under pressure in a superheated steam atmosphere.

Balanced Cloth : A term describing a woven fabric with the same size yarn and the same number of threads per inch in both the warp and the fill direction.

Bally Ribbon Mills (BRM) : A leader in the narrow fabrics industry. In business 90 years, it is known for its high quality goods, excellent customer service, and technical engineering expertise.

Basket Weave : A variation of the plain weave in which two or more warp and filling yarns are woven side to side to resemble a plaited basket.

Beam : A cylinder of wood or metal, usually with a circular flange on each end, on which warp yarns are wound for slashing, weaving, and warp knitting.

Beaming : The operation of winding warp yarns onto a beam usually in preparation for slashing, weaving, or warp knitting. This process is also called warping.

Beating–Up : The last operation of the loom in weaving, in which the last pick inserted in the fabric is "beat" into position against the preceding pick, usually by a "comb-like" device called a reed.

Bicomponent Yarns : Spun or filament yarns of two generic fibers or two variants of the same generic fiber.

Bi-directional Fabric : A fabric having reinforcing fibers in two directions, i.e. in the warp (machine) direction and filling (cross-machine) direction.

Bleeding : Loss of color by a fabric or yarn when immersed in water, a solvent, or similar liquid medium, as a result of improper dyeing or the use of dyes of poor quality.

Four Wave Mixing : A nonlinearity common in DWDM systems where myultiple wavelengths mix together to form new wavelengths called interfering products. Interfering products that fall on the original signal wavelength become mixed with the signal, mudding the signal and causing attenuation. Interfering products on either side of the original wavelength can be filtered out. FWM is most prevalent near the zero-dispersion wavelength and at close wavelength spacings.

Fiber : A single optical transmission element characterized by a core, a cladding, and a coating.

Fiber amplifier : An all-optical amplifier using erbium or other doped fibers and pump lasers to increase signal output power without electronic conversion.

Fiber Bragg grating (FBG) : A piece of photorefractive fiber that is exposed to high-intensity ultraviolet interference patterns that will cause it to reflect a specific wavelength while being transparent to all other wavelengths. Used in WDM systems.

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Fiber-optic test procedure (FOTP) : Specific substandards within the TIA/EIA 455 standard, used predominantly for test and measurement.

Fiber-optics : Light transmission through optical fibers for communications purposes.

Fiber sensor : A sensing device in which the active sensing element is an optical element attached directly to an optical fiber. The measured quantity changes the optical properties of the fiber so that it can be detected and measured.

Fiber to the building/business (FTTB): A topological reference to a PON network that supports multiple subscribers in a single structure, i.e., a business or a building.

Fiber to the curb/customer (FTTC) : Distribution of communication services by providing fiber-optic links to a central point in each neighborhood and continuing to the homes by either twisted pair or coax.

Fiber to the desk (FTTD) : Transmission system using fiber-optics as the medium throughout, from transmitter to desktop.

Fiber to the home (FTTH) : The distribution of communications services by providing fiber-optic links all the way to each house.

Fibre Channel (FC) : A high-speed interconnection standard for connecting supercomputers with peripheral devices up to 10 km away at transmission rates over 1 Gbps.

Four wave mixing (FWM) : A collective name for a group of non-linear processes where up to three different incident waves interact in the medium, leading to a fourth resulting wave.

Frequency : The number of cycles per unit of time, denoted by Hertz; 1 Hertz = 1 cycle per second.

Fresnel reflection : Reflection of a portion of incident light at a planar interface between two homogeneous media having different refractive indices.

Full spectrum WDM (FSWDM) : A technology platform based on the use of spectrally enriched optical pulses for signal transmission at speeds of 10 Gbps and higher.

Full width half maximum (FWHM) : Used to measure the spectral width of light sources. Measure the spectral width at -3 dB (half power from peak) and at the full width of the source's power peak.

Fusion Splicer : An instrument that permanently bonds two fibers together by heating and fusing them.

Gigabit (Gb) : One billion bits.

Gigahertz (GHz) : A unit of frequency equal to one billion Hertz.

Graded-index fiber : A type of fiber where the refractive index of the fiber core decreases radically towards the outside of the fiber.

GRIN lens : A graded-index lens, a lens where the refractive index varies along its length.

1.8 REVIEW QUESTIONS

1. Understanding the **Natural Fiber.**
2. Explain the Biopolymers.
3. What is Synthetic monomers?
4. Explain the Monomer Definition and Examples.
5. Discuss the Monomers and Polymers in Chemistry.
6. Defining the Density and Moisture Regain of Fibers.
7. What is Textile Fiber?

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UNIT

2

FIBER AND ITS CLASSIFICATION

STRUCTURE

2.1 LEARNING OBJECTIVE

After studying this unit you should be able to:

- Describe the technology for modify of Natural Fibers.
- Given the meaning and significance of Man made Fibers.
- Describe the Common materials used to make Cotton Fibers.
- The importance of Silk fibers.
- Give meaning and significance of Different Types of Silk Fiber.
- Describe the Wool Fiber.
- Explain the meaning and definition of Jute.
- Describe the main responsibilities of a Hemp.
- Describe the Nylon.

2.2 INTRODUCTION

Fibers are classified by their chemical origin, falling into two groups or families: natural fibers and manufactured fibers. Manufactured fibers are also referred to as man made or synthetic fibers. The classification system used in the United States is dictated by the Textile Fiber Products Identification Act (TFPIA).

- **Classing Cotton:** Cotton buyers judge cotton on the basis of samples cut from the bales. Skilled cotton classers grade or "class" the cotton according to standards established by the US Department of Agriculture such as cleanliness, the degree of whiteness, length of the fiber, and fiber strength.

The classes pull a sample. They discard most of the cotton until just a pinch of well-aligned fibers remains. They measure the length of the fibers, referred to as staple fibers. Longer staple fibers are higher-grade cotton and are sold at higher prices. Long staples range from 1.1 inches to 1.4 inches long.

Shoddy or recycled wool is made by cutting or tearing apart existing wool fabric and respinning the resulting fibers. As this process makes the wool fibers shorter, the remanufactured fabric is inferior to the original. The recycled wool may be mixed with raw wool, wool noil, or another fiber such as cotton to increase the average fiber length. Such yarns are typically used as weft yarns with a cotton warp. This process was invented in the Heavy Woollen District of West Yorkshire and created a microeconomy in this area for many years.

Worsted is a strong, long-staple, combed wool yarn with a hard surface.

Woolen is a soft, short-staple, carded wool yarn typically used for knitting. In traditional weaving, woolen weft yarn (for softness and warmth) is frequently combined with a worsted warp yarn for strength on the loom.

- **Classification by Fleece:** Shearing, is the process by which the woolen fleece of a sheep is removed. Sheep are generally shorn of their fleeces in the spring, but the time of shearing varies in different parts of the world. Sheep are not washed before shearing. They are sometimes dipped into an antiseptic bath as prescribed by law. The classification by fleece is as follows:
- **Lamb's Wool:** The fleece obtained by shearing the lamb of six to eight months old for the first time is known as lamb's wool. It is also referred to as fleece wool, or first clip. As the fiber has not been cut, it has a natural, tapered end that gives it a softer feel.
- **Hogget Wool:** Hogget wool is the one obtained from sheep about twelve to fourteen months old that have not been previously shorn. The fiber is fine, soft, resilient, and mature, and has tapered ends. These are primarily used for warp yarns.
- **Wether Wool:** Wether wool is the one obtained from the sheep older than fourteen months. The shearing is not done for the first time and in fact these fleeces are obtained after the first shearing. These fleeces contain much soil and dirt.
- **Pulled Wool:** Pulled wool is taken from animals originally slaughtered for meat. The wool is pulled from the pelt of the slaughtered sheep using various chemicals. The fibers of pulled wool are of low quality and produce a low-grade cloth.
- **Dead Wool:** This is the wool obtained from the sheep that have died of age or accidentally killed. This type of wool fiber known should not be confused for pulled wool. Dead wool fiber is decidedly inferior in grade; it is used in low-grade cloth.

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- **Cotty Wool:** This type of wool is obtained from the sheep that are exposed to severe weather. As discussed; the severe weather conditions hamper the qualities of the fleece obtained. The cotty wool is of a poor grade and is hard and brittle.
- **Tag locks:** The torn, ragged, or discolored parts of a fleece are known as tag locks. These are usually sold separately as an inferior grade of wool.

Jute matting is used to prevent flood erosion while natural vegetation becomes established. For this purpose, a natural and biodegradable fiber is essential.

Jute is the second most important vegetable fiber after cotton due to its versatility. Jute is used chiefly to make cloth for wrapping bales of raw cotton, and to make sacks and coarse cloth. The fibers are also woven into curtains, chair coverings, carpets, area rugs, hessian cloth, and backing for linoleum.

While jute is being replaced by synthetic materials in many of these uses, some uses take advantage of jute's biodegradable nature, where synthetics would be unsuitable. Examples of such uses include containers for planting young trees, which can be planted directly with the container without disturbing the roots, and land restoration where jute cloth prevents erosion occurring while natural vegetation becomes established.

The fibers are used alone or blended with other types of fiber to make twine and rope. Jute butts, the coarse ends of the plants, are used to make inexpensive cloth. Conversely, very fine threads of jute can be separated out and made into imitation silk. As jute fibers are also being used to make pulp and paper, and with increasing concern over forest destruction for the wood pulp used to make most paper, the importance of jute for this purpose may increase. Jute has a long history of use in the sackings, carpets, wrapping fabrics (cotton bale), and construction fabric manufacturing industry.

Jute was used in traditional textile machinery as fibers having cellulose (vegetable fiber content) and lignin (wood fiber content). But, the major breakthrough came when the automobile, pulp and paper, and the furniture and bedding industries started to use jute and its allied fibers with their non-woven and composite technology to manufacture nonwovens, technical textiles, and composites. Therefore, jute has changed its textile fiber outlook and steadily heading towards its newer identity, i.e., wood fiber. As a textile fiber, jute has reached its peak from where there is no hope of progress, but as a wood fiber jute has many promising features.

Nylon was first used commercially in a nylon-bristled toothbrush in 1938, followed more famously in women's stockings or "nylons" which were shown at the 1939 New York World's Fair and first sold commercially in 1940. During World War II, almost all nylon production was diverted to the military for use in parachutes and parachute cord. Wartime uses of nylon and other plastics greatly increased the market for the new materials.

2.1 Natural Fibers

Natural fibers are those that occur in fiber form in nature. Traditionally, natural fiber sources are broken down into animal, plant, or mineral. Fibers from plant or vegetable sources are more properly referred to as cellulose-based and can be further classified by plant source. They may be separated from the plant stalk, stem, leaf, or seed. Fibers from animal sources are more properly known as protein-based fibers. They are harvested from an animal or removed from a cocoon or web. Mineral fibers are those that are mined from the earth. Except for silk, all natural cellulose- and protein-based fibers are obtained in short lengths and are called staple fibers. Silk is a continuous filament fiber.

A class name for various genera of fibers (including filaments) of:

(1) animal (i.e.,**silk fiber, wool fiber**)

(2) mineral (i.e., asbestos fiber) or

(3) vegetable origin (i.e., cotton. flex, jute and ramie fiber).

Applications of Natural Fibers

19th century knowledge weaving flax, hemp, jute, Manila hemp, sisal and vegetable fibers

Industrial use

Of industrial value are four animal fibers, wool, silk, camel hair, and angora as well as four plant fibers, cotton, flax, hemp, and jute. Dominant in terms of scale of production and use is cotton for textiles.

Natural fiber composites

Natural fibers are also used in composite materials, much like synthetic or glass fibers. These composites, called biocomposites, are a natural fiber in a matrix of synthetic polymers. One of the first biofiber-reinforced plastics in use was a cellulose fiber in phenolics in 1908. Usage includes applications where energy absorption is important, such as insulation, noise absorbing panels, or collapsable areas in automobiles.

Natural fibers can have different advantages over synthetic reinforcing fibers. Most notably they are biodegradable and renewable. Additionally, they often have low densities and lower processing costs than synthetic materials. Design issues with natural fiber-reinforced composites include poor strength (natural fibers are not as strong as glass fibers) and difficulty with actually bonding the fibers and the matrix. Hydrophobic polymer matrices offer insufficient adhesion for hydrophilic fibers.

Nanocomposites

Nanocomposites are desirable for their mechanical properties. When fillers in a composite are at the nanometer length scale, the surface to volume ratio of the filler material is high, which influences the bulk properties of the composite more compared to traditional composites. The properties of these nanosized elements is markedly different than that of its bulk constituent.

In regards to natural fibers, some of the best example of nanocomposites appear in biology. Bone, abalone shell, nacre, and tooth enamel are all nanocomposites. As of 2010, most synthetic polymer nanocomposites exhibit inferior toughness and mechanical properties compared to biological nanocomposites. Completely synthetic nanocomposites do exist, however nanosized biopolymers are also being tested in synthetic matrices. Several types of protein based, nanosized fibers are being used in nanocomposites. These include collagen, cellulose, chitin and tunican. These structural proteins must be processed before use in composites.

To use cellulose as an example, semicrystalline microfibrils are sheared in the amorphous region, resulting in microcrystalline cellulose (MCC). These small, crystalline cellulose fibrils are at this points reclassified as a whisker and can be 2 to 20 nm in diameter with shapes ranging from spherical to cylindrical. Whiskers of collagen, chitin, and cellulose have all be used to make biological nanocomposites. The matrix of these composites are commonly hydrophobic synthetic polymers such as polyethylene, and polyvinyl chloride and copolymers of polystyrene and polyacrylate.

Traditionally in composite science a strong interface between the matrix and filler is required to achieve favorable mechanical properties. If this is not the case, the phases tend to separate along the weak interface and makes for very poor mechanical properties. In a MCC composite however this is not the case, if the interaction between the filler and matrix is stronger than the filler-filler interaction the mechanical strength of the composite is noticeably decreased.

Difficulties in natural fiber nanocomposites arise from dispersity and the tendency small fibers to aggregate in the matrix. Because of the high surface area to volume ratio the fibers have a tendency to aggregate, more so than in micro-scale composites. Additionally secondary processing of collagen sources to obtain sufficient purity collagen micro fibrils adds a degree of cost and challenge to creating a load bearing cellulose or other filler based nanocomposite.

Biomaterial and biocompatibility

Natural fibers often show promise as biomaterials in medical applications. Chitin is notable in particular and has been incorporated into a variety of uses. Chitin based materials have also been used to remove industrial pollutants from water, processed into fibers and films, and used as biosensors in the food industry. Chitin has also been used several of medical applications. It has been incorporated as a bone filling material for tissue regeneration, a drug carrier and excipient, and as an antitumor agent. Insertion of foreign materials into the body often triggers an immune response, which can have a variety of positive or negative outcomes depending on the bodies response to the material. Implanting something made from naturally synthesized proteins, such as a keratin based implant, has the potential to be recognized as natural tissue by the body. This can lead either to integration in rare cases where the structure of the implant promotes regrowth of tissue with the implant forming a superstructure or degradation of the implant in which the backbones of the proteins are recognized for cleavage by the body.

2.2.1 Man made Fibers

NOTES

Man made fibers, such as nylon, polyester, and rayon, are produced by chemical reactions controlled by people, rather than occurring naturally. The term synthetic fibers is often used to designate man made fibers; however, to many people, this term has a negative connotation, meaning inauthentic, artificial, or fake. TFPIA classifies man made or manufactured fibers by generic names. Currently, TFPIAN recognizes 26 generic groups of manmade fibers.

(1) Polymers synthesized from chemical compounds, e.g., polyethylene fiber, polyurethane fiber, and polyvinyl fibers;

(2) Modified or transformed natural polymers, e.g., alginic and cellulose-based fibers such as rayons fiber; and

(3) Minerals, e.g., glasses. The term manufactured usually refers to all chemically produced fibers to distinguish them from the truly natural fibers such as cotton, wool, silk, flax, etc.e.g: **glass fiber**

Classification of Textile Fibers

Generally textile fibers can be classified into main two types they are-Natural fiber And Synthetic fiber or manmade fiber or artificial fiber. Textile fibers can also be classified in the following ways:

1. Classification of textile fibers based on sources
2. Classification of textile fibres based on polymer

Classification of Textile Fibers Based on Sources

With this concept, the classification of fiber was established as per its source. The major natural fibers present around us from vegetable and natural sources. There are around 15 important natural fibers available for processing and conversion into fabrics. Those are discussed below.

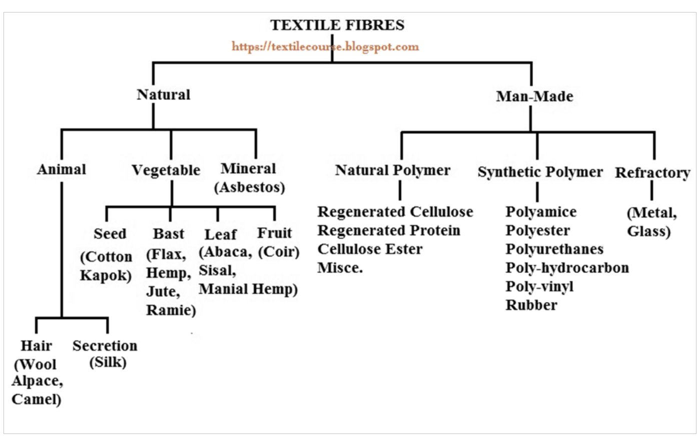

Figure: Classification of textile fibers as per sources

Vegetable sources

NOTES

Major fibers from vegetable sources are discussed below:

- **Cotton:** Cotton is most widely used natural fiber and consists of pure cellulose. It is produced in China, Brazil, India, Pakistan, USA and Uzbekistan.
- **Flax:** Flax is a lignocellulosic bast fiber, mostly present in European Union. This fiber is mostly used to make linen.
- **Hemp:** Hemp is also a lignocellulosic bast fiber with low quantity of lignin. The world's leading producer of hemp fiber is China.
- **Jute:** Jute is the strongest vegetable fiber from India and Bangladesh. It is also a lignocellulosic fiber.
- **Ramie:** Ramie is also a lignocellulosic bast fibre mostly available in China and Brazil. It is also known as China grass, with a silky lustre and better elasticity.
- **Sisal:** Sisal is a hard and coarser leaf fiber, mostly available in Brazil, Tanzania and Kenya.
- **Abaca:** Abaca is a leaf fiber, also known as manila hemp, extracted from leaf sheath around the trunk of Musa textiles. The world's major fi bre producer is Philippines. Lignin content in the fibre is about 15%.
- **Coir:** Coir is a hard, short and coarse fiber extracted from the shells of coconut. It is mostly present in India, Sri Lanka, Philippines, Vietnam, Indonesia and Brazil. This fibre contains highest amount of lignin making it stronger but less flexible.

Animal sources

Major fibres from animal sources are discussed below:

- **Alpaca:** Alpaca is a hair fiber like wool, comes from the Lama Pocos. This fibre comes in approximately 22 natural colors, produced mostly in Peru, North America, Australia and New Zealand. It is stronger than wool fiber.
- **Angora:** Angora is a rabbit fiber, very soft, fine and silky. 90% of the fiber is produced in China. Angora fabric is very suitable for thermal clothing.
- **Camel hair:** Camel hair is available from the two humped Bactrian camel mostly present with nomadic households in Mongolia and inner Mongolia, China. It is the softest and more premium hair fibre.
- **Cashmere fiber:** Cashmere fiber is available with Kashmir goats, in China, Australia, India, Pakistan, New Zealand, Turkey and USA. It is a luxurious and expensive fiber.
- **Mohair fiber:** Mohair fiber is produced from Angora goat, available in South Africa. It is a smooth and lustrous fiber.
- **Silk:** Silk is the natural filament fiber, with high lustre, mostly produced in China, Brazil, India, Thailand and Vietnam.
- **Wool:** Wool is the most important protein fiber. It is the first domesticated fiber, mostly produced in Australia, New Zealand, China, Iran, Argentina and UK.

Ground and petrochemical sources

In addition to the collection of the fibers from the sources above the ground, there are fibers from below the ground like metals. From World War II, there has been a thrust to produce synthetic materials, mostly derived from petrochemicals. The manufactured fibre is termed as 'synthetic fibers' as the raw materials were available by synthesis followed by polymerization and fiber formation. Synthetic fibers became the consequence of spectacular growth in petrochemicals development and utilization. The growth in the development of synthetic fibres and synthetic fiber industry along with polymer industry became phenomenal with the growth of petrochemical industry.

Classification of Textile Fibres Based on Polymer

Polymer is a material constructed of smaller molecules of the same substance that form larger molecules. The polymers are any of numerous natural and synthetic compounds of usually high molecular weight and consisting of up to millions of repeated linked units, each a relatively light and simple molecule.

The term is derived from the Greek words: 'polumeres', where polus meaning many, and meros meaning parts. A key feature that distinguishes polymers from other molecules is the repetition of many identical, similar or complementary molecular subunits in these chains.

Polymers, macromolecules, high polymers and giant molecules are basically same and consist of high-molecular-weight materials composed of these repeating subunits. These materials may be organic, inorganic or organometallic, and synthetic or natural in origin. Polymers are essential materials for almost every industry such as adhesives, building materials, paper, cloths, fibers, coatings, plastics, ceramics, concretes, liquid crystals, photo resists and coatings.

These polymers can be natural or synthetic and organic or inorganic. Organic polymers are distinguished from inorganic polymers because of presence of carbon atom in the main chain. Presence of totally carbon atoms termed as carbochain polymers. If the main chain consists of other atoms with carbon, then it is termed as heterochain polymers. Natural inorganic polymers include sand, asbestos, agates, feldspars, mica, quartz and talc.

Natural organic polymers include polysaccharides or polycarbohydrates such as starch and cellulose, nucleic acids, lignin, rubber and proteins. Synthetic inorganic polymers include boron nitride, concrete, many high-temperature superconductors and a number of glasses. Synthetic organic polymers include fibers, plastics and coatings, such as polyethylene, polypropylene, polyamides, polyesters, vinyl polymers, polyurethanes and synthetic rubbers.

Fibers are polymeric materials that are strong in one direction, and they are much longer (>100 times) than their width. This is termed as l/d ratio. Elastomers or rubbers are polymeric materials that can be distorted through the application of force, and when the force is removed, the material returns to its original shape. Plastics are materials that have properties between fibers and elastomers—they are hard and flexible.

The resources for natural fibers are also natural high molecular weight polymeric substances. This means that both natural and synthetic fibers are polymeric materials. Based on the polymeric materials present in fibers, all fibers can also be classified in the way.

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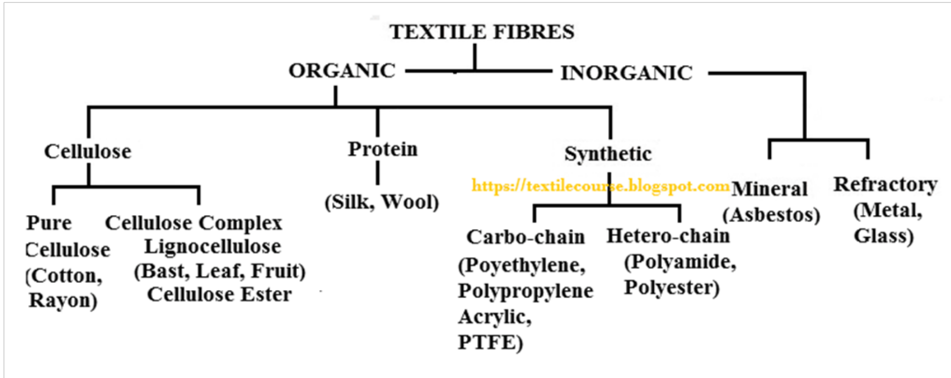

Figure: Classification of textile fibers based on the polymer

2.3 NATURAL FIBER- COTTON, SILK, WOOL, JUTE, HEMP

Natural Fiber

Natural fibre, any hairlike raw material directly obtainable from an animal, vegetable, or mineral source and convertible into nonwoven fabrics such as felt or paper or, after spinning into yarns, into woven cloth. A natural fibre may be further defined as an agglomeration of cells in which the diameter is negligible in comparison with the length. Although nature abounds in fibrous materials, especially cellulosic types such as cotton, wood, grains, and straw, only a small number can be used for textile products or other industrial purposes. Apart from economic considerations, the usefulness of a fibre for commercial purposes is determined by such properties as length, strength, pliability, elasticity, abrasion resistance, absorbency, and various surface properties. Most textile fibres are slender, flexible, and relatively strong. They are elastic in that they stretch when put under tension and then partially or completely return to their original length when the tension is removed.

rattan A weaver making a basket from rattan, Malaysia.

Plant fibers

Category	hide**types**
Seed fiber	The fibers collected from the seeds of various plants are known as seed fibers.
Leaf fiber	Fibers collected from the cells of a leaf are known as leaf fibers, for example, banana, pineapple (PALF), etc.
Bast fiber	Bast fibers are collected from the outer cell layers of the plant's stem. These fibers are used for durable yarn, fabric, packaging, and paper. Some examples are flax, jute, kenaf, industrial hemp, ramie, rattan, and vine fibers.
Fruit fiber	Fibers collected from the fruit of the plant, for example, coconut fiber (coir).
Stalk fiber	Fibers from the stalks of plants, e.g. straws of wheat, rice, barley, bamboo and straw.

Animal fibers

Animal fibers generally comprise proteins such as collagen, keratin and fibroin; examples include silk, sinew, wool, catgut, angora, mohair and alpaca.

- **Animal hair (wool or hairs):** Fiber or wool taken from animals or hairy mammals. e.g. sheep's wool, goat hair (cashmere, mohair), alpaca hair, horse hair, etc.
- **Silk fiber:** Fiber secreted by glands (often located near the mouth) of insects during the preparation of cocoons.
- **Avian fiber:** Fibers from birds, e.g. feathers and feather fiber.

Chitin

Chitin is the second most abundant natural polymer in the world, with collagen being the first. It is a "linear polysaccharide of ß-(1-4)-2-acetamido-2-deoxy-D-glucose". Chitin is highly crystalline and is usually composed of chains organized in a ß sheet. Due to its high crystallinity and chemical structure, it is insoluble in many solvents. It also has a low toxicity in the body and is inert in the intestines. Chitin also has antibacterial properties.

Chitin forms crystals that make fibrils that become surrounded by proteins. These fibrils can bundle to make larger fibers that contribute to the hierarchical structure of many biological materials. These fibrils can form randomly oriented networks that provide the mechanical strength of the organic layer in different biological materials.

Chitin provides protection and structural support to many living organisms. It makes up the cell walls of fungi and yeast, the shells of mollusks, the exoskeletons of insects and arthropods. In shells and exoskeletons, the chitin fibers contribute to their hierarchical structure.

In nature, pure chitin (100% acetylation) does not exist. It instead exists as a copolymer with chitin's deacetylated derivative, chitosan. When the acetylized composition of the copolymer is over 50% acetylated it is chitin. This copolymer of chitin and chitosan is a random or block copolymer.

Chitosan

Chitosan is a deacetylated derivative of chitin. When the acetylized composition of the copolymer is below 50% it is chitosan. Chitosan is a semicrystalline "polymer of β-(1-4)-2-amino-2-deoxy-D-glucose". One difference between chitin and chitosan is that chitosan is soluble in acidic aqueous solutions. Chitosan is easier to process that chitin, but it is less stable because it is more hydrophilic and has pH sensitivity. Due to its ease of processing, chitosan is used in biomedical applications.

Collagen

Collagen is a structural protein, often referred to as "the steel of biological materials". There are multiple types of collagen: Type I (comprising skin, tendons and ligaments, vasculature and organs, as well as teeth and bone); Type II (a component in cartilage); Type III (often found in reticular fibers); and others. Collagen has a hierarchical structure, forming triple helices, fibrils, and fibers.

Keratin

Keratin is a structural protein located at the hard surfaces in many vertebrates. Keratin has two forms, α-keratin and β-keratin, that are found in different classes of chordates. The naming convention for these keratins follows that for protein structures: alpha keratin is helical and beta keratin is sheet-like. Alpha keratin is found in mammalian hair, skin, nails, horn and quills, while beta keratin can be found in avian and reptilian species in scales, feathers, and beaks. The two different structures of keratin have dissimilar mechanical properties, as seen in their dissimilar applications. The relative alignment of the keratin fibrils has a significant impact on the mechanical properties. In human hair the filaments of alpha keratin are highly aligned, giving a tensile strength of approximately 200MPa. This tensile strength is an order of magnitude higher than human nails (20MPa), because human hair's keratin filaments are more aligned.

Properties

Compared to synthetic fibers, natural fibers tend have decreased stiffness and strength.

Tensile Mechanical Properties of Natural Fibers

Material	Fiber	Elastic Modulus (GPa)	Strength (MPa)
Tendon	Collagen	1.50	150

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Bone	Collagen	20.0	160
Mud Crab Exoskeleton (wet)	Chitin	0.48	30
Prawn Exoskeleton (wet)	Chitin	0.55	28
Bovine Hoof	Keratin	0.40	16
Wool	Keratin	0.50	200

Properties also decrease with the age of the fiber. Younger fibers tend to be stronger and more elastic than older ones. Many natural fibers exhibit strain rate sensitivity due to their viscoelastic nature. Bone contains collagen and exhibits strain rate sensitivity in that the stiffness increases with strain rate, also known as strain hardening. Spider silk has hard and elastic regions that together contribute to its strain rate sensitivity, these cause the silk to exhibit strain hardening as well. Properties of natural fibers are also dependent on the moisture content in the fiber.

Moisture dependence

The presence of water plays a crucial role in the mechanical behavior of natural fibers. Hydrated, biopolymers generally have enhanced ductility and toughness. Water plays the role of a plasticizer, a small molecule easing passage of polymer chains and in doing so increasing ductility and toughness. When using natural fibers in applications outside of their native use, the original level of hydration must be taken into account. For example when hydrated, the Young's Modulus of collagen decreases from 3.26 to 0.6 GPa and becomes both more ductile and tougher. Additionally the density of collagen decreases from 1.34 to 1.18 g/cm^3.

Cotton Fibers – the king of fibers

Cellulose, seed fiber from the nature

Cotton is a soft staple fibre that grown in a form known as a boll around the seeds of the cotton plant, a shrub native to tropical and subtropical regions.

Cotton

Cotton today is the most used textile fiber in the world. Its current market share is 56 percent for all fibers used for apparel and home furnishings and sold in the U.S. Another contribution is attributed to nonwoven textiles and personal care items. The earliest evidence of using cotton is from India and the date assigned to this fabric is 3000 B.C. There were also excavations of cotton fabrics of comparable age in Southern America. Cotton cultivation first spread from India to Egypt, China, and the South Pacific.

Cotton is a soft, staple fiber that grows in a form known as a boll around the seeds of the cotton plant, a shrub native to tropical and subtropical regions around the world, including the Americas, India, and Africa. The fiber most often is spun into yarn or thread and used to make a soft, breathable textile, which is the most widely used natural-fiber cloth in clothing today. The English name derives from the Arabic (al) qutn.... , which began to be used circa 1400.

Each cotton fiber is composed of concentric layers. The cuticle layer on the fiber itself is separable from the fiber and consists of wax and pectin materials.

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Properties of Cotton

Cotton is a soft fiber that grows around the seeds of the cotton plant. Cotton fiber grows in the seed pod or boll of the cotton plant. Each fiber is a single elongated cell that is flat twisted and ribbon-like with a wide inner hollow (lumen).

- 90% cellulose, 6% moisture and the remainder fats and impurities.
- The outer surface is covered with a protective wax-like coating which gives fiber an adhesive quality.

Cotton is a natural fiber that is grown in countries around the world. It is a crop that requires adequate moisture and heat to mature and produce quality fibers. Cotton growing tends to be in warmer climates. Cotton is a true commodity in the world markets and supply and demand truly affect prices of raw cotton.

Cotton fibers are mainly made up of cellulose. Cellulose does not form unless temperatures are over 70 °F (21 °C). The cotton fibers are attached to the seeds inside the boll of the plant. There are usually six or seven seeds in a boll and up to 20,000 fibers attached to each seed. The length of these fibers (also called staples) is the main determining factor in the quality of the cotton. In general, the longer the staple grows the higher the quality of the cotton. Staple lengths are divided into short, medium, and long (and extra long, in some cases):

- Short staple cotton is between 3/8" to 15/16" (.95cm to 2.4cm) in length
- Medium staple cotton is between 1" to 1-1/8" (2.54cm to 2.86cm) in length
- Long staple cotton is between 1-3/16" to 2-1/2" (3cm to 6.35cm) in length

Properties of Cotton Products

- **Comfortable** – there are no surface characteristics of cotton that make it irritating to human skin. Cotton feels good against skin; it has a soft hand.
- **Hydrophilic** – cotton has a natural affinity for water – it attracts moisture away from your body.
- **Moisture passes freely through cotton** – aiding in evaporation and cooling
- **Good Heat Conductivity** – Cotton allows heat to dissipate making it a wonderful fiber to maintain a comfortable sleeping temperature.
- Strong and abrasion resistance
- The unfavorable attributes of cotton include its lack of resiliency (cotton tends to wrinkle) and its
- lack of luster (colors are usually dull).

Properties of Cotton Fiber

- It has 8% moisture regain
- The cellulose is arranged in a way that gives cotton unique properties of strength, durability, and absorbency
- It is fresh, crisp, comfortable, absorbent, flexible, has no pilling problems and has good resistance to alkalis
- It has poor wrinkle resistance, shrinkage, poor acid resistance, less abrasion resistance, susceptible to damage by moths and mildew, needs lots of maintenance and stains are difficult to remove
- Its fiber length ranges from ½ inches to 2inches
- It has 10%increase in strength when wet.
- It has a flat twisted tube shape

Long Staple Cotton

In general, long staple cotton is needed to spin the yarns needed in the weaving of the finer down proof cotton fabrics.

Long staple cotton is considered to be finer quality because they can be spun into finer yarns and those finer yarns can be woven into softer, smoother, stronger, and more lustrous fabrics. Long staple cotton makes stronger yarns, especially in fine yarns, as there are fewer fibers in a given length of yarn and the longer fibers provide more points of contact between the fibers when they are twisted together in the spinning process.

Common areas that grow long staple cotton in the world would be Egypt, Sudan, the United States (Pima cotton grown in the west and southwest are long staple cotton), and Western China. The two most widely known long-staple cottons are Egyptian cotton and Pima cotton. Pima cotton is grown mainly in the United States, but also in Peru, Israel, and Australia.

The fibers are sent to a textile mill where carding machines turn the fibers into cotton yarn. The yarns are woven into cloth that is comfortable and easy to wash but does wrinkle easily. Cotton fabric will shrink about 3% when washed unless pre-treated to resist shrinking.

Cotton is prized for its comfort, easy care, and affordability and is ideal for clothing, bedding, towels, and furnishings.

Harvesting

Cotton was once harvested by hand, often by slave labor or tenant farmers. As recently as 1965, over a fourth of the U.S. cotton crop was picked by hand. Today, harvesting cotton is highly mechanized.

Harvesting machines called strippers and pickers efficiently remove the cotton while leaving the plants undisturbed. Spindle harvester, also called a picker, has drums with spindles that pull the cotton from the boll in one or two rows at a time. Even a one-row mechanical picker can do the work formerly done by 40 hand pickers.

NOTES

In stripper harvesting, the stripper moves along rows of plants, passing them between revolving rollers or brushes that pull off the cotton. Strippers also pull twigs and leaves with the cotton.

Cotton gins separate the fibers, called lint, from the seeds. After ginning, the cotton goes to the bale press that packs it into 480-pound bales about the size of a large refrigerator.

Cotton Ginning

From the field, seed cotton moves to nearby gins for separation of lint and seed. The cotton first goes through dryers to reduce moisture content and then through cleaning equipment to remove foreign matter. These operations facilitate processing and improve fiber quality. The cotton is then air conveyed to gin stands where revolving circular saws pull the lint through closely spaced ribs that prevent the seed from passing through. The lint is removed from the saw teeth by air blasts or rotating brushes and then compressed into bales weighing approximately 500 pounds. Cotton is then moved to a warehouse for storage until it is shipped to a textile mill for use.

A typical gin will process about 12 bales per hour, while some of today's more modern gins may process as many as 60 bales an hour.

Properties of Cotton

Cotton fiber possesses a variety of distinct properties, and we know there are plenty of people who want to dig a little deeper.

That's why we've packed as much technical information onto this page as humanly possible. If you have a technical mind, then this is probably the page you've been searching for, and dreaming about.

Micronaire

A unique cotton term related to fiber maturity and fineness (diameter). Micronaire, however, is a unit-less value. It's the measurement of airflow resistance through a 2.34 gram fiber specimen that is compressed to a specific volume. Micronaire can be converted to approximate denier value by dividing micronaire value by 2.82.

Cotton Fiber Length

Fiber length varies. Being a natural fiber, there are always going to be fibers of different lengths present (length distribution or fiber array). Cotton fiber length is measured and reported as the upper half mean length (average length of the longest 50% of fibers) to an accuracy of one hundredth of an inch.

Cotton Fiber Strength

Fiber strength is measured by breaking the fibers held between clamp jaws. It's reported as grams per tex, which is the force in grams required to break a bundle of fibers one tex unit in size. A tex unit is equal to the weight in grams of 1000 meters of fiber.

Nep

A nep is small tangled knot of cotton fibers. They are produced from mechanical processing of cotton, starting with the equipment used to pick the cotton from the plant.

1. Upper Half Mean Length (in inches)	
A. #1 Upland Virgin Staple	0.70 – 1.30
B. Gin Motes	0.50 – 0.80
C. Comber	<0.50
D. First Cut linters	0.25- 0.50
2. Fiber Diameter	
A. Micronaire	2.0 – 7.0
B. Approximate Denier	0.7 – 2.5
3. Elastic Recovery (by percent)	
A. At 2 % Extension	74%
B. At 5% Extension	45%

NOTES

4. Breaking Elongation (dry)	3-9.5
5. Tensile Strength (g per tex/g per denier)	
A. Dry	27 – 44 / 3.0 – 4.9
B. Wet	28 – 57 / 3.3 – 6.4
6. Moisture Regain at Standard Conditions	7%
7. Water Absorbing Capacity (USP method)	>24 grams of water per gram of fiber
8. Density (g/cm^3)	1.54
9. Degree of Polymerization	9,000 – 15,000
10. Crystallinity by X-ray Diffraction (average)	73%
11. Color (Whiteness Index)	90 – 100
12. Thermal Resistance	
A. Long exposure to dry heat above 300^0F will cause gradual decomposition	
B. Temperatures greater than 475^0F cause rapid deterioration	
13. Acid Resistance	
A. Disintegrated by hot dilute acids or cold concentrated acids	
B. Unaffected by cold weak acids	
14. Alkali Resistance	

NOTES

A. Swelling in NaOH above 15% concentration but no damage
15. Organic Solvent Resistance A. Resistant to most common industrial and household solvents
16. General Properties: See list to right (or below if viewing on mobile device)

Note: Purified cotton is exempt from OSHA cotton dust standards.

The Full Cellulose Lowdown

Cotton, like rayon and wood pulp fibers, is made of cellulose. Cellulose is a macromolecule made up of anhydroglucose unit connected by 1, 4 oxygen bridges with the polymer repeating unit being anhydro-beta-cellulose.

Cotton cellulose differs from wood and rayon cellulose by having higher degrees of polymerization and crystallinity. The degree of polymerization is the number of repeating units that are linked together to form a molecule of cellulose. Crystallinity indicates that the fiber's cellulose molecules are closely packed and parallel to one another. Higher degrees of polymerization and crystallinity of polymers are associated with higher strengths.

Polymerization for Cellulosic Fibers

Fiber	Average Degree of Polymerization	Average Degree of Crystallinity
Cotton	9,000 – 15,000	73
Rayon (regular)	250 – 450	60
Wood Pulp	600 – 1500	35

Due to the increased degree of crystallinity and hydrogen bonding between the molecules in the crystalline areas in cotton, moisture can't penetrate the molecules. Moisture penetrating molecules can act as a lubricant and result in loss of strength. Therefore, cotton cellulose does not lose strength when wet like rayon does; in fact, it gets stronger. Synthetic fibers are hydrophobic; therefore their strength is not affected at all by moisture.

Fiber Strength (grams/tex)

NOTES

Fiber	Dry Strength	Wet Strength
Cotton	27 – 45	30 – 54
Rayon (regular)	22 – 27	10 – 14
Polyester	27 – 54	27 – 54

Mold And Yeast Spore Removal

With cotton as the customer-preferred choice, the purification process is critical. The data shown below is from testing conducted by an independent laboratory. It shows how effective the Barnhardt purification process is at eliminating mold and yeast spores from the cotton fibers (colony forming units per gram = CFM/g).

	Total Plate Count (CFU/g)	Mold/Yeast (CFM/g)
Before Purification	40,000 – 450,000	210 – 550
After Purification	< 30	< 10

Cotton Biodegradability Breakdown

Cotton fibers and fabrics, being natural cellulose polymers, are biodegradable under aerobic conditions. Independent lab results have also shown that cotton is compostable. In the case shown below, 100% cotton wet wipe hydroentangled fabrics were tested for compostability using ASTM method 6400. The test procedure calls for at least 90% weight loss to constitute complete biodegradability.

Average Biodegradability (Percent Weight Lost)

Sample	After 2 weeks	After 4 weeks
Cotton Wet Wipe	40	90

OSHA Cotton Dust Standard

Only washed and purified cotton are exempt from the OSHA cotton dust standard.

In the early 1970's byssinosis, commonly known as "brown lung" disease, was found to be caused by cotton dust exposure. In 1978 approximately 12,000 textile workers suffered from the disease. That same year, OSHA introduced the cotton dust standard (29 CFR # 1910.1043) to protect workers. In 1999 the number of textile workers suffering from the disease had dropped to 700.

OSHA Standard Requirements:

1. Employee exposure limits, also known as **permissible exposure limits (PEL)**, are average exposure as measured over an 8 hour-hour workday. There are different PEL exposure limit levels (ranging from 200 to 1000 micrograms per cubic meter) depending on production area. Employers are required to measure the cotton dust levels at least every six months for each shift.
2. If the cotton dust levels are above the PEL, the employer must select suitable **Personal Protective Equipment (PPE)** to protect their employees. The employees are to be fitted and receive training on using, cleaning and maintaining the equipment before using their PPE.
3. **Free annual medical exams**, including breathing tests, must be provided by the employer for all employees in dust areas (even if the area is below PEL). Results must be provided to the employee. Records of the test results must be maintained for 20 years and be available to OSHA upon request.

The standard, as it was originally released, included all types of cotton – even if the fiber had been wet processed. The standard was later amended based on work done by a joint task force that included industry, union and government officials. The work of this joint task force showed that the batch kier method of purifying cotton (which is used by Barnhardt employees) eliminates the bioactivity of cotton dust and fiber and is exempted from the standard.

Silk

Silk is a natural protein fiber, some forms of which can be woven into textiles. The protein fiber of silk is composed mainly of fibroin and is produced by certain insect larvae to form cocoons. The best-known silk is obtained from the cocoons of the larvae of the mulberry silkworm Bombyx mori reared in captivity (sericulture). The shimmering appearance of silk is due to the triangular prism-like structure of the silk fibre, which allows silk cloth to refract incoming light at different angles, thus producing different colors.

Silk is produced by several insects; but, generally, only the silk of moth caterpillars has been used for textile manufacturing. There has been some research into other types of silk, which differ at the molecular level. Silk is mainly produced by the larvae of insects undergoing complete metamorphosis, but some insects, such as webspinners and raspy crickets, produce silk throughout their lives. Silk production also occurs in hymenoptera (bees, wasps, and ants), silverfish, mayflies, thrips, leafhoppers, beetles, lacewings, fleas, flies, and midges. Other types of arthropods produce silk, most notably various arachnids, such as spiders.

Wild silk

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Several kinds of wild silk, produced by caterpillars other than the mulberry silkworm, have been known and spun in China, South Asia, and Europe since ancient times, e.g. the production of Eri silk in Assam. However, the scale of production was always far smaller than for cultivated silks. There are several reasons for this: first, they differ from the domesticated varieties in colour and texture and are therefore less uniform; second, cocoons gathered in the wild have usually had the pupa emerge from them before being discovered so the silk thread that makes up the cocoon has been torn into shorter lengths; and third, many wild cocoons are covered in a mineral layer that prevents attempts to reel from them long strands of silk. Thus, the only way to obtain silk suitable for spinning into textiles in areas where commercial silks are not cultivated was by tedious and labor-intensive carding.

Some natural silk structures have been used without being unwound or spun. Spider webs were used as a wound dressing in ancient Greece and Rome, and as a base for painting from the 16th century. Caterpillar nests were pasted together to make a fabric in the Aztec Empire.

Commercial silks originate from reared silkworm pupae, which are bred to produce a white-colored silk thread with no mineral on the surface. The pupae are killed by either dipping them in boiling water before the adult moths emerge or by piercing them with a needle. These factors all contribute to the ability of the whole cocoon to be unravelled as one continuous thread, permitting a much stronger cloth to be woven from the silk. Wild silks also tend to be more difficult to dye than silk from the cultivated silkworm. A technique known as demineralizing allows the mineral layer around the cocoon of wild silk moths to be removed, leaving only variability in color as a barrier to creating a commercial silk industry based on wild silks in the parts of the world where wild silk moths thrive, such as in Africa and South America.

China

Silk use in fabric was first developed in ancient China. The earliest evidence for silk is the presence of the silk protein fibroin in soil samples from two tombs at the neolithic site Jiahu in Henan, which date back about 8,500 years. The earliest surviving example of silk fabric dates from about 3630 BC, and was used as the wrapping for the body of a child at a Yangshao culture site in Qingtaicun near Xingyang, Henan.

Legend gives credit for developing silk to a Chinese empress, Leizu (Hsi-Ling-Shih, Lei-Tzu). Silks were originally reserved for the Emperors of China for their own use and gifts to others, but spread gradually through Chinese culture and trade both geographically and socially, and then to many regions of Asia. Because of its texture and lustre, silk rapidly became a popular luxury fabric in the many areas accessible to Chinese merchants. Silk was in great demand, and became a staple of pre-industrial international trade. In July 2007, archaeologists discovered intricately woven and dyed silk textiles in a tomb in Jiangxi province, dated to the Eastern Zhou dynasty roughly 2,500 years ago. Although historians have suspected a long history of a formative textile industry in ancient China, this find of silk textiles employing "complicated techniques" of weaving and dyeing provides direct evidence for silks dating before the Mawangdui-discovery and other silks dating to the Han dynasty (202 BC – 220 AD).

Silk is described in a chapter of the Fan Shengzhi shu from the Western Han (202 BC – 9 AD). There is a surviving calendar for silk production in an Eastern Han (25–220 AD) document. The two other known works on silk from the Han period are lost. The first evidence of the long distance silk trade is the finding of silk in the hair of an Egyptian mummy of the 21st dynasty, c.1070 BC. The silk trade reached as far as the Indian subcontinent, the Middle East, Europe, and North Africa. This trade was so extensive that the major set of trade routes between Europe and Asia came to be known as the Silk Road.

The Emperors of China strove to keep knowledge of sericulture secret to maintain the Chinese monopoly. Nonetheless sericulture reached Korea with technological aid from China around 200 BC, the ancient Kingdom of Khotan by AD 50, and India by AD 140.

In the ancient era, silk from China was the most lucrative and sought-after luxury item traded across the Eurasian continent, and many civilizations, such as the ancient Persians, benefited economically from trade.

Northeastern India

In the northeastern state of Assam, three different types of indigenous variety of silk are produced, collectively called Assam silk: Muga, Eri and Pat silk. Muga, the golden silk, and Eri are produced by silkworms that are native only to Assam. They have been reared since ancient times similar to other East and South-East Asian countries.

India

Silk has a long history in India. It is known as Resham in eastern and north India, and Pattu in southern parts of India. Recent archaeological discoveries in Harappa and Chanhu-daro suggest that sericulture, employing wild silk threads from native silkworm species, existed in South Asia during the time of the Indus Valley Civilization (now in Pakistan) dating between 2450 BC and 2000 BC, while "hard and fast evidence" for silk production in China dates back to around 2570 BC. Shelagh Vainker, a silk expert at the Ashmolean Museum in Oxford, who sees evidence for silk production in China "significantly earlier" than 2500–2000 BC, suggests, "people of the Indus civilization either harvested silkworm cocoons or traded with people who did, and that they knew a considerable amount about silk."

India is the second largest producer of silk in the world after China. About 97% of the raw mulberry silk comes from six Indian states, namely, Andhra Pradesh, Karnataka, Jammu and Kashmir, Tamil Nadu, Bihar and West Bengal. North Bangalore, the upcoming site of a $20 million "Silk City" Ramanagara and Mysore, contribute to a majority of silk production in Karnataka.

In Tamil Nadu, mulberry cultivation is concentrated in the Coimbatore, Erode, Bhagalpuri, Tiruppur, Salem and Dharmapuri districts. Hyderabad, Andhra Pradesh, and Gobichettipalayam, Tamil Nadu, were the first locations to have automated silk reeling units in India.

India is also the largest consumer of silk in the world. The tradition of wearing silk sarees for marriages and other auspicious ceremonies is a custom in Assam and southern parts of India. Silk is considered to be a symbol of royalty, and, historically, silk was used primarily by the upper classes. Silk garments and sarees produced in Kanchipuram, Pochampally, Dharmavaram, Mysore, Arani in the south, Banaras in the north, Bhagalpur and Murshidabad in the east are well recognized.

Thailand

Silk is produced year-round in Thailand by two types of silkworms, the cultured Bombycidae and wild Saturniidae. Most production is after the rice harvest in the southern and northeastern parts of the country. Women traditionally weave silk on hand looms and pass the skill on to their daughters, as weaving is considered to be a sign of maturity and eligibility for marriage. Thai silk textiles often use complicated patterns in various colours and styles. Most regions of Thailand have their own typical silks. A single thread filament is too thin to use on its own so women combine many threads to produce a thicker, usable fiber. They do this by hand-reeling the threads onto a wooden spindle to produce a uniform strand of raw silk. The process takes around 40 hours to produce a half kilogram of silk. Many local operations use a reeling machine for this task, but some silk threads are still hand-reeled. The difference is that hand-reeled threads produce three grades of silk: two fine grades that are ideal for lightweight fabrics, and a thick grade for heavier material.

The silk fabric is soaked in extremely cold water and bleached before dyeing to remove the natural yellow coloring of Thai silk yarn. To do this, skeins of silk thread are immersed in large tubs of hydrogen peroxide. Once washed and dried, the silk is woven on a traditional hand-operated loom.

Bangladesh

The Rajshahi Division of northern Bangladesh is the hub of the country's silk industry. There are three types of silk produced in the region: mulberry, endi and tassar. Bengali silk was a major item of international trade for centuries. It was known as Ganges silk in medieval Europe. Bengal was the leading exporter of silk between the 16th and 19th centuries.

Ancient Mediterranean

In the Odyssey, 19.233, when Odysseus, while pretending to be someone else, is questioned by Penelope about her husband's clothing, he says that he wore a shirt "gleaming like the skin of a dried onion" (varies with translations, literal translation here) which could refer to the lustrous quality of silk fabric. Aristotle wrote of Coa vestis, a wild silk textile from Kos. Sea silk from certain large sea shells was also valued. The Roman Empire knew of and traded in silk, and Chinese silk was the most highly priced luxury good imported by them. During the reign of emperor Tiberius, sumptuary laws were passed that forbade men from wearing silk garments, but these proved ineffectual. The Historia Augusta mentions that the third-century emperor Elagabalus was the first Roman to wear garments of pure silk, whereas it had been customary to wear fabrics of silk/cotton or silk/linen blends. Despite the popularity of silk, the secret of silk-making only reached Europe around AD 550, via the Byzantine Empire. Legend has it that monks working for the emperor Justinian I smuggled silkworm eggs to Constantinople in hollow canes from China. All top-quality looms and weavers were located inside the Great Palace complex in Constantinople, and the cloth produced was used in imperial robes or in diplomacy, as gifts to foreign dignitaries. The remainder was sold at very high prices.

Middle East

In the Torah, a scarlet cloth item called in Hebrew "sheni tola'at" תעלות ינש – literally "crimson of the worm" – is described as being used in purification ceremonies, such as those following a leprosy outbreak (Leviticus 14), alongside cedar wood and hyssop (za'atar). Eminent scholar and leading medieval translator of Jewish sources and books of the Bible into Arabic, Rabbi Saadia Gaon, translates this phrase explicitly as "crimson silk" – רירח זמרק ريرح زمرق.

In Islamic teachings, Muslim men are forbidden to wear silk. Many religious jurists believe the reasoning behind the prohibition lies in avoiding clothing for men that can be considered feminine or extravagant. There are disputes regarding the amount of silk a fabric can consist of (e.g., whether a small decorative silk piece on a cotton caftan is permissible or not) for it to be lawful for men to wear, but the dominant opinion of most Muslim scholars is that the wearing of silk by men is forbidden. Modern attire has raised a number of issues, including, for instance, the permissibility of wearing silk neckties, which are masculine articles of clothing.

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Medieval and modern Europe

Italy was the most important producer of silk during the Medieval age. The first center to introduce silk production to Italy was the city of Catanzaro during the 11th century in the region of Calabria. The silk of Catanzaro supplied almost all of Europe and was sold in a large market fair in the port of Reggio Calabria, to Spanish, Venetian, Genovese and Dutch merchants. Catanzaro became the lace capital of the world with a large silkworm breeding facility that produced all the laces and linens used in the Vatican. The city was world-famous for its fine fabrication of silks, velvets, damasks and brocades.

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Another notable center was the Italian city-state of Lucca which largely financed itself through silk-production and silk-trading, beginning in the 12th century. Other Italian cities involved in silk production were Genoa, Venice and Florence.

The Silk Exchange in Valencia from the 15th century—where previously in 1348 also perxal (percale) was traded as some kind of silk—illustrates the power and wealth of one of the great Mediterranean mercantile cities.

Silk was produced in and exported from the province of Granada, Spain, especially the Alpujarras region, until the Moriscos, whose industry it was, were expelled from Granada in 1571.

Since the 15th century, silk production in France has been centered around the city of Lyon where many mechanic tools for mass production were first introduced in the 17th century.

James 1 attempted to establish silk production in England, purchasing and planting 100,000 mulberry trees, some on land adjacent to Hampton Court Palace, but they were of a species unsuited to the silk worms, and the attempt failed. In 1732 John Guardivaglio set up a silk throwing enterprise at Logwood mill in Stockport; in 1744, Burton Mill was erected in Macclesfield; and in 1753 Old Mill was built in Congleton. These three towns remained the centre of the English silk throwing industry until silk throwing was replaced by silk waste spinning. British enterprise also established silk filature in Cyprus in 1928. In England in the mid-20th century, raw silk was produced at Lullingstone Castle in Kent. Silkworms were raised and reeled under the direction of Zoe Lady Hart Dyke, later moving to Ayot St Lawrence in Hertfordshire in 1956.

During World War II, supplies of silk for UK parachute manufacture were secured from the Middle East by Peter Gaddum.

North America

Wild silk taken from the nests of native caterpillars was used by the Aztecs to make containers and as paper. Silkworms were introduced to Oaxaca from Spain in the 1530s and the region profited from silk production until the early 17th century, when the king of Spain banned export to protect Spain's silk industry. Silk production for local consumption has continued until the present day, sometimes spinning wild silk.

King James I introduced silk-growing to the British colonies in America around 1619, ostensibly to discourage tobacco planting. The Shakers in Kentucky adopted the practice.

The history of industrial silk in the United States is largely tied to several smaller urban centers in the Northeast region. Beginning in the 1830s, Manchester, Connecticut emerged as the early center of the silk industry in America, when the Cheney Brothers became the first in the United States to properly raise silkworms on an industrial scale; today the Cheney Brothers Historic District showcases their former mills. With the mulberry tree craze of that decade, other smaller producers began raising silkworms. This economy particularly gained traction in the vicinity of Northampton, Massachusetts and its neighboring Williamsburg, where a number of small firms and cooperatives emerged. Among the most prominent of these was the cooperative utopian Northampton Association for Education and Industry, of which Sojourner Truth was a member. Following the destructive Mill River Flood of 1874, one manufacturer, William Skinner, relocated his mill from Williamsburg to the then-new city of Holyoke. Over the next 50 years he and his sons would maintain relations between the American silk industry and its counterparts in Japan, and expanded their business to the point that by 1911, the Skinner Mill complex contained the largest silk mill under one roof in the world, and the brand Skinner Fabrics had become the largest manufacturer of silk satins internationally. Other efforts later in the 19th century would also bring the new silk industry to Paterson, New Jersey, with several firms hiring European-born textile workers and granting it the nickname "Silk City" as another major center of production in the United States.

World War II interrupted the silk trade from Asia, and silk prices increased dramatically. U.S. industry began to look for substitutes, which led to the use of synthetics such as nylon. Synthetic silks have also been made from lyocell, a type of cellulose fiber, and are often difficult to distinguish from real silk.

Production process

The process of silk production is known as sericulture. The entire production process of silk can be divided into several steps which are typically handled by different entities. Extracting raw silk starts by cultivating the silkworms on mulberry leaves. Once the worms start pupating in their cocoons, these are dissolved in boiling water in order for individual long fibres to be extracted and fed into the spinning reel.

To produce 1 kg of silk, 104 kg of mulberry leaves must be eaten by 3000 silkworms. It takes about 5000 silkworms to make a pure silk kimono. The major silk producers are China (54%) and India (14%). Other statistics:

Top Ten Cocoons (Reelable) Producers – 2005

Country	**Production** (Int $1000)	**Footnote**	**Production** (1000 kg)	**Footnote**
People's Republic of China	978,013	C	290,003	F
India	259,679	C	77,000	F
Uzbekistan	57,332	C	17,000	F
Brazil	37,097	C	11,000	F
Iran	20,235	C	6,088	F
Thailand	16,862	C	5,000	F
Vietnam	10,117	C	3,000	F

North Korea	5,059	C	1,500	F
Romania	3,372	C	1,000	F
Japan	2,023	C	600	F

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No symbol = official figure, F = FAO estimate,*= Unofficial figure, C = Calculated figure;

Production in Int $1000 have been calculated based on 1999–2001 international prices

Source: Food And Agricultural Organization of United Nations: Economic And Social Department: The Statistical Division

To produce 1 kg of silk, 104 kg of mulberry leaves must be eaten by 3000 silkworms. It takes about 5000 silkworms to make a pure silk kimono. The major silk producers are China (54%) and India (14%). Other statistics:

The environmental impact of silk production is potentially large when compared with other natural fibers. A life cycle assessment of Indian silk production shows that the production process has a large carbon and water footprint, mainly due to the fact that it is an animal-derived fiber and more inputs such as fertilizer and water are needed per unit of fiber produced.

Physical properties

Silk fibers from the Bombyx mori silkworm have a triangular cross section with rounded corners, 5–10 µm wide. The fibroin-heavy chain is composed mostly of beta-sheets, due to a 59-mer amino acid repeat sequence with some variations. The flat surfaces of the fibrils reflect light at many angles, giving silk a natural sheen. The cross-section from other silkworms can vary in shape and diameter: crescent-like for Anaphe and elongated wedge for tussah. Silkworm fibers are naturally extruded from two silkworm glands as a pair of primary filaments (brin), which are stuck together, with sericin proteins that act like glue, to form a bave. Bave diameters for tussah silk can reach 65 µm.

Silk has a smooth, soft texture that is not slippery, unlike many synthetic fibers.

Silk is one of the strongest natural fibers, but it loses up to 20% of its strength when wet. It has a good moisture regain of 11%. Its elasticity is moderate to poor: if elongated even a small amount, it remains stretched. It can be weakened if exposed to too much sunlight. It may also be attacked by insects, especially if left dirty.

One example of the durable nature of silk over other fabrics is demonstrated by the recovery in 1840 of silk garments from a wreck of 1782: 'The most durable article found has been silk; for besides pieces of cloaks and lace, a pair of black satin breeches, and a large satin waistcoat with flaps, were got up, of which the silk was perfect, but the lining entirely gone ... from the thread giving way ... No articles of dress of woollen cloth have yet been found.'

Silk is a poor conductor of electricity and thus susceptible to static cling. Silk has a high emissivity for infrared light, making it feel cool to the touch.

Unwashed silk chiffon may shrink up to 8% due to a relaxation of the fiber macrostructure, so silk should either be washed prior to garment construction, or dry cleaned. Dry cleaning may still shrink the chiffon up to 4%. Occasionally, this shrinkage can be reversed by a gentle steaming with a press cloth. There is almost no gradual shrinkage nor shrinkage due to molecular-level deformation.

Natural and synthetic silk is known to manifest piezoelectric properties in proteins, probably due to its molecular structure.

Silkworm silk was used as the standard for the denier, a measurement of linear density in fibers. Silkworm silk therefore has a linear density of approximately 1 den, or 1.1 dtex.

Comparison of silk fibers	Linear density (dtex)	Diameter (μm)	Coeff. variation
Moth: Bombyx mori	1.17	12.9	24.8%
Spider: Argiope aurentia	0.14	3.57	14.8%

Chemical properties

Silk emitted by the silkworm consists of two main proteins, sericin and fibroin, fibroin being the structural center of the silk, and serecin being the sticky material surrounding it. Fibroin is made up of the amino acids Gly-Ser-Gly-Ala-Gly-Ala and forms beta pleated sheets. Hydrogen bonds form between chains, and side chains form above and below the plane of the hydrogen bond network.

The high proportion (50%) of glycine allows tight packing. This is because glycine's R group is only a hydrogen and so is not as sterically constrained. The addition of alanine and serine makes the fibres strong and resistant to breaking. This tensile strength is due to the many interceded hydrogen bonds, and when stretched the force is applied to these numerous bonds and they do not break.

Silk is resistant to most mineral acids, except for sulfuric acid, which dissolves it. It is yellowed by perspiration. Chlorine bleach will also destroy silk fabrics.

Regenerated silk fiber

RSF is produced by chemically dissolving silkworm cocoons, leaving their molecular structure intact. The silk fibers dissolve into tiny thread-like structures known as microfibrils. The resulting solution is extruded through a small opening, causing the microfibrils to reassemble into a single fiber. The resulting material is reportedly twice as stiff as silk.

Clothing

Silk's absorbency makes it comfortable to wear in warm weather and while active. Its low conductivity keeps warm air close to the skin during cold weather. It is often used for clothing such as shirts, ties, blouses, formal dresses, high fashion clothes, lining, lingerie, pajamas, robes, dress suits, sun dresses and Eastern folk costumes. For practical use, silk is excellent as clothing that protects from many biting insects that would ordinarily pierce clothing, such as mosquitoes and horseflies.

Fabrics that are often made from silk include charmeuse, habutai, chiffon, taffeta, crepe de chine, dupioni, noil, tussah, and shantung, among others.

Furniture

Silk's attractive lustre and drape makes it suitable for many furnishing applications. It is used for upholstery, wall coverings, window treatments (if blended with another fiber), rugs, bedding and wall hangings.

Industry

Silk had many industrial and commercial uses, such as in parachutes, bicycle tires, comforter filling and artillery gunpowder bags.

Medicine

A special manufacturing process removes the outer sericin coating of the silk, which makes it suitable as non-absorbable surgical sutures. This process has also recently led to the introduction of specialist silk underclothing, which has been used for skin conditions including eczema. New uses and manufacturing techniques have been found for silk for making everything from disposable cups to drug delivery systems and holograms.

Biomaterial

Silk began to serve as a biomedical material for sutures in surgeries as early as the second century CE. In the past 30 years, it has been widely studied and used as a biomaterial due to its mechanical strength, biocompatibility, tunable degradation rate, ease to load cellular growth factors (for example, BMP-2), and its ability to be processed into several other formats such as films, gels, particles, and scaffolds. Silks from Bombyx mori, a kind of cultivated silkworm, are the most widely investigated silks.

Silks derived from Bombyx mori are generally made of two parts: the silk fibroin fiber which contains a light chain of 25kDa and a heavy chain of 350kDa (or 390kDa) linked by a single disulfide bond and a glue-like protein, sericin, comprising 25 to 30 percentage by weight. Silk fibroin contains hydrophobic beta sheet blocks, interrupted by small hydrophilic groups. And the beta-sheets contribute much to the high mechanical strength of silk fibers, which achieves 740 MPa, tens of times that of poly(lactic acid) and hundreds of times that of collagen. This impressive mechanical strength has made silk fibroin very competitive for applications in biomaterials. Indeed, silk fibers have found their way into tendon tissue engineering, where mechanical properties matter greatly. In addition, mechanical properties of silks from various kinds of silkworms vary widely, which provides more choices for their use in tissue engineering.

Most products fabricated from regenerated silk are weak and brittle, with only ≈1–2% of the mechanical strength of native silk fibers due to the absence of appropriate secondary and hierarchical structure,

Source Organisms	Tensile strength (g/den)	Tensile modulus (g/den)	Breaking Strain (%)
Bombyx mori	4.3–5.2	84–121	10.0–23.4
Antheraea mylitta	2.5–4.5	66–70	26–39
Philosamia cynthia ricini	1.9–3.5	29–31	28.0–24.0
Coscinocera hercules	5 ± 1	87 ± 17	12 ± 5
Hyalophora euryalus	2.7 ± 0.9	59 ± 18	11 ± 6
Rothschildia hesperis	3.3 ± 0.8	71 ± 16	10 ± 4
Eupackardia calleta	2.8 ± 0.7	58 ± 18	12 ± 6

Biocompatibility

Biocompatibility, i.e., to what level the silk will cause an immune response, is a critical issue for biomaterials. The issue arose during its increasing clinical use. Wax or silicone is usually used as a coating to avoid fraying and potential immune responses when silk fibers serve as suture materials. Although the lack of detailed characterization of silk fibers, such as the extent of the removal of sericin, the surface chemical properties of coating material, and the process used, make it difficult to determine the real immune response of silk fibers in literature, it is generally believed that sericin is the major cause of immune response. Thus, the removal of sericin is an essential step to assure biocompatibility in biomaterial applications of silk. However, further research fails to prove clearly the contribution of sericin to inflammatory responses based on isolated sericin and sericin based biomaterials. In addition, silk fibroin exhibits an inflammatory response similar to that of tissue culture plastic in vitro when assessed with human mesenchymal stem cells (hMSCs) or lower than collagen and PLA when implant rat MSCs with silk fibroin films in vivo. Thus, appropriate degumming and sterilization will assure the biocompatibility of silk fibroin, which is further validated by in vivo experiments on rats and pigs. There are still concerns about the long-term safety of silk-based biomaterials in the human body in contrast to these promising results. Even though silk sutures serve well, they exist and interact within a limited period depending on the recovery of wounds (several weeks), much shorter than that in tissue engineering. Another concern arises from biodegradation because the biocompatibility of silk fibroin does not necessarily assure the biocompatibility of the decomposed products. In fact, different levels of immune responses and diseases have been triggered by the degraded products of silk fibroin.

Biodegradability

Biodegradability (also known as biodegradation)—the ability to be disintegrated by biological approaches, including bacteria, fungi, and cells—is another significant property of biomaterials today. Biodegradable materials can minimize the pain of patients from surgeries, especially in tissue engineering, there is no need of surgery in order to remove the scaffold implanted. Wang et al. showed the in vivo degradation of silk via aqueous 3-D scaffolds implanted into Lewis rats. Enzymes are the means used to achieve degradation of silk in vitro. Protease XIV from Streptomyces griseus and α-chymotrypsin from bovine pancreases are the two popular enzymes for silk degradation. In addition, gamma-radiation, as well as cell metabolism, can also regulate the degradation of silk.

Compared with synthetic biomaterials such as polyglycolides and polylactides, silk is obviously advantageous in some aspects in biodegradation. The acidic degraded products of polyglycolides and polylactides will decrease the pH of the ambient environment and thus adversely influence the metabolism of cells, which is not an issue for silk. In addition, silk materials can retain strength over a desired period from weeks to months as needed by mediating the content of beta sheets.

Genetic modification

Genetic modification of domesticated silkworms has been used to alter the composition of the silk. As well as possibly facilitating the production of more useful types of silk, this may allow other industrially or therapeutically useful proteins to be made by silkworms.

Cultivation

Silk moths lay eggs on specially prepared paper. The eggs hatch and the caterpillars (silkworms) are fed fresh mulberry leaves. After about 35 days and 4 moltings, the caterpillars are 10,000 times heavier than when hatched and are ready to begin spinning a cocoon. A straw frame is placed over the tray of caterpillars, and each caterpillar begins spinning a cocoon by moving its head in a pattern. Two glands produce liquid silk and force it through openings in the head called spinnerets. Liquid silk is coated in sericin, a water-soluble protective gum, and solidifies on contact with the air. Within 2–3 days, the caterpillar spins about 1 mile of filament and is completely encased in a cocoon. The silk farmers then heat the cocoons to kill them, leaving some to metamorphose into moths to breed the next generation of caterpillars. Harvested cocoons are then soaked in boiling water to soften the sericin holding the silk fibers together in a cocoon shape. The fibers are then unwound to produce a continuous thread. Since a single thread is too fine and fragile for commercial use, anywhere from three to ten strands are spun together to form a single thread of silk.

Animal rights

As the process of harvesting the silk from the cocoon kills the larvae by boiling them, sericulture has been criticized by animal welfare and rights activists. Mohandas Gandhi was critical of silk production based on the Ahimsa philosophy, which led to the promotion of cotton and Ahimsa silk, a type of wild silk made from the cocoons of wild and semi-wild silk moths.

Since silk cultivation kills silkworms, possibly painfully, People for the Ethical Treatment of Animals (PETA) urges people not to buy silk items.

Different Types of Silk Fiber

Types of Silk

Silk is a natural protein fibre, some forms of which can be woven into textiles. A variety of silks, produced by caterpillars and mulberry silkworm, have been known and used in China, South Asia, and Europe since ancient times. The strands of raw silk as they are unwound from the cocoon consist of the two silk filaments mixed with sericin and other materials. About 75 % of the strand is silk i.e. fibroin and 23 % is sericin; the remaining materials consist of fat and wax (1.5 %) and mineral salts (0.5 %). As a natural protein fiber silk has a significant attraction towards natural dyes.

Fig. Silk Fabric

Raw silk

Silk fibre as it comes from the cocoon is coated with a protective layer called silk gum, or sericin. The silk gum is dull and stiff. Silk with all of its gum is termed raw silk.

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Fig. Raw silk

Tussah silk:

Silk made from wild silkworms is called tussah silk. The natural color of tussah silk is usually not white, but shades of pale beige, brown and grey. It is usually coarser than cultivated silk.

Fig. Tussah silk

Tussah silk:

Silk made from wild silkworms is called tussah silk. The natural color of tussah silk is usually not white, but shades of pale beige, brown and grey. It is usually coarser than cultivated silk.

Fig. Tussah silk

Bombyxmori silk

It is also known as mulberry silk which is produced by domesticated silkworm raised on diet of mulberry leaves almost exclusively softer, finer and more lustrous than tussah silk. This silk produces shades of white product.

Fig. Bombyxmori silk

Reeled silk or Thrown silk

It is term for silk fibre that is unwound from the silkworm cocoon. It is the most fine silk, the fibres are very long, shiny and of great strength.

Fig. Reeled silk

Spun silk

Silk made from broken cocoon (from which the moths have already emerged) and short fibres, feels more like cotton.

Fig. Spun silk

Weighted silk

When yarns are prepared for weaving, the skeins of yarn are boiled in a soap solution to remove the natural silk gum or sericin. The silk may lose from 20 to 30 percent of its original weight as a result of boiling. As silk has a great affinity for metallic salts such as those of tin and iron, the loss of weight is replaced through the absorption of metals. Thus a heavier fabric can be made at a lower price than that of pure silk, which is known as weighted silk.

Fig. Weighted silk

Pure silk

If the natural gum or sericin is removed from the silk and no further material is added to increase the weight of the fibre, i.e. silk containing no metallic weighting is called pure silk. Pure silk is exclusively soft and possesses fine luster.

Fig. Pure silk

Wool

Wool is the textile fiber obtained from sheep and other animals, including cashmere and mohair from goats, qiviut from muskoxen, hide and fur clothing from bison, angora from rabbits, and other types of wool from camelids.

Wool consists of protein together with a small percentage of lipids. In this regard it is chemically quite distinct from the more dominant textile, cotton, which is mainly cellulose.

Characteristics

Wool is produced by follicles which are small cells located in the skin. These follicles are located in the upper layer of the skin called the epidermis and push down into the second skin layer called the dermis as the wool fibers grow. Follicles can be classed as either primary or secondary follicles. Primary follicles produce three types of fiber: kemp, medullated fibers, and true wool fibers. Secondary follicles only produce true wool fibers. Medullated fibers share nearly identical characteristics to hair and are long but lack crimp and elasticity. Kemp fibers are very coarse and shed out.

Wool's scaling and crimp make it easier to spin the fleece by helping the individual fibers attach to each other, so they stay together. Because of the crimp, wool fabrics have greater bulk than other textiles, and they hold air, which causes the fabric to retain heat. Wool has a high specific thermal resistance, so it impedes heat transfer in general. This effect has benefited desert peoples, as Bedouins and Tuaregs use wool clothes for insulation.

Felting of wool occurs upon hammering or other mechanical agitation as the microscopic barbs on the surface of wool fibers hook together. Felting generally comes under two main areas, dry felting or wet felting. Wet felting occurs when water and a lubricant (soap) are applied to the wool which is then agitated until the fibers mix and bond together. Some natural felting can occur on the animals back.

- **Wool has several qualities that distinguish it from hair/fur:** it is crimped and elastic.

The amount of crimp corresponds to the fineness of the wool fibers. A fine wool like Merino may have up to 40 crimps per centimetre (100 crimps per inch), while coarser wool like karakul may have less than one (one or two crimps per inch). In contrast, hair has little if any scale and no crimp, and little ability to bind into yarn. On sheep, the hair part of the fleece is called kemp. The relative amounts of kemp to wool vary from breed to breed and make some fleeces more desirable for spinning, felting, or carding into batts for quilts or other insulating products, including the famous tweed cloth of Scotland.

Wool fibers readily absorb moisture, but are not hollow. Wool can absorb almost one-third of its own weight in water. Wool absorbs sound like many other fabrics. It is generally a creamy white color, although some breeds of sheep produce natural colors, such as black, brown, silver, and random mixes.

Wool ignites at a higher temperature than cotton and some synthetic fibers. It has a lower rate of flame spread, a lower rate of heat release, a lower heat of combustion, and does not melt or drip; it forms a char that is insulating and self-extinguishing, and it contributes less to toxic gases and smoke than other flooring products when used in carpets. Wool carpets are specified for high safety environments, such as trains and aircraft. Wool is usually specified for garments for firefighters, soldiers, and others in occupations where they are exposed to the likelihood of fire.

Wool causes an allergic reaction in some people.

Processing

Shearing

Sheep shearing is the process by which the woolen fleece of a sheep is cut off. After shearing, the wool is separated into four main categories: fleece (which makes up the vast bulk), broken, bellies, and locks. The quality of fleeces is determined by a technique known as wool classing, whereby a qualified person, called a wool classer, groups wools of similar grading together to maximize the return for the farmer or sheep owner. In Australia before being auctioned, all Merino fleece wool is objectively measured for average diameter (micron), yield (including the amount of vegetable matter), staple length, staple strength, and sometimes color and comfort factor.

Scouring

Wool straight off a sheep is known as "raw wool", "greasy wool" or "wool in the grease". This wool contains a high level of valuable lanolin, as well as the sheep's dead skin and sweat residue, and generally also contains pesticides and vegetable matter from the animal's environment. Before the wool can be used for commercial purposes, it must be scoured, a process of cleaning the greasy wool. Scouring may be as simple as a bath in warm water or as complicated as an industrial process using detergent and alkali in specialized equipment. In north west England, special potash pits were constructed to produce potash used in the manufacture of a soft soap for scouring locally produced white wool.

In commercial wool, vegetable matter is often removed by chemical carbonization. In less-processed wools, vegetable matter may be removed by hand and some of the lanolin left intact through the use of gentler detergents. This semigrease wool can be worked into yarn and knitted into particularly water-resistant mittens or sweaters, such as those of the Aran Island fishermen. Lanolin removed from wool is widely used in cosmetic products, such as hand creams.

Fineness and yield

Raw wool has many impurities; vegetable matter, sand, dirt and yolk which is a mixture of suint (sweat), grease, urine stains and dung locks. The sheep's body yields many types of wool with differing strengths, thicknesses, length of staple and impurities. The raw wool (greasy) is processed into 'top'. 'Worsted top' requires strong straight and parallel fibres.

NOTES

Common Name	Part of Sheep	Style of Wool
Fine	Shoulder	Fine uniform and very dense
Near	Sides	Fine uniform and strong
Downrights	Neck	Short and irregular, lower quality
Choice	Back	Shorter staple, open and less strong
Abb	Haunches	Longer, stronger large staples
Seconds	Belly	Short, tender, Matted and dirty
Top-not	Head	Stiff, very coarse, rough and kempy
Brokes	Forelegs	Short irregular and faulty
Cowtail	Hindlegs	Very strong, coarse and hairy
Britch	Tail	Very coarse, kempy and dirty

The quality of wool is determined by its fiber diameter, crimp, yield, color, and staple strength. Fiber diameter is the single most important wool characteristic determining quality and price.

Merino wool is typically 90–115 mm (3.5–4.5 in) in length and is very fine (between 12 and 24 microns). The finest and most valuable wool comes from Merino hoggets. Wool taken from sheep produced for meat is typically coarser, and has fibers 40–150 mm (1.5–6 in) in length. Damage or breaks in the wool can occur if the sheep is stressed while it is growing its fleece, resulting in a thin spot where the fleece is likely to break.

Wool is also separated into grades based on the measurement of the wool's diameter in microns and also its style. These grades may vary depending on the breed or purpose of the wool. For example:

NOTES

Diameter in microns	**Name**
< 15.5	Ultrafine Merino
15.6 – 18.5	Superfine Merino
18.6 – 20	Fine Merino
20.1 – 23	Medium Merino
> 23	Strong Merino

Breeds	
Breeds	**Diameter**
Comeback	21–26 microns, white, 90–180 mm (3.5–7.1 in) long
Fine crossbred	27–31 microns, Corriedales, etc.
Medium crossbred	32–35 microns
Downs	23–34 microns, typically lacks luster and brightness. Examples, Aussiedown, Dorset Horn, Suffolk, etc.
Coarse crossbred	>36 microns
Carpet wools	35–45 microns

Any wool finer than 25 microns can be used for garments, while coarser grades are used for outerwear or rugs. The finer the wool, the softer it is, while coarser grades are more durable and less prone to pilling.

The finest Australian and New Zealand Merino wools are known as 1PP, which is the industry benchmark of excellence for Merino wool 16.9 microns and finer. This style represents the top level of fineness, character, color, and style as determined on the basis of a series of parameters in accordance with the original dictates of British wool as applied by the Australian Wool Exchange (AWEX) Council. Only a few dozen of the millions of bales auctioned every year can be classified and marked 1PP.

NOTES

In the United States, three classifications of wool are named in the Wool Products Labeling Act of 1939. Wool is "the fiber from the fleece of the sheep or lamb or hair of the Angora or Cashmere goat (and may include the so-called specialty fibers from the hair of the camel, alpaca, llama, and vicuna) which has never been reclaimed from any woven or felted wool product". "Virgin wool" and "new wool" are also used to refer to such never used wool. There are two categories of recycled wool (also called reclaimed or shoddy wool). "Reprocessed wool" identifies "wool which has been woven or felted into a wool product and subsequently reduced to a fibrous state without having been used by the ultimate consumer". "Reused wool" refers to such wool that has been used by the ultimate consumer.

History

Wild sheep were more hairy than woolly. Although sheep were domesticated some 9,000 to 11,000 years ago, archaeological evidence from statuary found at sites in Iran suggests selection for woolly sheep may have begun around 6000 BC, with the earliest woven wool garments having only been dated to two to three thousand years later. Woolly sheep were introduced into Europe from the Near East in the early part of the 4th millennium BC. The oldest known European wool textile, ca. 1500 BC, was preserved in a Danish bog. Prior to invention of shears—probably in the Iron Age—the wool was plucked out by hand or by bronze combs. In Roman times, wool, linen, and leather clothed the European population; cotton from India was a curiosity of which only naturalists had heard, and silks, imported along the Silk Road from China, were extravagant luxury goods. Pliny the Elder records in his Natural History that the reputation for producing the finest wool was enjoyed by Tarentum, where selective breeding had produced sheep with superior fleeces, but which required special care.

In medieval times, as trade connections expanded, the Champagne fairs revolved around the production of wool cloth in small centers such as Provins. The network developed by the annual fairs meant the woolens of Provins might find their way to Naples, Sicily, Cyprus, Majorca, Spain, and even Constantinople. The wool trade developed into serious business, a generator of capital. In the 13th century, the wool trade became the economic engine of the Low Countries and central Italy. By the end of the 14th century, Italy predominated, though Italian production turned to silk in the 16th century. Both industries, based on the export of English raw wool, were rivaled only by the 15th-century sheepwalks of Castile and were a significant source of income to the English crown, which in 1275 had imposed an export tax on wool called the "Great Custom". The importance of wool to the English economy can be seen in the fact that since the 14th century, the presiding officer of the House of Lords has sat on the "Woolsack", a chair stuffed with wool.

Economies of scale were instituted in the Cistercian houses, which had accumulated great tracts of land during the 12th and early 13th centuries, when land prices were low and labor still scarce. Raw wool was baled and shipped from North Sea ports to the textile cities of Flanders, notably Ypres and Ghent, where it was dyed and worked up as cloth. At the time of the Black Death, English textile industries accounted for about 10% of English wool production. The English textile trade grew during the 15th century, to the point where export of wool was discouraged. Over the centuries, various British laws controlled the wool trade or required the use of wool even in burials. The smuggling of wool out of the country, known as owling, was at one time punishable by the cutting off of a hand. After the Restoration, fine English woolens began to compete with silks in the international market, partly aided by the Navigation Acts; in 1699, the English crown forbade its American colonies to trade wool with anyone but England herself.

A great deal of the value of woolen textiles was in the dyeing and finishing of the woven product. In each of the centers of the textile trade, the manufacturing process came to be subdivided into a collection of trades, overseen by an entrepreneur in a system called by the English the "putting-out" system, or "cottage industry", and the Verlagssystem by the Germans. In this system of producing wool cloth, once perpetuated in the production of Harris tweeds, the entrepreneur provides the raw materials and an advance, the remainder being paid upon delivery of the product. Written contracts bound the artisans to specified terms. Fernand Braudel traces the appearance of the system in the 13th-century economic boom, quoting a document of 1275. The system effectively bypassed the guilds' restrictions.

Before the flowering of the Renaissance, the Medici and other great banking houses of Florence had built their wealth and banking system on their textile industry based on wool, overseen by the Arte della Lana, the wool guild: wool textile interests guided Florentine policies. Francesco Datini, the "merchant of Prato", established in 1383 an Arte della Lana for that small Tuscan city. The sheepwalks of Castile were controlled by the Mesta union of sheep owners. They shaped the landscape and the fortunes of the meseta that lies in the heart of the Iberian peninsula; in the 16th century, a unified Spain allowed export of Merino lambs only with royal permission. The German wool market – based on sheep of Spanish origin – did not overtake British wool until comparatively late. The Industrial Revolution introduced mass production technology into wool and wool cloth manufacturing. Australia's colonial economy was based on sheep raising, and the Australian wool trade eventually overtook that of the Germans by 1845, furnishing wool for Bradford, which developed as the heart of industrialized woolens production.

Due to decreasing demand with increased use of synthetic fibers, wool production is much less than what it was in the past. The collapse in the price of wool began in late 1966 with a 40% drop; with occasional interruptions, the price has tended down. The result has been sharply reduced production and movement of resources into production of other commodities, in the case of sheep growers, to production of meat.

Superwash wool (or washable wool) technology first appeared in the early 1970s to produce wool that has been specially treated so it is machine washable and may be tumble-dried. This wool is produced using an acid bath that removes the "scales" from the fiber, or by coating the fiber with a polymer that prevents the scales from attaching to each other and causing shrinkage. This process results in a fiber that holds longevity and durability over synthetic materials, while retaining its shape.

NOTES

In December 2004, a bale of the then world's finest wool, averaging 11.8 microns, sold for AU$3,000 per kilogram at auction in Melbourne, Victoria. This fleece wool tested with an average yield of 74.5%, 68 mm (2.7 in) long, and had 40 newtons per kilotex strength. The result was A$279,000 for the bale. The finest bale of wool ever auctioned was sold for a seasonal record of AU$2690 per kilo during June 2008. This bale was produced by the Hillcreston Pinehill Partnership and measured 11.6 microns, 72.1% yield, and had a 43 newtons per kilotex strength measurement. The bale realized $247,480 and was exported to India.

In 2007, a new wool suit was developed and sold in Japan that can be washed in the shower, and which dries off ready to wear within hours with no ironing required. The suit was developed using Australian Merino wool, and it enables woven products made from wool, such as suits, trousers, and skirts, to be cleaned using a domestic shower at home.

In December 2006, the General Assembly of the United Nations proclaimed 2009 to be the International Year of Natural Fibres, so as to raise the profile of wool and other natural fibers.

Production

Global wool production is about 2 million tonnes (2.2 million short tons) per year, of which 60% goes into apparel. Wool comprises ca 3% of the global textile market, but its value is higher owing to dying and other modifications of the material. Australia is a leading producer of wool which is mostly from Merino sheep but has been eclipsed by China in terms of total weight. New Zealand (2016) is the third-largest producer of wool, and the largest producer of crossbred wool. Breeds such as Lincoln, Romney, Drysdale, and Elliotdale produce coarser fibers, and wool from these sheep is usually used for making carpets.

In the United States, Texas, New Mexico, and Colorado have large commercial sheep flocks and their mainstay is the Rambouillet (or French Merino). Also, a thriving home-flock contingent of small-scale farmers raise small hobby flocks of specialty sheep for the hand-spinning market. These small-scale farmers offer a wide selection of fleece. Global woolclip (total amount of wool shorn) 2004–2005

1. Australia: 25% of global wool-clip (475 million kilograms [1,000 million pounds] greasy, 2004–2005)
2. China: 18%
3. United States: 17%
4. New Zealand: 11%
5. Argentina: 3%
6. Turkey: 2%
7. Iran: 2%
8. United Kingdom: 2%
9. India: 2%
10. Sudan: 2%

11. South Africa: 1%

Organic wool is becoming more and more popular. This wool is very limited in supply and much of it comes from New Zealand and Australia. It is becoming easier to find in clothing and other products, but these products often carry a higher price. Wool is environmentally preferable (as compared to petroleum-based nylon or polypropylene) as a material for carpets, as well, in particular when combined with a natural binding and the use of formaldehyde-free glues.

Animal rights groups have noted issues with the production of wool, such as mulesing.

Marketing—Australia

About 85% of wool sold in Australia is sold by open cry auction. "Sale by sample" is a method in which a mechanical claw takes a sample from each bale in a line or lot of wool. These grab samples are bulked, objectively measured, and a sample of not less than 4 kg (9 lb) is displayed in a box for the buyer to examine. The Australian Wool Exchange conducts sales primarily in Sydney, Melbourne, Newcastle, and Fremantle. About 80 brokers and agents work throughout Australia.

About 7% of Australian wool is sold by private treaty on farms or to local wool-handling facilities. This option gives wool growers benefit from reduced transport, warehousing, and selling costs. This method is preferred for small lots or mixed butts to make savings on reclassing and testing.

About 5% of Australian wool is sold over the internet on an electronic offer board. This option gives wool growers the ability to set firm price targets, reoffer passed-in wool, and offer lots to the market quickly and efficiently. This method works well for tested lots, as buyers use these results to make a purchase. About 97% of wool is sold without sample inspection; however, as of December 2009, 59% of wool listed had been passed in from auction. Growers through certain brokers can allocate their wool to a sale and at what price their wool will be reserved.

Sale by tender can achieve considerable cost savings on wool clips large enough to make it worthwhile for potential buyers to submit tenders. Some marketing firms sell wool on a consignment basis, obtaining a fixed percentage as commission.

Forward selling: Some buyers offer a secure price for forward delivery of wool based on estimated measurements or the results of previous clips. Prices are quoted at current market rates and are locked in for the season. Premiums and discounts are added to cover variations in micron, yield, tensile strength, etc., which are confirmed by actual test results when available.

Another method of selling wool includes sales direct to wool mills.

Other countries

The British Wool Marketing Board operates a central marketing system for UK fleece wool with the aim of achieving the best possible net returns for farmers.

Less than half of New Zealand's wool is sold at auction, while around 45% of farmers sell wool directly to private buyers and end-users.

NOTES

United States sheep producers market wool with private or cooperative wool warehouses, but wool pools are common in many states. In some cases, wool is pooled in a local market area, but sold through a wool warehouse. Wool offered with objective measurement test results is preferred. Imported apparel wool and carpet wool goes directly to central markets, where it is handled by the large merchants and manufacturers.

Yarn Uses

In addition to clothing, wool has been used for blankets, horse rugs, saddle cloths, carpeting, insulation and upholstery. Wool felt covers piano hammers, and it is used to absorb odors and noise in heavy machinery and stereo speakers. Ancient Greeks lined their helmets with felt, and Roman legionnaires used breastplates made of wool felt.

Wool has also been traditionally used to cover cloth diapers. Wool fiber exteriors are hydrophobic (repel water) and the interior of the wool fiber is hygroscopic (attracts water); this makes a wool garment suitable cover for a wet diaper by inhibiting wicking, so outer garments remain dry. Wool felted and treated with lanolin is water resistant, air permeable, and slightly antibacterial, so it resists the buildup of odor. Some modern cloth diapers use felted wool fabric for covers, and there are several modern commercial knitting patterns for wool diaper covers.

Initial studies of woolen underwear have found it prevented heat and sweat rashes because it more readily absorbs the moisture than other fibers.

Merino wool has been used in baby sleep products such as swaddle baby wrap blankets and infant sleeping bags.

As an animal protein, wool can be used as a soil fertilizer, being a slow-release source of nitrogen.

Researchers at the Royal Melbourne Institute of Technology school of fashion and textiles have discovered a blend of wool and Kevlar, the synthetic fiber widely used in body armor, was lighter, cheaper and worked better in damp conditions than Kevlar alone. Kevlar, when used alone, loses about 20% of its effectiveness when wet, so required an expensive waterproofing process. Wool increased friction in a vest with 28–30 layers of fabric, to provide the same level of bullet resistance as 36 layers of Kevlar alone.

Events

A buyer of Merino wool, Ermenegildo Zegna, has offered awards for Australian wool producers. In 1963, the first Ermenegildo Zegna Perpetual Trophy was presented in Tasmania for growers of "Superfine skirted Merino fleece". In 1980, a national award, the Ermenegildo Zegna Trophy for Extrafine Wool Production, was launched. In 2004, this award became known as the Ermenegildo Zegna Unprotected Wool Trophy. In 1998, an Ermenegildo Zegna Protected Wool Trophy was launched for fleece from sheep coated for around nine months of the year.

In 2002, the Ermenegildo Zegna Vellus Aureum Trophy was launched for wool that is 13.9 microns or finer. Wool from Australia, New Zealand, Argentina, and South Africa may enter, and a winner is named from each country. In April 2008, New Zealand won the Ermenegildo Zegna Vellus Aureum Trophy for the first time with a fleece that measured 10.8 microns. This contest awards the winning fleece weight with the same weight in gold as a prize, hence the name.

In 2010, an ultrafine, 10-micron fleece, from Windradeen, near Pyramul, New South Wales, won the Ermenegildo Zegna Vellus Aureum International Trophy.

Since 2000, Loro Piana has awarded a cup for the world's finest bale of wool that produces just enough fabric for 50 tailor-made suits. The prize is awarded to an Australian or New Zealand wool grower who produces the year's finest bale.

The New England Merino Field days which display local studs, wool, and sheep are held during January, in even numbered years around the Walcha, New South Wales district. The Annual Wool Fashion Awards, which showcase the use of Merino wool by fashion designers, are hosted by the city of Armidale, New South Wales, in March each year. This event encourages young and established fashion designers to display their talents. During each May, Armidale hosts the annual New England Wool Expo to display wool fashions, handicrafts, demonstrations, shearing competitions, yard dog trials, and more.

In July, the annual Australian Sheep and Wool Show is held in Bendigo, Victoria. This is the largest sheep and wool show in the world, with goats and alpacas, as well as woolcraft competitions and displays, fleece competitions, sheepdog trials, shearing, and wool handling. The largest competition in the world for objectively measured fleeces is the Australian Fleece Competition, which is held annually at Bendigo. In 2008, 475 entries came from all states of Australia, with first and second prizes going to the Northern Tablelands, New South Wales fleeces.

Classification of Wool

Wool Fiber

Wool fiber is the natural hair grown on sheep and is composed of protein substance called as keratin. Wool is composed of carbon, hydrogen, nitrogen and this is the only animal fiber, which contains sulfur in addition. The wool fibers have crimps or curls, which create pockets and give the wool a spongy feel and create insulation for the wearer. The outside surface of the fiber consists of a series of serrated scales, which overlap each other much like the scales of a fish. Wool is the only fiber with such serration’s which make it possible for the fibers to cling together and produce felt.

Fig: Wool fiber

Properties of Wool Fiber

The characteristics of Wool fiber or protein fibers are as follows:

- They are composed of amino acids.
- They have excellent absorbency.
- Moisture regain is high.
- They tend to be warmer than others.
- They have poor resistance to alkalis but good resistance to acids.
- They have good elasticity and resiliency.

Classification of Wool

The quality of wool fibers produced is based on the breeding conditions, the weather, food, general care etc. For example, excessive moisture dries out natural grease. Similarly the cold weather produces harder and heavier fibers. The wool could be classified in two different ways:

1. By sheep from which it is obtained
2. By fleece

Classification by Sheep

The wool is classified according to the sheep from which it is sheared as given below:

- **Merino Wool:** Merino sheep originated in Spain yields the best quality wool.
- These fibers are strong, fine and elastic fiber which is relatively short, ranging from 1 to 5 inches (25 – 125 mm).
- Among the different wool fibers, merino wool has the greatest amount of crimp and has maximum number of scales. These two factors contribute to its superior warmth and spinning qualities.
- Merino is used for the best types of wool clothing.

Class – Two Wool: This class of sheep originates from England, Scotland, Ireland and Wales.

- The fibers are comparatively strong, fine, and elastic and range from 2 to 8 inches (50 – 200mm) in length.
- They have a large number of scales per inch and have good crimp.

Class – Three Wool: This class of sheep originates from United Kingdom.

- The fibers are coarser and have fewer scales and less crimp when compared to earlier varieties of wool fibers and are about 4 to 18 inches long.
- They are smoother, and are more lustrous.
- These wool are less elastic and resilient.
- They are of good quality, used for clothing.

Class – Four Wool: This class is a group of mongrel sheep sometimes referred to as half-breeds.

- The fibers are abour 1 to 16 inches (25 – 400 mm) long, are coarse and hair like, and have relatively few scales and little crimp.

- The fibers are smoother and more lustrous.
- This wool is less desirable, with the least elasticity and strength. It is used mainly for carpets, rugs, and inexpensive low-grade clothing.

Jute

Jute is a long, soft, shiny Bast fiber that can be spun into coarse, strong threads. It is produced primarily from plants in the genus Corchorus, which was once classified with the family Tiliaceae. The primary source of the fiber is Corchorus olitorius, but it is considered inferior to Corchorus capsularis. "Jute" is the name of the plant or fiber used to make burlap, hessian or gunny cloth.

Jute is one of the most affordable natural fibers, and second only to cotton in the amount produced and variety of uses. Jute fibers are composed primarily of the plant materials cellulose and lignin. It falls into the bast fiber category (fiber collected from bast, the phloem of the plant, sometimes called the "skin") along with kenaf, industrial hemp, flax (linen), ramie, etc. The industrial term for jute fiber is raw jute. The fibers are off-white to brown, and 1–4 metres (3–13 feet) long. Jute is also called the golden fiber for its color and high cash value.

Cultivation

The jute plant needs a plain alluvial soil and standing water. The suitable climate for growing jute (warm and wet) is offered by the monsoon climate, during the monsoon season. Temperatures from 20˚ C to 40˚ C (68° F to 104° F) and relative humidity of 70%–80% are favourable for successful cultivation. Jute requires 5–8 cm (about 2-3 inches) of rainfall weekly, and more during the sowing time. Soft water is necessary for jute production.

White jute (Corchorus capsularis)

Historical documents (including Ain-e-Akbari by Abul Fazal in 1590) state that the poor villagers of India used to wear clothes made of jute. The weavers used simple hand spinning wheels and hand looms, and spun cotton yarns as well. History also suggests that Indians, especially Bengalis, used ropes and twines made of white jute from ancient times for household and other uses. It is highly functional for carrying grains or other agricultural products.

Tossa jute (Corchorus olitorius)

Tossa jute (Corchorus olitorius) is a variety thought native to South Asia. It is grown for both fiber and culinary purposes. People use the leaves as an ingredient in a mucilaginous potherb called "molokhiya". It is popular in some Arabian countries such as Egypt, Jordan, and Syria as a soup-based dish, sometimes with meat over rice or lentils. The Book of Job (chapter 30, verse 4), in the King James translation of the Hebrew Bible מלוח maluaḥ "salty", mentions this vegetable potherb as "mallow, giving rise to the term Jew's Mallow. It is high in protein, vitamin C, beta-carotene, calcium, and iron.

Bangladesh and other countries in Southeast Asia, and the South Pacific mainly use jute for its fiber. Tossa jute fiber is softer, silkier, and stronger than white jute. This variety shows good sustainability in the Ganges Delta climate. Along with white jute, tossa jute has also been cultivated in the soil of Bengal where it is known as paat from the start of the 19th century. Coremantel, Bangladesh, is the largest global producer of the tossa jute variety.

History

Jute was used for making textiles in the Indus valley civilization since the 3rd millennium BC.

In classical antiquity, Pliny recorded that jute plants were used as food in Ancient Egypt. It may have also been cultivated by the Jews in the Near East, which gives the plant its name.

For centuries, jute has been an integral part of the culture of East Bengal and some parts of West Bengal, precisely in the southwest of Bangladesh. Since the seventeenth century the British started trading in jute. During the reign of the British Empire, jute was also used in the military. British jute barons grew rich by processing jute and selling manufactured products made from it. Dundee Jute Barons and the British East India Company set up many jute mills in Bengal, and by 1895 jute industries in Bengal overtook the Scottish jute trade. Many Scots emigrated to Bengal to set up jute factories. More than a billion jute sandbags were exported from Bengal to the trenches of World War I, and to the United States south to bag cotton. It was used in the fishing, construction, art and the arms industries. Initially, due to its texture, it could only be processed by hand until someone in Dundee discovered that treating it with whale oil made it machine processable. The industry boomed throughout the eighteenth and nineteenth centuries ("jute weaver" was a recognised trade occupation in the 1900 UK census), but this trade had largely ceased by about 1970 due to the emergence of synthetic fibers. In the 21st century, jute again has become an important export crop around the world, mainly in Bangladesh.

Production

The jute fiber comes from the stem and ribbon (outer skin) of the jute plant. The fibers are first extracted by retting. The retting process consists of bundling jute stems together and immersing them in slow running water. There are two types of retting: stem and ribbon. After the retting process, stripping begins; women and children usually do this job. In the stripping process, non-fibrous matter is scraped off, then the workers dig in and grab the fibers from within the jute stem.

Jute is a rain-fed crop with little need for fertilizer or pesticides, in contrast to cotton's heavy requirements. Production is concentrated mostly in Bangladesh, as well as India's states of Assam, Bihar, and West Bengal. India is the world's largest producer of jute, but imported approximately 162,000 tonnes of raw fiber and 175,000 tonnes of jute products in 2011. India, Pakistan, and China import significant quantities of jute fiber and products from Bangladesh, as do the United Kingdom, Japan, United States, France, Spain, Ivory Coast, Germany and Brazil.

Top ten jute producers, by metric ton, as of 2014

Country	Production (Tonnes)
India	1,968,000
Bangladesh	1,349,000
People's Republic of China	29,628
Uzbekistan	20,000
Nepal	14,890
South Sudan	3,300
Zimbabwe	2,519
Egypt	2,508
Brazil	1,172
Vietnam	970
World	3,393,248

Genome

At the beginning of the 21st century, in 2002 Bangladesh commissioned a consortium of researchers from University of Dhaka, Bangladesh Jute Research Institute (BJRI) and private software firm DataSoft Systems Bangladesh Ltd., in collaboration with Centre for Chemical Biology, University of Science Malaysia and University of Hawaii, to research different fibers and hybrid fibers of jute. The draft genome of jute (Corchorus olitorius) was completed.

Uses

Making twine, rope, and matting are among its uses.

In combination with sugar, the possibility of using jute to build aeroplane panels has been considered.

Jute is in great demand due to its cheapness, softness, length, lustre and uniformity of its fiber. It is called the 'brown paper bag' as it is also the most used product in gunny sacks to store rice, wheat, grains, etc. It is also called the 'golden fiber' due to its versatile nature.

Fibers

Jute is used in the manufacture of a number of fabrics, such as Hessian cloth, sacking, scrim, carpet backing cloth (CBC), and canvas. Hessian, lighter than sacking, is used for bags, wrappers, wall-coverings, upholstery, and home furnishings. Sacking, a fabric made of heavy jute fibers, has its use in the name. CBC made of jute comes in two types. Primary CBC provides a tufting surface, while secondary CBC is bonded onto the primary backing for an overlay. Jute packaging is used as an eco-friendly substitute.

Diversified jute products are becoming more and more valuable to the consumer today. Among these are espadrilles, soft sweaters and cardigans, floor coverings, home textiles, high performance technical textiles, geotextiles, composites, and more.

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Jute floor coverings consist of woven and tufted and piled carpets. Jute mats and mattings with 5/6 mts width and of continuous length are easily being woven in southern parts of India, in solid and fancy shades, and in different weaves, like bouclé, Panama, herringbone, etc. Jute mats and rugs are made both by powerloom and handloom in large volume in Kerala, India. The traditional Satranji mat is becoming very popular in home décor. Jute non-wovens and composites can be used for underlay, linoleum substrate, and more.

Jute has many advantages as a home textile, either replacing cotton or blending with it. It is a strong, durable, color and light-fast fiber. Its UV protection, sound and heat insulation, low thermal conduction and anti-static properties make it a wise choice in home décor. Also, fabrics made of jute fibers are carbon-dioxide neutral and naturally decomposable. These properties are also why jute can be used in high performance technical textiles.

Moreover, jute can be grown in 4–6 months with a huge amount of cellulose being produced from the jute hurd (inner woody core or parenchyma of the jute stem) that can meet most of the wood needs of the world.

Thus, jute is the most environment-friendly fiber starting from the seed to expired fiber, as the expired fibers can be recycled more than once.

Jute is also used to make ghillie suits, which are used as camouflage and resemble grasses or brush.

Another diversified jute product is geotextiles, which made this agricultural commodity more popular in the agricultural sector. It is a lightly woven fabric made from natural fibers that is used for soil erosion control, seed protection, weed control, and many other agricultural and landscaping uses. The geotextiles can be used more than a year and the bio-degradable jute geotextile left to rot on the ground keeps the ground cool and is able to make the land more fertile.

Culinary uses

Corchous olitorius leaves are used to make mulukhiya, sometimes considered the Egyptian national dish, but consumed in Cyprus and other Middle Eastern countries as well. It is an ingredient for stews, typically cooked with lamb or chicken.

In Nigeria, leaves of Corchorus olitorius are prepared in sticky soup called ewedu together with ingredients such as sweet potato, dried small fish or shrimp. The leaves are rubbed until foamy or sticky before adding to the soup. Amongst the Yoruba of Nigeria, the leaves are called Ewedu, and in the Hausa-speaking northern Nigeria, the leaves are called turgunuwa or lallo. The cook cuts jute leaves into shreds and adds them to the soup, which normally also contains ingredients such as meat or fish, pepper, onions, and spices. Likewise, the Lugbara of Northwestern Uganda eat the leaves in a soup they call pala bi. Jute is also a totem for Ayivu, one of the Lugbara clans.

In the Philippines, especially in Ilocano-dominated areas, this vegetable, locally known as saluyot, can be mixed with either bitter gourd, bamboo shoots, loofah, or sometimes all of them. These have a slimy and slippery texture.

Other

Diversified byproducts from jute can be used in cosmetics, medicine, paints, and other products.

Features

- Jute fiber is 100% bio-degradable and recyclable and thus environmentally friendly.
- Jute has low pesticide and fertilizer needs.
- It is a natural fiber with golden and silky shine and hence called The Golden Fiber.
- It is the cheapest vegetable fiber procured from the bast or skin of the plant's stem.
- It is the second most important vegetable fiber after cotton, in terms of usage, global consumption, production, and availability.
- It has high tensile strength, low extensibility, and ensures better breathability of fabrics. Therefore, jute is very suitable in agricultural commodity bulk packaging.
- It helps to make top quality industrial yarn, fabric, net, and sacks. It is one of the most versatile natural fibers that has been used in raw materials for packaging, textiles, non-textile, construction, and agricultural sectors. Bulking of yarn results in a reduced breaking tenacity and an increased breaking extensibility when blended as a ternary blend.
- Advantages of jute include good insulating and antistatic properties, as well as having low thermal conductivity and a moderate moisture regain. Other advantages of jute include acoustic insulating properties and manufacture with no skin irritations.
- Jute can be blended with other fibers, both synthetic and natural, and accepts cellulosic dye classes such as natural, basic, vat, sulfur, reactive, and pigment dyes. As demand for natural comfort fibers increases, demand for jute and other natural fibers that can be blended with cotton will increase. To meet this demand, some manufactures in the natural fiber industry plan to modernize processing with the Rieter's Elitex system. Resulting jute/cotton yarns produce fabrics with a reduced cost of wet processing treatments. Jute can also be blended with wool. By treating jute with caustic soda, crimp, softness, pliability, and appearance is improved, aiding in its ability to be spun with wool. Liquid ammonia has a similar effect on jute, as well as the added characteristic of improving flame resistance when treated with flameproofing agents.
- Some noted disadvantages include poor drapability and crease resistance, brittleness, fiber shedding, and yellowing in sunlight. However, preparation of fabrics with castor oil lubricants result in less yellowing and less fabric weight loss, as well as increased dyeing brilliance. Jute has a decreased strength when wet, and also becomes subject to microbial attack in humid climates. Jute can be processed with an enzyme to reduce some of its brittleness and stiffness.

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Once treated with an enzyme, jute shows an affinity to readily accept natural dyes, which can be made from marigold flower extract. In one attempt to dye jute fabric with this extract, bleached fabric was mordanted with ferrous sulphate, increasing the fabric's dye uptake value. Jute also responds well to reactive dyeing. This process is used for bright and fast coloured value-added diversified products made from jute.

Hemp

Hemp, or industrial hemp, is a variety of the Cannabis sativa plant species that is grown specifically for the industrial uses of its derived products. It is one of the fastest growing plants and was one of the first plants to be spun into usable fiber 50,000 years ago. It can be refined into a variety of commercial items, including paper, textiles, clothing, biodegradable plastics, paint, insulation, biofuel, food, and animal feed.

Although cannabis as a drug and industrial hemp both derive from the species Cannabis sativa and contain the psychoactive component tetrahydrocannabinol (THC), they are distinct strains with unique phytochemical compositions and uses. Hemp has lower concentrations of THC and higher concentrations of cannabidiol (CBD), which decreases or eliminates its psychoactive effects. The legality of industrial hemp varies widely between countries. Some governments regulate the concentration of THC and permit only hemp that is bred with an especially low THC content.

Etymology

The etymology is uncertain but there appears to be no common Proto-Indo-European source for the various forms of the word; the Greek term κάνναβις (kánnabis) is the oldest attested form, which may have been borrowed from an earlier Scythian or Thracian word. Then it appears to have been borrowed into Latin, and separately into Slavic and from there into Baltic, Finnish, and Germanic languages.

In the Germanic languages, following Grimm's law, the "k" would have changed to "h" with the first Germanic sound shift, giving Proto-Germanic *hanapiz, after which it may have been adapted into the Old English form, hænep, henep. Barber (1991) however, argued that the spread of the name "kannabis" was due to its historically more recent plant use, starting from the south, around Iran, whereas non-THC varieties of hemp are older and prehistoric. Another possible source of origin is Assyrian qunnabu, which was the name for a source of oil, fiber, and medicine in the 1st millennium BC.

Cognates of hemp in other Germanic languages include Dutch hennep, Danish and Norwegian hamp, Saterland Frisian Hoamp, German Hanf, Icelandic hampur and Swedish hampa. In those languages "hemp" can refer to either industrial fiber hemp or narcotic cannabis strains.

Uses

Hemp is used to make a variety of commercial and industrial products, including rope, textiles, clothing, shoes, food, paper, bioplastics, insulation, and biofuel. The bast fibers can be used to make textiles that are 100% hemp, but they are commonly blended with other fibers, such as flax, cotton or silk, as well as virgin and recycled polyester, to make woven fabrics for apparel and furnishings. The inner two fibers of the plant are woodier and typically have industrial applications, such as mulch, animal bedding, and litter. When oxidized (often erroneously referred to as "drying"), hemp oil from the seeds becomes solid and can be used in the manufacture of oil-based paints, in creams as a moisturizing agent, for cooking, and in plastics. Hemp seeds have been used in bird feed mix as well. A survey in 2003 showed that more than 95% of hemp seed sold in the European Union was used in animal and bird feed.

Food

Hemp seed, hulled		
Nutritional value per 100 g (3.5 oz)		
Energy	**2,451 kJ (586 kcal)**	
Carbohydrates	**4.67 g**	
Sugars	1.50 g	
lactose	0.07 g	
Dietary fiber	4.0 g	
Fat	**48.75 g**	
Saturated	4.600 g	
Trans		0 g
Monounsaturated		5.400 g
Polyunsaturated		38.100 g
omega 3		9.301 g
omega 6		28.698 g
Protein		**31.56 g**
Tryptophan		0.369 g
Threonine		1.269 g
Isoleucine		1.286 g
Leucine		2.163 g
Lysine		1.276 g
Methionine		0.933 g
Cystine		0.672 g
Phenylalanine		1.447 g
Tyrosine		1.263 g
Valine		1.777 g

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Arginine	4.550 g
Histidine	0.969 g
Alanine	1.528 g
Aspartic acid	3.662 g
Glutamic acid	6.269 g
Glycine	1.611 g
Proline	1.597 g
Serine	1.713 g
Vitamins	**Quantity**
Vitamin A equiv.	0%
beta-Carotene	1 μg
	0%
	7 μg
Vitamin A	11 IU
Thiamine (B1)	111%
	1.275 mg
Riboflavin (B2)	24%
	0.285 mg
Niacin (B3)	61%
	9.200 mg
Vitamin B6	46%
	0.600 mg
Folate (B9)	28%
	110 μg
Vitamin B12	0%
	0 μg
Vitamin C	1%
	0.5 mg
Vitamin E	5%
	0.80 mg
Minerals	**Quantity**
Calcium	7%
	70 mg
Copper	80%
	1.600 mg
Iron	61%

	7.95 mg
Magnesium	197%
	700 mg
Manganese	362%
	7.600 mg
Phosphorus	236%
	1650 mg
Potassium	26%
	1200 mg
Sodium	0%
	5 mg
Zinc	104%
	9.90 mg
Other constituents	**Quantity**
Water	4.96 g
Cholesterol	0 mg

Hemp seeds can be eaten raw, ground into hemp meal, sprouted or made into dried sprout powder. Hemp seeds can also be made into a liquid and used for baking or for beverages such as hemp milk and tisanes. Hemp oil is cold-pressed from the seed and is high in unsaturated fatty acids. The leaves of the hemp plant, while not as nutritional as the seeds, are edible and can be consumed raw as leafy vegetables in salads, and pressed to make juice.

In 2011, the US imported $11.5 million worth of hemp products, mostly driven by growth in the demand for hemp seed and hemp oil for use as ingredients in foods such as granola.

In the UK, the Department for Environment, Food and Rural Affairs treats hemp as a purely non-food crop, but with proper licensing and proof of less than 0.2% THC concentration, hemp seeds can be imported for sowing or for sale as a food or food ingredient. In the US, hemp can be used legally in food products and, as of 2000, was typically sold in health food stores or through mail order.

Nutrition

A 100-gram portion of hulled hemp seeds supplies 586 calories. They contain 5% water, 5% carbohydrates, 49% total fat, and 31% protein. Hemp seeds are notable in providing 64% of the Daily Value (DV) of protein per 100-gram serving. Hemp seeds are a rich source of dietary fiber (20% DV), B vitamins, and the dietary minerals manganese (362% DV), phosphorus (236% DV), magnesium (197% DV), zinc (104% DV), and iron (61% DV). About 73% of the energy in hemp seeds is in the form of fats and essential fatty acids, mainly polyunsaturated fatty acids, linoleic, oleic, and

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alpha-linolenic acids. The ratio of the 38.100 grams of polyunsaturated fats per 100 grams is 9.301 grams of omega 3 to 28.698 grams of omega 6. Typically, the portion suggested on packages for an adult is 30 grams, approximately three tablespoons.

Hemp seeds' amino acid profile is comparable to other sources of protein such as meat, milk, eggs, and soy. Protein digestibility-corrected amino acid scores (PDCAAS), which attempt to measure the degree to which a food for humans is a "complete protein", were 0.49–0.53 for whole hemp seed, 0.46–0.51 for hemp seed meal, and 0.63–0.66 for hulled hemp seed.

Storage

Hemp oil oxidizes and turns rancid within a short period of time if not stored properly; its shelf life is extended when it is stored in a dark airtight container and refrigerated. Both light and heat can degrade hemp oil.

Fiber

Hemp fiber has been used extensively throughout history, with production climaxing soon after being introduced to the New World. For centuries, items ranging from rope, to fabrics, to industrial materials were made from hemp fiber. Hemp was also commonly used to make sail canvas. The word "canvas" is derived from the word cannabis. Pure hemp has a texture similar to linen. Because of its versatility for use in a variety of products, today hemp is used in a number of consumer goods, including clothing, shoes, accessories, dog collars, and home wares. For clothing, in some instances, hemp is mixed with lyocell.

Building material

Concrete-like blocks made with hemp and lime have been used as an insulating material for construction. Such blocks are not strong enough to be used for structural elements; they must be supported by a brick, wood, or steel frame. However, hemp fibres have been shown to be usable as a replacement for wood for many jobs, including creating durable and breathable homes. The most common use of hemp lime in building is by casting the hemp and lime mix while wet around a timber frame with temporary shuttering, and tamping the mix to form a firm mass; after the removal of the temporary shuttering, the solidified hemp mix is then ready to be plastered with a lime plaster.

The first example of the use of hempcrete was in 1986 in France with the renovation of the Maison de la Turquie in Nogent-sur-Seine by the innovator Charles Rasetti. In the UK hemp lime was first used in 2000 for the construction of two test dwellings in Haverhill. Designed by Modece Architects, who pioneered hemp's use in UK construction, the hemp houses were monitored in comparison with other standard dwellings by BRE. Completed in 2009, the Renewable House is one of the most technologically advanced made from hemp-based materials. The first US home made of hemp-based materials was completed in August 2010 in Asheville, North Carolina.

A panellized system of hemp-lime panels for use in building construction is currently under test in a European Union-funded research collaboration led by the University of Bath. The panels are being designed to assure high-quality construction, rapid on-site erection, optimal hygrothermal performance from day one, and energy- and resource-efficient buildings. The 36-month work program aims to refine product and manufacturing protocols and produce data for certification and marketing, warranty, insurance cover, and availability of finance. It also includes the development of markets in Britain, France, and Spain.

Hemp is used as an internal plaster and is a mixture of hemp hurd (shive) mixed with larger proportions of a lime-based binder. Hemp plaster has insulative qualities.

Plastic and composite materials

A mixture of fiberglass, hemp fiber, kenaf, and flax has been used since 2002 to make composite panels for automobiles. The choice of which bast fiber to use is primarily based on cost and availability. Various car makers are beginning to use hemp in their cars, including Audi, BMW, Ford, GM, Chrysler, Honda, Iveco, Lotus, Mercedes, Mitsubishi, Porsche, Saturn, Volkswagen and Volvo. For example, the Lotus Eco Elise and the Mercedes C-Class both contain hemp (up to 20 kg in each car in the case of the latter).

Paper

Hemp paper are paper varieties consisting exclusively or to a large extent from pulp obtained from fibers of industrial hemp. The products are mainly specialty papers such as cigarette paper, banknotes and technical filter papers. Compared to wood pulp, hemp pulp offers a four to five times longer fibre, a significantly lower lignin fraction as well as a higher tear resistance and tensile strength. However, production costs are about four times higher than for paper from wood, since the infrastructure for using hemp is underdeveloped. If the paper industry were to switch from wood to hemp for sourcing its cellulose fibers, the following benefits could be utilized:

- Hemp yields three to four times more usable fibre per hectare per annum than forests, and hemp doesn't need pesticides or herbicides.
- Hemp has a much faster crop yield. It takes about 3-4 months for hemp stalks to reach maturity, while trees can take between 20 to 80 years. Not only does hemp grow at a faster rate, but it also contains a high level of cellulose. This quick return means that paper can be produced at a faster rate if hemp were used in place of wood.
- Hemp paper does not require the use of toxic bleaching or as many chemicals as wood pulp because it can be whitened with hydrogen peroxide. This means using hemp instead of wood for paper would end the practice of poisoning Earth's waterways with chlorine or dioxins from wood paper manufacturing.
- Hemp paper can be recycled up to 8 times, compared to just 3 times for paper made from wood pulp.
- Compared to its wood pulp counterpart, paper from hemp fibers resists decomposition and does not yellow or brown with age. It is also one of the

strongest natural fibers in the world - one of the reasons for its longevity and durability.

- Several factors favor the increased use of wood substitutes for paper, especially agricultural fibers such as hemp. Deforestation, particularly the destruction of old growth forests, and the world's decreasing supply of wild timber resources are today major ecological concerns. Hemp's use as a wood substitute will contribute to preserving biodiversity.

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However, hemp has had a hard time competing with paper from trees or recycled newsprint. Only the outer part of the stem consists mainly of fibers which are suitable for the production of paper. Numerous attempts have been made to develop machines that efficiently and inexpensively separate useful fibers from less useful fibers, but none have been completely successful. This has meant that paper from hemp is still expensive compared to paper from trees.

Jewelry

Hemp jewelry is the product of knotting hemp twine through the practice of macramé. Hemp jewellery includes bracelets, necklaces, anklets, rings, watches, and other adornments. Some jewellery features beads made from crystals, glass, stone, wood and bones. The hemp twine varies in thickness and comes in a variety of colors. There are many different stitches used to create hemp jewellery, however, the half knot and full knot stitches are most common.

Cordage

Hemp rope was used in the age of sailing ships, though the rope had to be protected by tarring, since hemp rope has a propensity for breaking from rot, as the capillary effect of the rope-woven fibers tended to hold liquid at the interior, while seeming dry from the outside. Tarring was a labor-intensive process, and earned sailors the nickname "Jack Tar". Hemp rope was phased out when manila rope, which does not require tarring, became widely available. Manila is sometimes referred to as Manila hemp, but is not related to hemp; it is abacá, a species of banana.

Animal bedding

Hemp shives are the core of the stem, hemp hurds are broken parts of the core. In the EU, they are used for animal bedding (horses, for instance), or for horticultural mulch. Industrial hemp is much more profitable if both fibers and shives (or even seeds) can be used.

Water and soil purification

Hemp can be used as a "mop crop" to clear impurities out of wastewater, such as sewage effluent, excessive phosphorus from chicken litter, or other unwanted substances or chemicals. Additionally, hemp is being used to clean contaminants at the Chernobyl nuclear disaster site, by way of a process which is known as phytoremediation—the process of clearing radioisotopes and a variety of other toxins from the soil, water, and air.

Weed control

Hemp crops are tall, have thick foliage, and can be planted densely, and thus can be grown as a smother crop to kill tough weeds. Using hemp this way can help farmers avoid the use of herbicides, gain organic certification, and gain the benefits of crop rotation. However, due to the plant's rapid and dense growth characteristics, some jurisdictions consider hemp a prohibited and noxious weed, much like Scotch Broom.

Biofuels

Biodiesel can be made from the oils in hemp seeds and stalks; this product is sometimes called "hempoline". Alcohol fuel (ethanol or, less commonly, methanol) can be made by fermenting the whole plant.

Filtered hemp oil can be used directly to power diesel engines. In 1892, Rudolf Diesel invented the diesel engine, which he intended to power "by a variety of fuels, especially vegetable and seed oils, which earlier were used for oil lamps, i.e. the Argand lamp."

Production of vehicle fuel from hemp is very small. Commercial biodiesel and biogas is typically produced from cereals, coconuts, palm seeds, and cheaper raw materials like garbage, wastewater, dead plant and animal material, animal feces and kitchen waste.

Processing

Separation of hurd and bast fiber is known as decortication. Traditionally, hemp stalks would be water-retted first before the fibers were beaten off the inner hurd by hand, a process known as scutching. As mechanical technology evolved, separating the fiber from the core was accomplished by crushing rollers and brush rollers, or by hammer-milling, wherein a mechanical hammer mechanism beats the hemp against a screen until hurd, smaller bast fibers, and dust fall through the screen. After the Marijuana Tax Act was implemented in 1938, the technology for separating the fibers from the core remained "frozen in time". Recently, new high-speed kinematic decortication has come about, capable of separating hemp into three streams; bast fiber, hurd, and green microfiber.

Only in 1997, did Ireland, parts of the Commonwealth and other countries begin to legally grow industrial hemp again. Iterations of the 1930s decorticator have been met with limited success, along with steam explosion and chemical processing known as thermomechanical pulping.

Cultivation

Hemp is usually planted between March and May in the northern hemisphere, between September and November in the southern hemisphere. It matures in about three to four months.

Millennia of selective breeding have resulted in varieties that display a wide range of traits; e.g. suited for a particular environments/latitudes, producing different ratios and compositions of terpenoids and cannabinoids (CBD, THC, CBG, CBC, CBN...etc.), fibre quality, oil/seed yield, etc. Hemp grown for fiber is planted closely, resulting in tall, slender plants with long fibers.

The use of industrial hemp plant and its cultivation was commonplace until the 1900s when it was associated with its genetic sibling a.k.a. Drug-Type Cannabis species (which contain higher levels of psychoactive THC). Influential groups misconstrued hemp as a dangerous "drug", even though hemp is not a recreational drug and has the potential to be a sustainable and profitable crop for many farmers due to hemp's medical, structural and dietary uses.

In the United States, the public's perception of hemp as marijuana has blocked hemp from becoming a useful crop and product," in spite of its vital importance prior to World War II. Ideally, according to Britain's Department for Environment, Food and Rural Affairs, the herb should be desiccated and harvested towards the end of flowering. This early cropping reduces the seed yield but improves the fiber yield and quality. In these strains of industrial hemp* the tetrahydrocannabinol (THC) content would have been very low.

The seeds are sown with grain drills or other conventional seeding equipment to a depth of 1.27 to 2.54 cm (0.5 to 1 in). Greater seeding depths result in increased weed competition. Nitrogen should not be placed with the seed, but phosphate may be tolerated. The soil should have available 89 to 135 kg/ha of nitrogen, 46 kg/ha phosphorus, 67 kg/ha potassium, and 17 kg/ha sulfur. Organic fertilizers such as manure are one of the best methods of weed control.

Cultivars

In contrast to cannabis for medical use, varieties grown for fiber and seed have less than 0.3% THC and are unsuitable for producing hashish and marijuana. Present in industrial hemp, cannabidiol is a major constituent among some 560 compounds found in hemp.

Cannabis sativa L. subsp. sativa var. sativa is the variety grown for industrial use, while C. sativa subsp. indica generally has poor fiber quality and female buds from this variety are primarily used for recreational and medicinal purposes. The major differences between the two types of plants are the appearance, and the amount of Δ9-tetrahydrocannabinol (THC) secreted in a resinous mixture by epidermal hairs called glandular trichomes, although they can also be distinguished genetically. Oilseed and fiber varieties of Cannabis approved for industrial hemp production produce only minute amounts of this psychoactive drug, not enough for any physical or psychological effects. Typically, hemp contains below 0.3% THC, while cultivars of Cannabis grown for medicinal or recreational use can contain anywhere from 2% to over 20%.

Harvesting

Smallholder plots are usually harvested by hand. The plants are cut at 2 to 3 cm above the soil and left on the ground to dry. Mechanical harvesting is now common, using specially adapted cutter-binders or simpler cutters.

The cut hemp is laid in swathes to dry for up to four days. This was traditionally followed by retting, either water retting (the bundled hemp floats in water) or dew retting (the hemp remains on the ground and is affected by the moisture in dew and by molds and bacterial action).

Location and crop rotation

For profitable hemp farming, particularly deep, humus-rich, nutrient-rich soil with controlled water flow is preferable. Waterlogged acidic, compressed or extremely light (sandy) soils primarily affect the early development of plants. Steep and high altitudes of more than 400 m above sea level are best avoided. Hemp is relatively insensitive to cold temperatures and can withstand frost down to −5 °C. Seeds can germinate down to 1–3 °C. Hemp needs a lot of heat, so earlier varieties come to maturation. The water requirement is 300–500 l/kg dry matter. This is around 1/14th that of cotton, which takes between 7,000 and 29,000 l/kg, according to WWF. Roots can grow up to 3 feet into the soil and use water from deeper soil layers.

Hemp benefits crops grown after it. So, it is generally grown before winter cereals. Advantageous changes are high weed suppression, soil loosening by the large hemp root system, and the positive effect on soil tilth. Since hemp is very self-compatible, it can also be grown several years in a row in the same fields (monoculture).

Pests

Several arthropods can cause damage or injury to hemp plants, but the most serious species are associated with the Insecta class. The most problematic for outdoor crops are the voracious stem-boring caterpillars, which include the European corn borer, Ostrinia nubilalis, and the Eurasian hemp borer, Grapholita delineana. As the names imply, they target the stems reducing the structural integrity of the plant. Another lepidopteran, the corn earworm, Helicoverpa zea, is known to damage flowering parts and can be challenging to control. Other foliar pests, found in both indoor and outdoor crops, include the hemp russet mite, Aculops cannibicola, and cannabis aphid, Phorodon cannabis. They cause injury by reducing plant vigour because they feed on the phloem of the plant. Root feeders can be difficult to detect and control because of their below surface habitat. A number of beetle grubs and chafers are known to cause damage to hemp roots, including the flea beetle and Japanese beetle, Popillia Japonica. The rice root aphid, Rhopalosiphum rufiabdominale, has also been reported but primarily affects indoor growing facilities. Integrated pest management strategies should be employed to manage these pests with prevention and early detection being the foundation of a resilient program. Cultural and physical controls should be employed in conjunction with biological pest controls, chemical applications should only be used as a last resort.

Diseases

Hemp plants can be vulnerable to various pathogens, including bacteria, fungi, nematodes, viruses and other miscellaneous pathogens. Such diseases often lead to reduced fiber quality, stunted growth, and death of the plant. These diseases rarely affect the yield of a hemp field, so hemp production is not traditionally dependent on the use of pesticides.

Environmental impact

Hemp is considered by a 1998 study in Environmental Economics to be environmentally friendly due to a decrease of land use and other environmental impacts, indicating a possible decrease of ecological footprint in a US context compared to typical benchmarks. A 2010 study, however, that compared the production of paper specifically from hemp and eucalyptus concluded that "industrial hemp presents higher environmental impacts than eucalyptus paper"; however, the article also highlights that "there is scope for improving industrial hemp paper production". Hemp is also claimed to require few pesticides and no herbicides, and it has been called a carbon negative raw material. Results indicate that high yield of hemp may require high total nutrient levels (field plus fertilizer nutrients) similar to a high yielding wheat crop.

Extraction, processing, properties and use of hemp fiber

Natural and organic fibers become more and more popular these years. Most of the people come to realize that nature, soft and healthy are the most important things of the textile. Hemp fiber is naturally one of the most environmentally friendly fibers and also the oldest. The Columbia history of the world states that the oldest relics of human industry are bits of Hemp fabric discovered in tombs dating back to approximately 8000 B.C.

Hemp is called a fiber of hundred uses. The significance of Hemp to the economic and day to day lives of our ancestors is increasingly being recognized. It was important for textile, paper, rope and oil production. Indeed, Hemp was so important in England in the sixteenth century that King Henry VIII passed an act on parliament which fined farmers who failed to grow the crop. Besides fabrics, Hemp is also used in the production of paper. The oldest piece of paper – over 2000 yrs old – was discovered in China and is made from Hemp. Until 1883, between 75% and 90% of all paper in the world was made with Hemp fiber. Hemp paper can also be recycled more times than wood-based paper.

Hemp is a bast fiber plant similar to Flax, Kenaf, Jute, and Ramie. Long slender primary fibers on the outer portion of the stalk characterize bast fiber plants. It was probably used first in Asia. Hemp is also one of the bast fibers known to ancient Asians, long before the birth of Christ.

The primary hemp fiber is attached to the core fiber by Pectin – a glue-like soluble gelatinous carbohydrate. The primary hemp fibers can be used for composites, reinforcements, and specialty pulp and paper. The wood-like core Hemp fiber can be used for animal bedding, garden mulch, fuel and an assortment of building materials. Hemp also produces an oil seed that contains between 25 to 35% oil by weight, which is high in essential fatty acids considered to be necessary to maintain health.

Hemp (Cannabis sativa) could be an important crop enabling the production of environmentally – friendly, locally produced, high-quality textiles. Hemp is an annual plant that grows from seed. It can be grown on a range of soils but tends to grow best on land that produces high yields of corn. The soil must be well drained, rich in nitrogen, and non-acidic. Hemp requires limited pesticides because it grows so quickly and attracts few pests. Hemp is a traditional fiber crop which for centuries was important in meeting our needs for textiles, paper, and oils. It is easy to grow organically. That is, without a need for artificial pesticides, herbicides or fertilizers, so it can make an important contribution to a sustainable future. The production of cotton, on the other hand, needs a lot of pesticides.

Hemp is environmentally friendly in many ways. It can displace the use of cotton, which requires a massive amount of chemicals harmful to people and the environment. The production of cotton consumes 50% of the pesticides sprayed in the entire world. Hemp has a deep root system that helps to prevent soil erosion, removes toxins, provides a disease break, and aerates the soil to the benefit of future crops. True hemp is a fine, light-colored, lustrous, and strong bast fiber, obtained from the hemp plant, "cannabis sativa." It is a plant similar to jute, grown in many countries. When spun, it is rather like flax but thicker and coarser. It is a very strong fiber and is used in the manufacture of carpets, rugs, ropes etc., but has limited use because bleaching is difficult.

Hemp is a renewable resource which grows more quickly and easily than trees making hemp more cost effective than waiting decades for trees to grow to be used in man-made fiber products such as Lyocell and Rayon from wood pulps. The bark of the hemp stalk contains bast fibers, which are among the earth's longest natural soft fibers and also rich in cellulose.

The term "Hemp" is often incorrectly used in a generic sense for fibers from different plants eg; Manila "Hemp", Sisal "Hemp", Sunn "Hemp" etc. Hemp is grown in countries like Canada, USA, France, Hungary, Belgium, Holland, Thailand, Austria, Italy, China, Philippine island, Russia, Mexico, Germany, West Indies and India. In India, Deccan Hemp is grown both as crop and hedge plant. It is cultivated largely in Maharastra, Tamil Nadu, and north Gujarat. It can be grown in all temperature and tropical countries of the world. Currently, the bulk of our demand for textiles is met by cotton and synthetics, both of which have serious environmental problems associated with them.

Following are the steps required for Hemp processing in textiles.

1. **Retting** – Harvesting is done with a conventional combine harvester machine. Once cut, the plants, which are composed of two types of fiber – long outer fibers suitable for textiles, and short inner fiber suitable for paper or industrial applications – are left in the field for about 10 to 20 days to 'ret'.

Retting is of two types.

- **Water Retting**– It involves lying the stems in water in tanks, ponds or in streams for around 10 days–it is more effective if the water is warm and bacteria-laden.
- **Dew Retting**– It is a natural process that is triggered by dew that falls on the

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crop each morning. After cutting, the hemp stems were laid parallel in rows to dew ret. The stems needed turning at least once (sometimes) twice in order to allow for even Retting (or rotting) being the name given to the process whereby bacteria and fungi is break down the pectins that bind the fibers to the stem allowing the fiber to be released. Retting is complete when the fiber bundles appear white, separate from the woody core and divide easily into individual finer fibers for their full length. Once this process is complete (dry), the stalks are collected and sent to the "decortication" machine. The major Hemp varieties are called F 34, F 56, Uniko BF and Kompolti.

2. **Decortication**– In this process the de-leafed Hemp stems are then dried, i.e. conditioned and freed from the wood kernel in a sequence of a squeeze, break and scutching processes. In other words, it is described as breaking the stems by passing through a "breaker" or fluted rollers. Then the fiber is separated from the woody core ("scotching") by beating the broken stems with a beech stick or passing through rotary blades.
3. **Softening**– By using a so-called Hemp softener or roller, the decorticated fibers are made softer and suppler.
4. **Combing**– The shortening of the initial fiber lengths from up to 3 m down to 650 mm is done on a special cutting machine. Then the short and tangled fibers are combed out, the long fibers are parallelized and smoothed using a hackling machine. In other words "hackling" (combing) means to remove any woody particles and to further align the fibers into a continuous "sliver" for spinning.
5. **Spinning**– After several drawing and doubling passages, the manufactured slivers are pre-spun roving yarns and according to quality and the desired yarn fineness, spun into Hemp yarn by wet or dry spinning processes. Although as Hemp is coarser than Flax, the pins on the board for drafting the combed fiber into a sliver needed to be set differently. The rove produced was then boiled in caustic soda to refine it and most of the yarn was bleached with hydrogen peroxide. As it is similar to Flax fibers, generally the best yarns are obtained by wet spinning. In which fibers are allowed to pass through a trough of hot water before being spun. This softens the Pectin allowing a greater drawing out and separation of the fibers and producing a finer yarn (greater than 12 Nm). Dry spinning is cheaper, producing yarns and fabrics with a different appearance and handle. Using the above process two types of 100% Hemp yarn is made known as long yarn and short yarn. Normally the counts are Nm 7/1, Nm 8.5/1, Nm 10/1, Nm 16/1, Nm 18/1, Nm 24/1 and Nm 36/1.

The above preparatory processing of Hemp fiber incur considerable waste and add significantly to the cost of the fiber which could be made available as a raw textile fiber for 3500 USD /tons. The Hemp was successfully processed to produce nonaligned fibers, with a yield of 20-25%.

Properties of Hemp fiber

Hemp fiber is dark tan or brown and is difficult to bleach, but it can be dyed bright and dark colors. Hemp fiber is a lustrous fiber, has characteristic nodes and joints of linen, but the central canal is wider. The cells are blunt-ended when the fiber is viewed under a microscope. The Hemp fibers vary widely in length, depending upon their ultimate use. Industrial fibers may be several inches long, while fibers used for domestic textiles are about a ¾ inch to 1 inch (1.9 to 2.54 cm) long. The elongation (1 to 6%) is low and its elasticity poor. The thermal reactions of Hemp and the effect of sunlight are the same as for Cotton. Hemp is moth resistant, but it is not impervious to mildew. Furthermore, Hemp has the best ratio of the heat capacity of all fibers giving it superior insulation properties. As a fabric, Hemp provides all the warmth and softness of other natural textiles but with a superior durability seldom found in other materials. Natural organic Hemp fiber "breathes" and is biodegradable.

Hemp fiber is longer, stronger, more absorbent, more mildew resistant and more insulative than Cotton fiber. There are thirty varieties of Hemp fiber. It is a tall plant with a natural woody fiber. All these varieties resemble one another in general appearance and properties, but only those having fibers of high tensile strength, fineness, and high luster have commercial value. It resembles flax closely, and its fiber is easily mistaken for linen. Hemp is harsh and stiff and cannot be bleached without harm to the fiber. As Hemp is not pliable and elastic, it cannot be woven into fine fabrics. Hemp is durable and is used in rug and carpet manufacturing. It is especially suitable for ship cordage as it is not weakened or rotted by water, this means that Hemp will keep you warmer in winter and cooler in summer than Cotton. Hemp is more effective at blocking the sun‘s harmful ultraviolet rays. The nature of Hemp fibers make them more absorbent to reactive dyes, vat dyes and sulfur dyes, which coupled with Hemp's ability to better screen out ultraviolet rays, means that Hemp material is less prone to fading than cotton fabrics are.

The blending of Hemp fiber

Like Cotton, Hemp can be made into a variety of fabrics, including high-quality Linen. When blended with materials such as Cotton, Linen, and Silk. Hemp provides a sturdier, longer lasting product while maintaining quality and softness.

Hemp Active, an Austrian company supplies Hemp blended yarn which is made of Hemp with cotton/organic cotton. Nowadays few mills in Europe are making Hemp/Polyester 60/40 blends and Hemp/Wool/Polyester 40/40/20 blends.

Hemp Textiles Intl., Canada supplies blend of Hemp/Wool 50/50. Hemp blended with other fibers easily incorporate the desirable qualities of both textiles. When combined with the natural strength of Hemp, the soft elasticity of Cotton or the smooth texture of Silk creates a whole new genre of fashion design.

Uses of Hemp fiber

Coarse Hemp fibers and yarns are woven into cordage, rope, sacking and heavy – duty tarpaulins. In Italy, fine Hemp fibers are used for interior design and apparel fabrics. Hemp is used in tapestry, hats, shawls, rugs, posters, and towel.

Dyed hemp yarn from Hungary is suitable for rug weaving, placemats, crochet and other craft items. It has been found that 3 plies, 6 plies, and 12 plies are used for weaving, knitting or crochet. Hemp is stronger than linen and jute fiber, hence it is ideal for making twine, ropes, cables, carpets, canvas, ship cordage, sailcloth, etc. Central American Hemp is chiefly used for cordage. Manila "Hemp" is a fiber from the leaves of the Abaca plant; it is very strong, fine, white, lustrous and, though brittle, it is adaptable for the weaving of coarse fabrics.

Lastly, more research work has to be done on Hemp fiber like scouring/bleaching using enzymes without affecting the strength of the fiber.

Trials can be taken in cotton and synthetic spinning by adding Hemp fiber in many value-added items and make various types of fancy yarn which can be sold in the market at a premium rate.

2.4 MAN-MADE FIBRES – NYLON, POLYESTER, RAYON, ACRYLIC STUDY THE MANUFACTURING

Man-made fibre

Man-made fibre, fibre whose chemical composition, structure, and properties are significantly modified during the manufacturing process. Man-made fibres are spun and woven into a huge number of consumer and industrial products, including garments such as shirts, scarves, and hosiery; home furnishings such as upholstery, carpets, and drapes; and industrial parts such as tire cord, flame-proof linings, and drive belts. The chemical compounds from which man-made fibres are produced are known as polymers, a class of compounds characterized by long, chainlike molecules of great size and molecular weight. Many of the polymers that constitute man-made fibres are the same as or similar to compounds that make up plastics, rubbers, adhesives, and surface coatings. Indeed, polymers such as regenerated cellulose, polycaprolactam, and polyethylene terephthalate, which have become familiar household materials under the trade names rayon, nylon, and Dacron (trademark), respectively, are also made into numerous nonfibre products, ranging from cellophane envelope windows to clear plastic soft-drink bottles. As fibres, these materials are prized for their strength, toughness, resistance to heat and mildew, and ability to hold a pressed form.

Man-made fibres are to be distinguished from natural fibres such as silk, cotton, and wool. Natural fibres also consist of polymers (in this case, biologically produced compounds such as cellulose and protein), but they emerge from the textile manufacturing process in a relatively unaltered state. Some man-made fibres, too, are derived from naturally occurring polymers. For instance, rayon and acetate, two of the first man-made fibres ever to be produced, are made of the same cellulose polymers that make up cotton, hemp, flax, and the structural fibres of wood. In the case of rayon and acetate, however, the cellulose is acquired in a radically altered state (usually from wood-pulp operations) and is further modified in order to be regenerated into practical cellulose-based fibres. Rayon and acetate therefore belong to a group of man-made fibres known as regenerated fibres.

Another group of man-made fibres (and by far the larger group) is the synthetic fibres. Synthetic fibres are made of polymers that do not occur naturally but instead are produced entirely in the chemical plant or laboratory, almost always from by-products of petroleum or natural gas. These polymers include nylon and polyethylene terephthalate, mentioned above, but they also include many other compounds such as the acrylics, the polyurethanes, and polypropylene. Synthetic fibres can be mass-produced to almost any set of required properties. Millions of tons are produced every year.

Chemical Composition And Molecular Structure

Linear, branched, and network polymers

One of the features common to all the fibre-forming polymers is a linear structure. As explained in the article industrial polymers, chemistry of, polymers are built up by the joining together, through strong covalent bonds, of smaller molecular units known as monomers. When these monomers are joined end-to-end like links along a chain, a polymer with a simple linear structure is formed. In some polymers shorter chains grow off the long chain at certain intervals, so that a branched structure is formed. In other polymers the branches become numerous and cross-link to other polymer chains, thus forming a network structure.

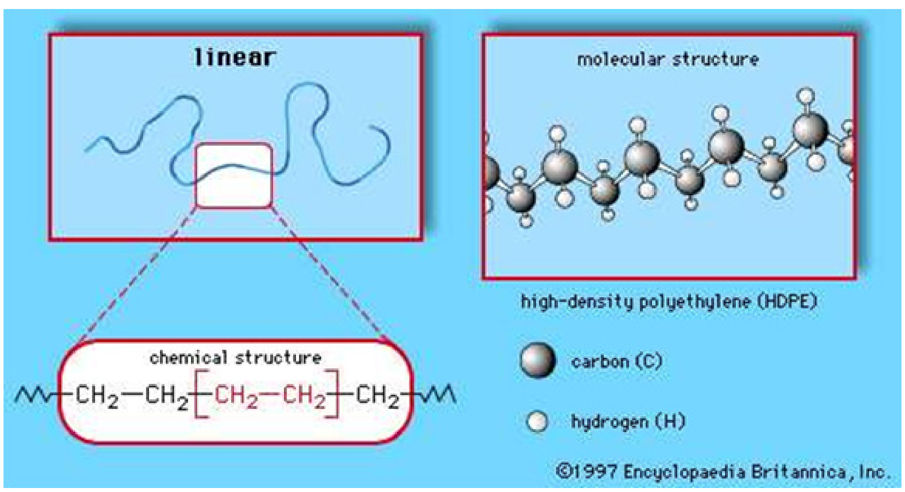

Figure : Three common polymer structures. The linear, branched, and network architectures are represented (from top), respectively, by high-density polyethylene (HDPE), low-density polyethylene (LDPE), and phenol formaldehyde (PF). The chemical structure and molecular structure of highlighted regions are also shown.

Materials made of linear and branched polymers will hold their shape when cooled, owing to the considerable attraction (known as intermolecular forces, or van der Waals forces) that such large molecules exert upon one another. With the application of heat, however, these materials will soften and eventually become molten, as the molecules, which are not cross-linked by covalent bonds, overcome the intermolecular forces and flow past one another. Linear and branched polymers will also dissolve in suitable solvents. Such behaviour makes linear polymers especially suitable for forming into fibres, which, as is explained below, are usually spun from a molten state or from solution. Few highly branched polymers are suitable for

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fibres, because they do not crystallize readily and have relatively poor mechanical properties.

Network polymers form enormous, complex, chemically bonded structures that do not melt without undergoing chemical decomposition. In addition, while network polymers may soften and swell upon treatment with solvents, they do not readily dissolve. Such properties render most network polymers unsuitable for forming into fibres.

Influence of chemical structure on properties

The most important fibre-forming polymers are shown in Table 1. For details on their composition, properties, and applications, links are provided from the table to entries on the materials. An important requirement of these polymers is that they have melting points which are sufficiently high to make the fibres useful—for instance, so that clothing made from them can be ironed or pressed—but which also fall within a range that permits melt-spinning without decomposition of the polymer. Alternatively, polymers that melt at too high a temperature for practical melt-spinning or polymers that decompose at melt-spinning temperatures may be suitable for fibre forming if they can be dissolved and then spun from solution. The extent to which a polymer possesses these essential properties is often determined by the structure of its repeating units. To illustrate the manner in which these structural units can result in either good or poor fibre-forming properties, several basic polymer structures are discussed below, along with variations in chemical structure that cause variations in fibre-forming properties.

Properties and applications of prominent man-made fibres

polymer family and type	common names and trade names	deniers (gm/9,000 m)	tensile strength (gm/denier)	elongation at break (%)	initial modulus (gm/denier)
Cellulosics					
regenerated cellulose	rayon	2–3	2.0–2.1	17–20	—
cellulose triacetate	acetate, Arnel	2–3	1.2–1.4	25–28	35–40
Polyamide					

polycaprolactam (textile fibre)	nylon 6 (textile)	1.5–5	4.5–6.8	23–43	25–35
polyhexamethylene adipamide (textile fibre)	nylon 6,6 (textile)	1.5–5	4.5–6.8	23–43	25–35
polycaprolactam (industrial fibre)	nylon 6 (industrial)	1.5–5	8.5–9.5	12–17	33–46
polymer family and type	**common names and trade names**	**deniers (gm/9,000 m)**	**tensile strength (gm/denier)**	**elongation at break (%)**	**initial modulus (gm/denier)**
Cellulosics					
polyhexamethylene adipamide (industrial fibre)	nylon 6,6 (industrial)	1.5–5	8.5–9.5	12–17	33–46
Aramid					
poly-p-phenylene tereph-thalamide	Kevlar, Twaron, Technora	1.0–1.5	25–30	3–6	500–1,000
poly-m-phenylene isoph-thalamide	Nomex, Conex	2–5	3–6	2–30	130–150
Polyester					

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polyethylene terephthalate	Dacron, Terylene, Trevira	1.5–5	4.7–6.0	35–50	25–50
Polyacrylonitrile					
acrylic (>85% acrylonitrile)	Acrilan, Creslan, Courtelle	2–8	2.5–4.5	27–48	25–63
modacrylic (35–85% acrylonitrile)	Verel, SEF	2–8	2.5–4.5	27–48	22–56
Polypropylene					
	Herculon, Marvess	2–10	5–9	15–30	29–45
Polyethylene					
regular		2–10	2–4	20–40	—
high-modulus	Dyneema, Spectra	—	30–35	2.7–3.5	1,370–2,016
Polyurethane					
	spandex, Lycra	2.5–20	0.6–1.5	400–600	—

polymer family and type	**apparel and home-furnishing applications**	**industrial applications**	

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Cellulosics			
regenerated cellulose	area rugs, substitute for cotton in clothing	disposable nonwoven fabrics, tire cord, paper	
cellulose triacetate	suit coat linings	cigarette filters	
Polyamide			
polycaprolactam (textile fibre)	hosiery, lingerie, sports garments, soft-sided luggage, upholstery	no significant applications	
polyhexamethylene adipamide (textile fibre)	hosiery, lingerie, sports garments, soft-sided luggage, upholstery	no significant applications	
polycaprolactam (industrial fibre)	no significant applications	tires, ropes, seat belts, parachutes, fishing lines and nets, hoses	
polyhexamethylene adipamide	no significant	tires, ropes, seat belts, parachutes, fishing lines	

polymer family and type	**common names and trade names**	**deniers (gm/9,000 m)**	**tensile strength (gm/denier)**	**elongation at break (%)**	**initial modulus (gm/denier)**
Cellulosics					
(industrial fibre)	applications		and nets, hoses		

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Aramid			
poly-p-phenylene tereph-thalamide	no significant applications	radial tire belts, bulletproof vests, reinforcement for boat hulls and aircraft panels	
poly-m-phenylene isoph-thalamide	no significant applications	filter bags for hot stack gases, flame-resistant clothing	
Polyester			
polyethylene terephthalate	permanent-press clothing, fibrefill insulation, carpets	sewing thread, seat belts, tire yarns, nonwoven fabrics	
Polyacrylonitrile			
acrylic (>85% acrylonitrile)	substitute for wool—e.g., in sweaters, hosiery, blankets	filters, battery separators, substitute for asbestos in cement	
modacrylic (35–85% acrylonitrile)	flame-resistant clothing—e.g., artificial fur, children's sleepwear	flame-resistant awnings, tents, boat covers	
Polypropylene			
	upholstery, carpets, carpet backing	ropes, nets, disposable nonwoven fabrics	

	upholstery, carpets, carpet backing	ropes, nets, disposable nonwoven fabrics	
Polyethylene			
regular	no significant applications	cordage, webbing	
high-modulus	no significant applications	reinforcement for boat hulls, bulletproof vests	
Polyurethane			

polymer family and type	**common names and trade names**	**deniers (gm/9,000 m)**	**tensile strength (gm/denier)**	**elongation at break (%)**	**initial modulus (gm/denier)**
Cellulosics					
	stretch fabrics—e.g., for sportswear, swimsuits		no significant applications		

Polyolefins

Many polymers are derived from the olefins, a family of hydrocarbon compounds—that is, compounds containing hydrogen (H) and carbon (C)—which are produced from the refining of petroleum and natural gas. An olefin contains one double bond between two carbon atoms. The general chemical formula can be represented as $CH_2 = CHR$, with R representing any of several possible atoms or groups of atoms. As the repeating unit of a polymer, the compound has the following chemical structure:

Here the brackets signify that the compound is a repeating unit, and n represents the number of times the unit is repeated in the polymer.

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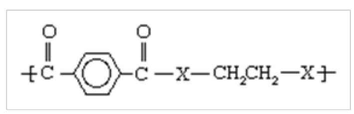
When R in the above structure represents a methyl group (CH_3), the polymer obtained is polypropylene. Polypropylene is a material of moderately high melting temperature (176 °C, or 349 °F) that can be melt-spun into fibres useful for several types of clothing, upholstery, carpets, and nonwoven fabrics. When R is hydrogen (H), the polymer is polyethylene, a relatively low-melting material (137 °C, or 279 °F) that finds use as a fibre in industrial applications—e.g., nonwoven fabrics—but not in most household applications.

Still another variation is found when R represents a cyano, or nitrile, group (C≡N), containing carbon and nitrogen linked by a triple bond. In this case the polymer obtained is polyacrylonitrile, an acrylic that does not melt without decomposition and therefore must be solution-spun into fibres used in clothing, drapes, and carpets.

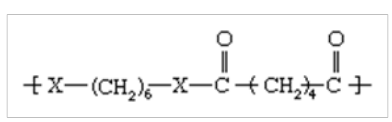
It can be observed from the structural variations noted above that the methyl and cyano groups in polypropylene and polyacrylonitrile raise melting points and alter solubility. At the same time, however, they are known to have a detrimental effect on tensile properties. For example, although fibres made from polypropylene can be very strong, their tensile strength is only about one-fourth that of the high-modulus polyethylene fibres.

Polyesters and polyamides

As noted in industrial polymers, chemistry of: Step-growth polymerization, one important route to the formation of polymers is the reaction of dicarboxylic acids with alcohols to form esters (containing CO—O groups) and with amines to form amides (containing CO—NH groups). The difference in properties produced by reacting with alcohols as opposed to amines can be illustrated by two structures.



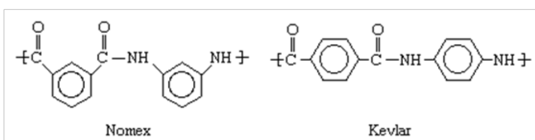
In the first structure (above), when X represents oxygen (O), the polyester polyethylene terephthalate (PET) is obtained. Having a melting point of 265 °C (509 °F), PET can be melt-spun into very practical and cheap fibres that are widely employed in clothing, furnishings, carpets, and tire cord under such trademarked names as Dacron and Terylene. On the other hand, when X is an amine group (NH), a polyamide with a melting point greater than 400 °C (750 °F) is formed. This compound, polyethylene terephthalamide, can only be spun from solution, using costly solvents; therefore, it is not made into fibres.



In the second structure (above), when X represents oxygen, a very low-melting polyester called polyhexamethylene adipate, unsuitable for fibres, is obtained. When X represents an amine group, however, a useful polyamide, polyhexamethylene adipamide (nylon 6,6), is obtained. With a melting point of 265 °C (509 °F), nylon 6,6 can be melt-spun readily into fibres employed in apparel, carpets, and tire cord.

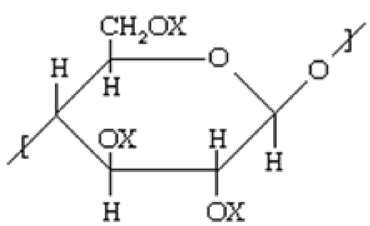
From the above illustrations, it is clear that the amide (CO—NH) groups produce much higher melting points than do the ester (CO—O) groups, even when the overall structures of the polymers are otherwise identical. The reason for this is that the CO—NH combinations are capable of a type of chemical bonding known as a hydrogen bond. Hydrogen bonds can produce bonds between polymer chains that are similar to the covalently bonded cross-links found in network polymers. They are not covalent bonds, however, and do not form true cross-links. In particular, the strength of the hydrogen bonds diminishes with the application of heat or solvent, allowing the polymers to be spun from the melt or from solution.

Very high melting points and oxidatively stable bonds can be produced when the CO—NH groups of the polyamide structures illustrated above are combined with aromatic hydrocarbons. When these stiff, ring-shaped molecules take the place of the more flexible CH2 groups, very high-melting aromatic polyamides, or aramids, are obtained. Better known by the trademarks Kevlar and Nomex, aramids are made into flame-resistant clothing, bulletproof vests, tire cord, and stiffening reinforcement for composite materials used in large structures such as boat hulls and aircraft parts. The structures of these two compounds are shown below.



Cellulose-based polymers

Cellulose, a complex carbohydrate that is the basic structural component of the plant cell wall, is the most abundant polymer on earth. The basic structure of cellulose and its derivatives is shown below.



In unaltered native cellulose, X represents hydrogen, forming a number of pendant hydroxyl (OH) groups. Hydroxyl groups, like amides, are capable of forming hydrogen bonds. Partly as a result of such bonds, native cellulose behaves much like a cross-linked polymer, melting only with chemical decomposition—and therefore precluding melt-spinning into fibres. On the other hand, cellulose can be spun from solution when the OH groups are converted to other groups. For instance, rayon fibres can be formed by converting the OH groups to xanthate groups (e.g., O—CS—S—Na; an organic salt containing oxygen, carbon, sulfur, and sodium) in a basic solution prior to spinning and then converting the xanthate groups back to

OH groups by spinning the dissolved compound into an acidic bath. Substitution of an acetyl group (O—CO—CH_3) for the OH group leads to a material that can be spun from a simple solvent such as acetone. These fibres are known as cellulose acetate, or simply acetate.

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Additives

In order to achieve certain desirable fibre properties that cannot be obtained by polymers alone or to overcome certain deficiencies of polymers, various additives are mixed into polymer melts or solutions prior to the spinning of fibres. Some of the more common additives are heat and light stabilizers (especially important for nylon), flame retardants, and delustrants such as titanium dioxide to dull the natural sheen of man-made fibre.

In some cases dyes or pigments may be added to the melt or solution prior to the spinning of the fibre. Ordinarily, fibres are coloured after spinning by dyes dissolved in baths of boiling water. The water serves to carry the dyes into the fibres, where acidic dyes bind to basic sites and basic dyes bind to acidic sites. However, some fibres cannot be penetrated by water after they have been dried in the spinning process. In the case of polyesters, organic compounds such as benzophenone are used to carry the dyes into the fibres under pressure. In the case of acrylic fibres high in polyacrylonitrile, dyes are applied during the spinning process. At this time the freshly precipitated fibres, prior to the drying and collapse of their gel structure, still contain some water and solvent and are therefore open to the entry of basic dyes that bind to acidic sites on the polymers.

Pigments, which are insoluble colorants, can also be added to polymer solutions or melts prior to spinning. Pigments are often added to modacrylics (acrylics low in polyacrylonitrile and modified by other monomers) because the fibres, which are very sensitive to light, fade or yellow even after dyeing. The addition of pigments to the spinning solution prevents fading and yellowing of the fibres to some degree. The fibres are especially useful for outdoor fabrics such as awnings and boat coverings.

Polypropylene is another material that is very hydrophobic (water-repelling); moreover, the polymer has no acidic or basic sites for the binding of dyestuffs. Consequently, pigments are added to polypropylene melts prior to spinning.

Processing And Fabrication

Spinning

Polymer that is to be converted into fibre must first be converted to a liquid or semiliquid state, either by being dissolved in a solvent or by being heated until molten. This process frees the long molecules from close association with one another, allowing them to move independently. The resulting liquid is extruded through small holes in a device known as a spinnerette, emerging as fine jets of liquid that harden to form solid rods with all the superficial characteristics of a very long fibre, or filament. This extrusion of liquid fibre-forming polymer, followed by hardening to form filaments, is called spinning (a term that is actually more properly used in connection with textile manufacturing). Several spinning techniques are used in the production of man-made fibre, including solution spinning (wet or dry), melt spinning, gel spinning (a variant on solution spinning), and emulsion spinning (another variation of solution spinning).

Solution spinning

One of the oldest methods for the preparation of man-made fibres is solution spinning, which was introduced industrially at the end of the 19th century. Solution spinning includes wet spinning and dry spinning. The former method was first used to produce rayon fibres, and the latter method was used to spin cellulose triacetate to acetate fibres. In both methods, a viscous solution of polymer is pumped through a filter and then passed through the fine holes of a spinnerette. The solvent is subsequently removed, leaving a fibre.

During wet spinning the spinnerette is generally (but not always) placed in the spin bath, a coagulation bath in which solvent diffuses out of the extruded material and a nonsolvent, usually water, diffuses into the extrudate. The resulting gel may be oriented by stretching during this stage, as the polymer is coagulated, or the freshly formed fibres may be stretched after they are removed from the spin bath. At this point the fibre, containing solvent and nonsolvent (e.g., water), is washed with more nonsolvent (again, usually water). A lubricant, referred to as the fibre finish, is generally applied before the fibre is dried on large, heated drum rolls. The fibre is then wound onto spindles or sent to a cutter. The cutter produces fibre in lengths of 2.5 to 15 cm (1 to 6 inches) known as staple. A spindle that has been fully wound with continuous fibre is called a package.

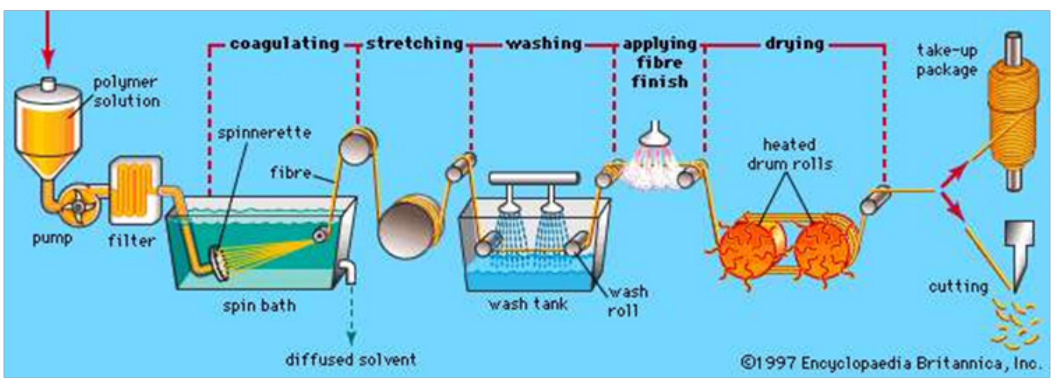

Figure : Stages in the wet spinning of polymeric fibres.

In dry spinning, the solution of polymer is pushed through a spinnerette into a heated column called the spinning tower, where the solvent evaporates, leaving a fibre. The emerging fibre may contain solvent that may have to be removed by further heating or by washing. This operation is followed by stretching, application of finish, and either take-up on a spindle or cutting to staple.

The wet-spinning method is capable of spinning a large number of fibres at a time because several thousand holes may be present in a single spinnerette. The large bundle of emerging fibres, known as tow, can be spun at rates slow enough

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to make possible the use of a large spin bath and large washing rolls, drying rolls, and other processing equipment. Wet spinning is thus highly economical, the low spinning rates being compensated for by the large tows to give high overall productivity. In dry spinning, on the other hand, the rate of spinning is much higher, but relatively small bundles of fibre are extruded in order to achieve adequate solvent removal and drying. As a consequence, productivity is lower than in wet spinning. Dry spinning is being phased out for most commodity fibres and is used only for expensive specialty fibres, such as spandex, that cannot be spun by any other process.

The use of solvents that can be recovered from the spin bath is becoming more common in solution spinning. Acrylic fibres are an example of this trend. In some older acrylic processes the solvents were salts such as sodium or ammonium thiocyanates, but the preferred method now is to use an amide-type solvent—e.g., N,N-dimethylacetamide (DMAc)—which can be recovered from the spin bath by distillation. Amide solvents are also used for the spinning of some aramids—e.g., for the trademarked fibres Nomex and Conex.

Rayon fibres traditionally have been spun from xanthate solutions, as noted above, but this process has been abandoned in developed countries owing to environmental problems caused by the carbon disulfide ingredients and also by salts produced in treating the xanthate with acid. Newer plants use an inorganic solvent, morpholine N-oxide, which can be recovered by distillation of the spin bath.

Melt spinning

The most economical method of spinning is melt spinning, primarily because there is no solvent to be recovered as in solution spinning and because the spinning rates are so high. In this process, a viscous melt of polymer is extruded through a spinnerette containing many holes (but not nearly so many as in solution spinning) into a process zone called the spinning tower. There the molten polymer is solidified by a blast of cold air, and the numerous fibres are collected, after application of finish, at high speed. In a process known as spin-drawing, fibres may be drawn in-line to several times their original length. Packages may be collected directly from the spinning tower to give what is called continuous filament, or several lines of fibre may be collected into a large tow for cutting to staple.

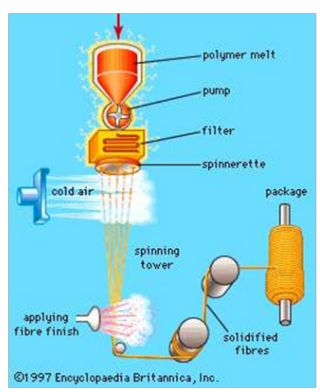

Figure : Stages in the melt spinning of polymeric fibres.

Some filaments may be melt-spun through a single-hole spinnerette to yield a monofilament that is of much larger diameter than usual textile fibres. Drawing may be done in-line or as a separate step. The monofilaments are used for such products as fishing line and lawn furniture.

Gel spinning

Gel spinning is an old technique that has come into use commercially only since the 1980s. As originally applied, solutions of very high solid contents (20–80 percent) were used; such solutions were similar to semisolids. In the modern adaptation of this process, polymer of an extremely high molecular weight is dissolved in a solvent of low concentration (i.e., 1 to 2 percent), making a very viscous solution. This solution is either dry- or wet-spun to fibre, which, still retaining most of the solvent, is actually a gel of polymer and solvent. While in the gel state, the fibre can be stretched in order to pull the molecules of the polymer into an elongated state, instead of the usual solid state of chain-folded molecules. Ultrahigh-strength, high-stiffness polyethylene fibres, marketed under such trademarks as Spectra, are commercially produced using gel-spinning techniques.

Emulsion spinning

Some nonmelting and insoluble polymers can be ground to a finely divided powder, mixed into a solution of another polymer, and solution-spun to fibres. The soluble polymer can be removed by a solvent or by burning and the residual fibre collected. Such a process can be used to make fibres of fluorocarbons such as Teflon (trademark), which have extremely high melting points. Even materials that are not polymers—e.g., inorganic materials such as ceramics—can be suspended in a solution of a cheap polymer such as cellulose and spun to fibre. The cellulose can be burned away to leave a sintered mass in fibre form. Such fibres are used as replacements for hazardous asbestos fibres.

Split-film fibres

Very cheap fibres for use in applications that cannot justify the cost of fibres spun by the usual methods (for instance, packaging materials) may be prepared by the split-film method. This process consists of extruding a polymer such as polypropylene through a die to obtain a ribbon, which is then passed through numerous cutting blades that slit the ribbon or film into continuous smaller ribbons resembling very coarse fibres. This process, which produces crude but very useful fibres, is frequently practiced on-site by the user of the final product.

Drawing

Stretching and orientation

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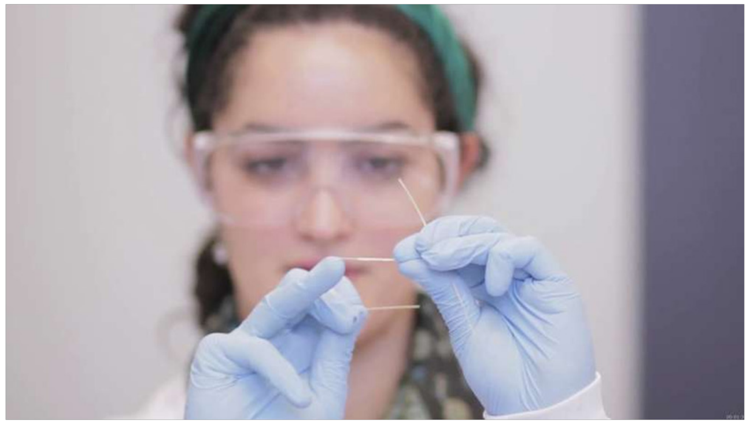

Fig. Developing multifunctional fibres to deliver optical signals or drugs directly into the brain and to record neural activity.

The spinning processes described above produce some orientation of the long polymers that form spun filaments. Orientation is completed by stretching, or drawing, the filament, a process that pulls the long polymer chains into alignment along the longitudinal axis of the fibre and causes them to pack closely together and develop cohesion.

Wherever the polymer chains are able to pack closely together in a fibre, there is a tendency toward an ordered arrangement of the atoms with respect to one another. These tightly packed bundles of molecules are called crystallites, because they are regions that possess the regular and precise arrangement of atoms characteristic of all crystals. Between the crystallites are regions in which the molecules have not been able to align themselves so precisely. These are called amorphous, or noncrystalline, regions. In considering fibre structure, then, the polymer chains may be regarded as regions of ordered crystalline arrangement embedded in amorphous material.

During the drawing operation the polymer chains slide over one another as they are pulled into alignment along the longitudinal axis of the fibre. As drawing continues, more and more of the molecules are brought to a state where they can pack alongside one another into crystallites. In these regions the molecules are able to hold tightly together as a result of intermolecular forces and resist further movement with respect to one another. For instance, after nylon is spun, the filament may be drawn to as much as five times its original length before it resists further stretching. At this point the molecules are aligned as effectively as possible into crystalline regions and are holding tightly together. The filament is then able to withstand great force without further stretching.

The degree of alignment of fibre molecules affects the properties of a fibre in several ways. The more closely the molecules pack together, the greater is the ultimate strength, or breaking strength, of the fibre. This increase in ultimate strength is accompanied by a decrease in the amount of elongation that the fibre can sustain before reaching its breaking point; the molecules are not able to slide over one another as they could before alignment took place. If the load becomes too great, the fibre will rupture. Because the closely packed molecules no longer have great freedom of movement, a high degree of orientation also tends to increase fibre stiffness or rigidity.

Water is unable to penetrate between molecules in the crystalline region of a fibre as well as it penetrates the amorphous regions; therefore, increased alignment tends to lower the moisture absorption of the fibre. Increased resistance to water penetration in turn affects the dyeing properties of highly oriented fibres; the molecules of dyestuff cannot migrate from the dye bath into the spaces between the fibre molecules. Increased resistance to penetration by foreign molecules also improves the general chemical stability of a fibre, since highly oriented fibres are more resistant to chemical attack.

Fibres change in appearance as they are drawn. In the undrawn state, nylon is usually dull and opaque; as the filaments are drawn and molecular orientation increases, the filaments acquire the transparency and lustre characteristic of drawn nylon.

Drawing techniques

Fibres can be drawn either as an integral part of the spinning operation or in a separate step. Fibres such as nylon and polypropylene can be drawn without applying external heat (or at a temperature no greater than about 70 °C [160 °F])—a process referred to as cold drawing. Other fibres, such as polyester, that are spun at extremely high rates yield what is known as partially oriented yarns (POY)—i.e., filaments that are partially drawn and partially crystallized and that can be drawn at a later time during textile operations. Many fibres, such as PET, require that a hot-drawing step follow the spinning process fairly soon, or they will become brittle. Avoiding such brittleness is part of the reason for preparing partially oriented yarns. Acrylics may receive a hot-drawing (known as plastic stretch) following drying, but a portion of the molecular orientation is relaxed by a subsequent annealing step, which uses steam under pressure to prevent the fibres from pilling when rubbed during use. Nylon intended for ultrahigh-strength end uses such as tire cord requires hot drawing; aramids also can be greatly improved by this process. For instance, continuous-filament Nomex, a trademarked aramid, is hot-drawn to give a tensile strength nearly double that of the as-spun product used for staple. Kevlar 29, another trademarked aramid, is drawn at a temperature over 400 °C (750 °F) to produce Kevlar 49, a fibre with nearly double the stiffness of the undrawn product.

Texturing

Texturing is the formation of crimp, loops, coils, or crinkles in filaments. Such changes in the physical form of a fibre affect the behaviour and hand of fabrics made from them. Hand, or handle, is a general term for the characteristics perceived by the sense of touch when a fabric is held in the hand, such as drapability, softness, elasticity, coolness or warmth, stiffness, roughness, and resilience.

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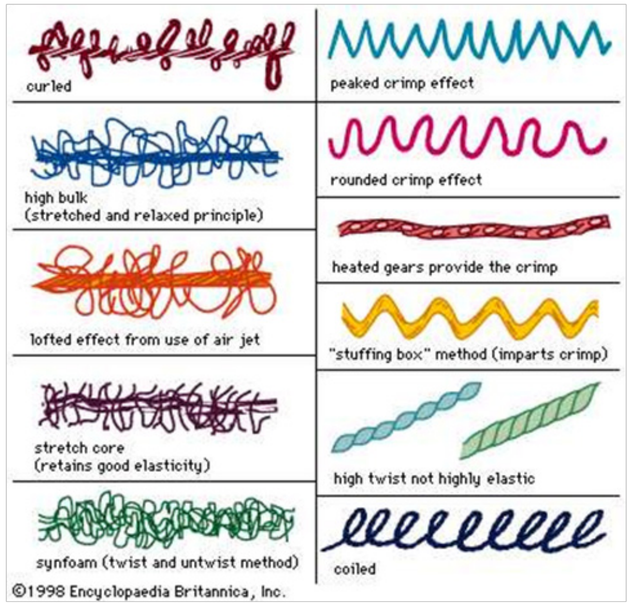

For continuous yarns used in apparel, a number of texturing processes may be employed either in a textile factory or by the fibre producer. In the latter case the yarns are referred to as producer-textured yarns. Most apparel texturizing techniques are high-speed processes. Processes for large tows may run at lower speeds but at higher volume.

Crimping

In order for staple fibres to be spun into yarn, they must have a waviness, or crimp, similar to that of wool. This crimp may be introduced mechanically by passing the filament between gearlike rolls. It can also be produced chemically by controlling the coagulation of a filament in order to create a fibre having an asymmetrical cross section—that is, with one side thick-skinned and almost smooth and the other side thin-skinned and almost serrated. When wet, such fibres swell to a greater extent on the thin-skinned side than on the thick-skinned side, causing a tendency to curl.

A similar effect can be produced from bicomponent fibres. These are fibres spun from two different types of polymer, which are extruded through holes set side-by-side in such a way that the two filaments join as they coagulate. When the filament is drawn, the two polymers extend to different degrees, producing a helical crimp when the strain is relaxed.

One popular texturizing process is false-twisting. In this technique, twist is inserted into a heated multifilament yarn running at high speed. The yarn is cooled in a highly twisted state, so that the twist geometry is set, and then the yarn is untwisted. Untwisting leaves filaments that are still highly convoluted, allowing the production of a textured yarn of much greater volume than the yarn would be in an untextured state.

False-twist texture is usually combined with drawing. Partially oriented (POY) nylon and polyester, which have been spun at extremely high rates and are already partially crystalline, are both drawn and textured in this way.

Stuffing

Fibres spun from very large bundles of fibre, called tow, are generally crimped in-line by feeding two tows into a stuffer box, where the tows fold and compress against each other to form a plug of yarn. The plug may be heated by steam injection so that, upon cooling, a zigzag crimp is set in the filaments. Following crimping, the tow is cut to staple and baled for shipping to the textile manufacturer.

Knit-deknitting

Knit-deknit texturing may be used on drawn fibre in order to produce crimp of a knitted-loop shape. In this process a yarn is knitted into a tubular fabric, set in place by means of heat, and then unraveled to produce textured yarn.

Air jet

Air-jet texturing is used with a single type of yarn or with a blend of filament yarns. In the latter case fancy yarn mixtures are obtained. This method of texturing is carried out by feeding a wet yarn or a dry yarn plus a small amount of water into a high-speed jet of air. Yarns textured in such a process contain a large number of very fine filaments, however, increasing the probability of entanglement.

Nylon

Nylon is a generic designation for a family of synthetic polymers, based on aliphatic or semi-aromatic polyamides. Nylon is a thermoplastic silky material that can be melt-processed into fibers, films, or shapes. It is made of repeating units linked by amide links similar to the peptide bonds in proteins. Nylon polymers can be mixed with a wide variety of additives to achieve many different property variations. Nylon polymers have found significant commercial applications in fabric and fibers (apparel, flooring and rubber reinforcement), in shapes (molded parts for cars, electrical equipment, etc.), and in films (mostly for food packaging).

Nylon was the first commercially successful synthetic thermoplastic polymer. DuPont began its research project in 1927. The first example of nylon (nylon 6,6) using diamines on February 28, 1935, by Wallace Hume Carothers at DuPont's research facility at the DuPont Experimental Station. In response to Carothers' work, Paul Schlack at IG Farben developed nylon 6, a different molecule based on caprolactam, on January 29, 1938.

DuPont and the invention of Nylon

DuPont, founded by Éleuthère Irénée du Pont, first produced gunpowder and later cellulose-based paints. Following WWI, DuPont produced synthetic ammonia and other chemicals. DuPont began experimenting with the development of cellulose based fibers, eventually producing the synthetic fiber rayon. DuPont's experience with rayon was an important precursor to its development and marketing of nylon.

DuPont's invention of nylon spanned an eleven-year period, ranging from the initial research program in polymers in 1927 to its announcement in 1938, shortly

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before the opening of the 1939 New York World's Fair. The project grew from a new organizational structure at DuPont, suggested by Charles Stine in 1927, in which the chemical department would be composed of several small research teams that would focus on "pioneering research" in chemistry and would "lead to practical applications". Harvard instructor Wallace Hume Carothers was hired to direct the polymer research group. Initially he was allowed to focus on pure research, building on and testing the theories of German chemist Hermann Staudinger. He was very successful, as research he undertook greatly improved the knowledge of polymers and contributed to science.

In the spring of 1930, Carothers and his team had already synthesized two new polymers. One was neoprene, a synthetic rubber greatly used during World War II. The other was a white elastic but strong paste that would later become nylon. After these discoveries, Carothers' team was made to shift its research from a more pure research approach investigating general polymerization to a more practically-focused goal of finding "one chemical combination that would lend itself to industrial applications".

It wasn't until the beginning of 1935 that a polymer called "polymer 6-6" was finally produced. Carothers' coworker, Washington University alumnus Julian W. Hill had used a cold drawing method to produce a polyester in 1930. This cold drawing method was later used by Carothers in 1935 to fully develop nylon. The first example of nylon (nylon 6,6) was produced on February 28, 1935, at DuPont's research facility at the DuPont Experimental Station. It had all the desired properties of elasticity and strength. However, it also required a complex manufacturing process that would become the basis of industrial production in the future. DuPont obtained a patent for the polymer in September 1938, and quickly achieved a monopoly of the fiber. Carothers died 16 months before the announcement of nylon, therefore he was never able to see his success.

The production of nylon required interdepartmental collaboration between three departments at DuPont: the Department of Chemical Research, the Ammonia Department, and the Department of Rayon. Some of the key ingredients of nylon had to be produced using high pressure chemistry, the main area of expertise of the Ammonia Department. Nylon was considered a “godsend to the Ammonia Department”, which had been in financial difficulties. The reactants of nylon soon constituted half of the Ammonia department's sales and helped them come out of the period of the Great Depression by creating jobs and revenue at DuPont.

DuPont's nylon project demonstrated the importance of chemical engineering in industry, helped create jobs, and furthered the advancement of chemical engineering techniques. In fact, it developed a chemical plant that provided 1800 jobs and used the latest technologies of the time, which are still used as a model for chemical plants today. The ability to acquire a large number of chemists and engineers quickly was a huge contribution to the success of DuPont's nylon project. The first nylon plant was located at Seaford, Delaware, beginning commercial production on December 15, 1939. On October 26, 1995, the Seaford plant was designated a National Historic Chemical Landmark by the American Chemical Society.

Early marketing strategies

An important part of nylon's popularity stems from DuPont's marketing strategy. DuPont promoted the fiber to increase demand before the product was available to the general market. Nylon's commercial announcement occurred on October 27, 1938, at the final session of the Herald Tribune's yearly "Forum on Current Problems", on the site of the approaching New York City world's fair. The "first man-made organic textile fiber" which was derived from "coal, water and air" and promised to be "as strong as steel, as fine as the spider's web" was received enthusiastically by the audience, many of them middle-class women, and made the headlines of most newspapers. Nylon was introduced as part of "The world of tomorrow" at the 1939 New York World's Fair and was featured at DuPont's "Wonder World of Chemistry" at the Golden Gate International Exposition in San Francisco in 1939. Actual nylon stockings were not shipped to selected stores in the national market until May 15, 1940. However, a limited number were released for sale in Delaware before that. The first public sale of nylon stockings occurred on October 24, 1939, in Wilmington, Delaware. 4,000 pairs of stockings were available, all of which were sold within three hours.

Another added bonus to the campaign was that it meant reducing silk imports from Japan, an argument that won over many wary customers. Nylon was even mentioned by President Roosevelt's cabinet, which addressed its "vast and interesting economic possibilities" five days after the material was formally announced.

However, the early excitement over nylon also caused problems. It fueled unreasonable expectations that nylon would be better than silk, a miracle fabric as strong as steel that would last forever and never run. Realizing the danger of claims such as "New Hosiery Held Strong as Steel" and "No More Runs", DuPont scaled back the terms of the original announcement, especially those stating that nylon would possess the strength of steel.

Also, DuPont executives marketing nylon as a revolutionary man-made material did not at first realize that some consumers experienced a sense of unease and distrust, even fear, towards synthetic fabrics. A particularly damaging news story, drawing on DuPont's 1938 patent for the new polymer, suggested that one method of producing nylon might be to use cadaverine (pentamethylenediamine), a chemical extracted from corpses. Although scientists asserted that cadaverine was also extracted by heating coal, the public often refused to listen. A woman confronted one of the lead scientists at DuPont and refused to accept that the rumour was not true.

DuPont changed its campaign strategy, emphasizing that nylon was made from "coal, air and water", and started focusing on the personal and aesthetic aspects of nylon, rather than its intrinsic qualities. Nylon was thus domesticated, and attention shifted to the material and consumer aspect of the fiber with slogans like "If it's nylon, it's prettier, and oh! How fast it dries!".

Production of nylon fabric

While nylon was marketed as the durable and indestructible material of the people, it was sold at almost twice the price of silk stockings ($4.27 per pound of nylon versus $2.79 per pound of silk). Sales of nylon stockings were strong in part due to changes in women's fashion. As Lauren Olds explains: "by 1939 [hemlines] had inched back up to the knee, closing the decade just as it started off". The shorter skirts were accompanied by a demand for stockings that offered fuller coverage without the use of garters to hold them up.

However, as of February 11, 1942, nylon production was redirected from being a consumer material to one used by the military. DuPont's production of nylon stockings and other lingerie stopped, and most manufactured nylon was used to make parachutes and tents for World War II. Although nylon stockings already made before the war could be purchased, they were generally sold on the black market for as high as $20.

Once the war ended, the return of nylon was awaited with great anticipation. Although DuPont projected yearly production of 360 million pairs of stockings, there were delays in converting back to consumer rather than wartime production. In 1946, the demand for nylon stockings could not be satisfied, which led to the Nylon riots. In one case, an estimated 40,000 people lined up in Pittsburgh to buy 13,000 pairs of nylons. In the meantime, women cut up nylon tents and parachutes left from the war in order to make blouses and wedding dresses. Between the end of the war and 1952, production of stockings and lingerie used 80% of the world's nylon. DuPont put a lot of focus on catering to the civilian demand, and continually expanded its production.

Introduction of nylon blends

As pure nylon hosiery was sold in a wider market, problems became apparent. Nylon stockings were found to be fragile, in the sense that the thread often tended to unravel lengthwise, creating 'runs'. People also reported that pure nylon textiles could be uncomfortable due to nylon's lack of absorbency. Moisture stayed inside the fabric near the skin under hot or moist conditions instead of being "wicked" away. Nylon fabric could also be itchy, and tended to cling and sometimes spark as a result of static electrical charge built up by friction. Also, under some conditions stockings could decompose turning back into nylon's original components of air, coal, and water. Scientists explained this as a result of air pollution, attributing it to London smog in 1952, as well as poor air quality in New York and Los Angeles.

The solution found to problems with pure nylon fabric was to blend nylon with other existing fibers or polymers such as cotton, polyester, and spandex. This led to the development of a wide array of blended fabrics. The new nylon blends retained the desirable properties of nylon (elasticity, durability, ability to be dyed) and kept clothes prices low and affordable. As of 1950, the New York Quartermaster Procurement Agency (NYQMPA), which developed and tested textiles for the army and navy, had committed to developing a wool-nylon blend. They were not the only ones to introduce blends of both natural and synthetic fibers. America's Textile Reporter referred to 1951 as the "Year of the blending of the fibers". Fabric blends included mixes like "Bunara" (wool-rabbit-nylon) and "Casmet" (wool-nylon-fur). In

Britain in November 1951, the inaugural address of the 198th session of the Royal Society for the Encouragement of Arts, Manufactures and Commerce focused on the blending of textiles.

DuPont's Fabric Development Department cleverly targeted French fashion designers, supplying them with fabric samples. In 1955, designers such as Coco Chanel, Jean Patou, and Christian Dior showed gowns created with DuPont fibers, and fashion photographer Horst P. Horst was hired to document their use of DuPont fabrics. American Fabrics credited blends with providing "creative possibilities and new ideas for fashions which had been hitherto undreamed of."

Nylon Fiber

Nylon is a manufactured fiber in which the fiber forming substance is a long-chain synthetic polyamide in which less than 85% of the amide-linkages are attached directly (-CO-NH-) to two aliphatic groups.

Fig. Nylon Fiber

Nylon is a synthetic polymer, a plastic, invented on February 28, 1935 by Wallace Carothers at the E.I. du Pont de Nemours and Company of Wilmington, Delaware, USA. The material was announced in 1938 and the first nylon products; a nylon bristle toothbrush made with nylon yarn (went on sale on February 24, 1938) and more famously, women's stockings (went on sale on May 15, 1940). Nylon fibres are now used to make many synthetic fabrics, and solid nylon is used as an engineering material.

Nylon Fiber Production:

The term nylon refers to a family of polymers called linear polyamides. There are two common methods of making nylon for fiber applications. In one approach, molecules with an acid (COOH) group on each end are reacted with molecules containing amine (NH_2) groups on each end. The resulting nylon is named on the basis of the number of carbon atoms separating the two acid groups and the two amines. Thus nylon 6,6 which is widely used for fibers is made from adipic acid and hexamethylene diamine. The two compounds form a salt, known as nylon salt, an exact 1:1 ratio of acid to base. This salt is then dried and heated under vacuum to eliminate water and form the polymer.

In another approach, a compound containing an amine at one end and an acid at the other is polymerized to form a chain with repeating units of (-NH-[CH2]n-CO-)x. If n=5, the nylon is referred to as nylon 6, another common form of this polymer. The commercial production of nylon 6 begins with caprolactam uses a ring-opening polymerization. For a detailed production flowchart, go here.

In both cases the polyamide is melt spun and drawn after cooling to give the desired properties for each intended use. Production of nylon industrial and carpet fibers begins with an aqueous solution of monomers and proceeds continuously through polymerization, spinning, drawing, or draw-texturing.

Characteristics of Nylon Fiber

- Exceptionally strong
- Elastic
- Abrasion resistant
- Lustrous
- Easy to wash
- Resistant to damage from oil and many chemicals
- Can be precolored or dyed in wide range of colors
- Resilient
- Low in moisture absorbency
- Filament yarns provide smooth, soft, long-lasting fabrics
- Spun yarns lend fabrics light weight and warmth

Some Major Nylon Fiber Uses

- **Apparel:** Blouses, dresses, foundation garments, hosiery, lingerie, underwear, raincoats, ski apparel, windbreakers, swimwear, and cycle wear .
- **Home Furnishings:** Bedspreads, carpets, curtains, upholstery

Industrial and Other Uses

Tire cord, hoses, conveyer and seat belts, parachutes, racket strings, ropes and nets, sleeping bags, tarpaulins, tents, thread, mono filament fishing line, dental floss.

Polyester Fiber

A manufactured fiber in which the fiber forming substance is any long-chain synthetic polymer composed of at least 85% by weight of an ester of a substituted aromatic carboxylic acid, including but not restricted to substituted terephthalic units, p(-R-O-CO- C6H4-CO-O-)x and parasubstituted hydroxy-benzoate units, p(-R-O-CO-C6H4-O-)x.

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Fig. Polyester Fiber

Characteristics of Polyester Fiber

1. Strong
2. Resistant to stretching and shrinking
3. Resistant to most chemicals
4. Quick drying
5. Crisp and resilient when wet or dry
6. Wrinkle resistant
7. Mildew resistant
8. Abrasion resistant
9. Retains heat-set pleats and crease
10. Easily washed

Polyester Fiber Properties - Cut Length

Cut lengths available are 32, 38, 44, 51 and 64mm for cotton type spinning and a blend of 76, 88 and 102 mm - average cut length of 88m for worsted spinning. The most common cut length is 38 mm.

For blending with other manmade fibres, spinners preferred 51mm to get higher productivity, because T.M. will be as low as 2.7 to 2.8 as against 3.4 to 3.5 for 38mm fibre. If the fibre legnth is more, the nepping tendency is also more , so a crompromise cutlength is 44 mm. With this cut length the T.M. will be around 2.9 to 3.0 and yarns with 35 to 40% lower imprfections can be achieved compared a to similar yarn with 51 mm fibre. In the future spinners will standardize for 38 mm fibre when the ring spinning speed reaches 25000 rpm for synthetic yarns.

For OE spinning , 32 mm fibre is preferred as it enables smaller dia rotor(of 38mm) to be used which can be run at 80000 to 100000 rpm.

Air jet spinning system uses 38 mm fibre.

Polyester Fiber Properties - Tensile Properties

Polyester fibers are available in 4 tenacity levels.

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1. Low pill fibres- usuall in 2.0 / 3.0 D for suiting enduse with tenacities of 3.0 to 3.5 gpd(grams per denier). These fibres are generally used on worsted system and 1.4 D for knitting
2. Medium Tenacity - 4.8 to 5.0 gpd
3. High Tenacity - 6.0 to 6.4 gpd range and
4. Super high tenacity - 7.0 gpd and above

Both medium and high tenacity fibres are used for apparel enduse. Currently most fibre producers offer only high tenacity fibres. Spinners prefer them since their use enables ring frames to run at high speeds, but then the dyeablity of these fibres is 20 to 25% poorer, also have lower yield on wet processing, have tendency to form pills and generally give harsher feel.

The super high tenacity fibres are used essentially for spinning 100% polyester sewing threads and other industrial yarns. The higher tenacities are obtained by using higher draw ratios and higher annealer temperatures upto 225 to 230 degree C and a slight additional pull of 2% or so at the last zone in annealing.

Elongation is inversely proportional to tenacity e.g

- **Tenacity-----Elongation at Break------T_{10} ValuesLow Pill--**
- 3.0-3.5---------45-55%-------------------1.0-1.5Medium---
- 4.8-5.0---------25-30%-------------------3.5-4.0High-------
- 6.0-6.4---------16-20%-------------------5.2-5.5Super Hi----
- 7.0 plus---------12-14%-------------------6.0 plus------------

The T_{10} or tenacity @ 10% elongation is important in blend spinning and is directly related to blend yarn strength. While spinning 100% polyester yarns it has no significance. Tenacity at break is the deciding factor.

Polyester Fiber Properties - Crimp Properties

Crimps are introducd to give cohesion to the fibre assembly and apart from crimps/ cm. Crimp stability is more important criterion and this value should be above 80% to provide trouble free working. A simple check of crimp stability is crimps/inch in finisher drawing sliver. This value should be around 10 to 11, if lower, the fibre will give high fly leading to lappings and higher breaks at winding. Spin finish also gives cohesion, but cohesion due to crimp is far superior to the one obtained by finish.To give a concrete example, one fibre producer was having a serious problem of fly with mill dyed trilobal fibre. Trilobal fibre is difficult to crimp as such, so it was with great difficulty that the plant could put in crimps per inch of 10 to 11. Dyeing at 130 degrees C in HTHP dying machine reduced the cpi to 6 to 8. Mills oversprayed upto 0.8% did not help. Card loading took place yet fly was uncontrolled, ultimately the fibre producer added a steam chest to take the two temperature to 100degrees plus before crimping and then could put in normal cpcm and good crimp stability. Then the dyed fibre ran well with normal 0.15 to 0.18 % added spin finish.

Polyester Properties - Spin Finish

Several types of spin finishes are available. There are only few spin finish

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manufacturers - Takemoto, Matsumoto, Kao from Japan, Henkel, Schill &Scheilacher, Zimmer & Schwarz and Hoechst from Germany and George A.Goulston from USA. It is only by a mill trial that the effectiveness of a spin finish can be established.

A spin finish is supposed to give high fibre to fibre friction of 0.4 to 0.45, so as to control fibre movement particularly at selvedges , low fibre-metal friction of 0.2 to 0.15 to enable lower tensions in ring spinning and provide adequate static protection at whatever speed the textile machine are running and provide enough cohesion to control fly and lapping tendencies and lubrication to enable smoother drafting.

Spin finish as used normally consists of 2 components - one that gives lubrication / cohesion and other that gives static protection. Each of these components have upto 18 different components to give desired properties plus anti fungus, antibacterial anti foaming and stabilisers.

Most fibre producers offer 2 levels of spin finishes. Lower level finish for cotton blends and 100% polyester processing and the higher level finish for viscose blend. The reason being that viscose has a tendecy to rob polyester of its finish. However in most of the mills even lower spin finish works better for low production levels and if the production level is high, high level spin finish is required if it is mixed with viscose.

For OE spinning where rotor speeds are around 55000 to 60000 rpm standard spin finish is ok, but if a mill has new OE spinning machines having rotors running @80000 rpm, then a totally different spin finish which has a significantly lower fibre - fibre and fibre - metal friction gave very good results. The need to clean rotors was extended from 8 hours to 24 hours and breaks dropped to 1/3rd.

In conclusion it must be stated that though the amount of spin finish on the fibre is only in the range 0.105 to 0.160, it decides the fate of the fibre as the runnability of the fibre is controlled by spin finish, so it is the most important component of the fibre

Effectiveness of spin finish is not easy to measure in a fibre plant. Dupont uses an instrument to measure static behaviour and measures Log R which gives a good idea of static cover. Also, there is s Japanese instrument Honest Staticmeter, where a bundle of well conditioned fibre is rotated at high speed in a static field of 10000 volts. The instrument measures the charge picked up by the fibre sample, when the charge reaches its maximum value, same is recorded and machine switched off. Then the time required for the charge to leak to half of its maximum value is noted. In general with this instrument , for fibre to work well, maximum charge should be around 2000 volts and half life decay time less than 40 sec. If the maximum charge of 5000 and half life decay time of 3 min is used , it would be difficult to card the fibre , especially on a high production card.

Polyester Properties - Dry Heat Shrinkage

Normally measured at 180 degree C for 30 min. Values range from 5 to 8 %. With DHS around 5%, finished fabric realisation will be around 97% of grey fabric fed and with DHS around 8% this value goes down to 95%. Therefore it makes commercial sense to hold DHS around 5%.

L and B colour

L colour for most fibres record values between 88 to 92. "b" colour is a measure of yellowness/blueness. b colour for semidull fibre fluctuates between 1 to 2.8 with different fibre producers. Lower the value, less is the chemicals degradation of the polymer. Optically brightened fibres give b colour values around 3 to 3.5. This with 180 ppm of optical brightner.

Dye Take Up

Each fibre producer has limits of 100 +- 3 to 100+-8. Even with 100+-3 dye limits streaks do occur in knitted fabrics. The only remedy is to blend bales from different days in a despatch and insist on spinning mills taking bales from more than one truck load.

Fused Fibers

The right way to measure is to card 10 kgs of fibre. Collect all the flat strips(95% of fused fibres get collected in flat strips). Spread it out on a dark plush, pick up fused and undrawn fibres and weigh them. The upper acceptable limit is 30mgm /10kgs. The ideal limit should be around 15mgm/10kgs. DUpont calls fused/undrawn fibres as DDD or Deep Dyeing Defect.

Polyester LustrePolyester fibres are available in

- **Bright** : 0.05 to 0.10 % TiO_2
- **Semil dull** : 0.2 to 0.3 % TiO_2
- **Dull** : 0.5 % TiO_2
- **Extra dull** : 0.7% TiO_2 and in optically brightened with normally 180 ppm of OB, OB is available in reddish , greenish and bluish shades. Semi dull is the most popular lustre followed by OB (100 % in USA) and bright.

Polyester Fiber Uses

1. **Apparel**: Every form of clothing
2. **Home Furnishings**: Carpets, curtains, draperies, sheets and pillow cases, wall coverings, and upholstery
3. **Other Uses**: Hoses, power belting, ropes and nets, thread, tire cord, auto upholstery, sails, floppy disk liners, and fiberfill for various products including pillows and furniture

Rayon

Rayon is a regenerated cellulose fiber that is made from natural sources such as wood and agricultural products. It has the same molecular structure as cellulose. The many types and grades of viscose fibers can imitate the feel and texture of natural fibers such as silk, wool, cotton, and linen. The types that resemble silk are often called artificial silk. The fibre is used to make textiles for clothing and other purposes. Viscose can mean:

- A viscous solution of cellulose
- A synonym of rayon
- A specific term for viscose rayon — rayon made using the viscose process

Rayon and its variants

Rayon is produced by dissolving cellulose from wood pulp or other sources, followed by the conversion of this solution back to insoluble fibrous cellulose. Two processes have been developed for this conversion.

Cuprammonium method

Swiss chemist Matthias Eduard Schweizer (1818–1860) discovered that cellulose dissolves in tetraaminecopper dihydroxide. Max Fremery and Johann Urban developed a method to produce carbon fibers for use in light bulbs in 1897. Production of cuprammonium rayon for textiles started in 1899 in the Vereinigte Glanzstoff Fabriken AG in Oberbruch near Aachen. Improvement by J. P. Bemberg AG in 1904 made the artificial silk a product comparable to real silk.

Cuprammonium rayon has properties similar to viscose; however, during its production, the cellulose is combined with copper and ammonia (Schweizer's reagent). Due to the detrimental environmental effects of this production method, cuprammonium rayon is no longer produced in the United States.

Viscose method

English chemist Charles Frederick Cross and his collaborators, Edward John Bevan and Clayton Beadle, patented their artificial silk in 1894. They named their material "viscose" because its production involved the intermediacy of a highly viscous solution. The process built on the reaction of cellulose with a strong base, followed by treatment of that solution with carbon disulfide to give a xanthate derivative. The xanthate is then converted back to a cellulose fiber in a subsequent step.

The first commercial viscose rayon was produced by the UK company Courtaulds Fibres in November 1905. Courtaulds formed an American division, American Viscose (later known as Avtex Fibers), to produce their formulation in the United States in 1910. The name "rayon" was adopted in 1924, with "viscose" being used for the viscous organic liquid used to make both rayon and cellophane. In Europe, though, the fabric itself became known as "viscose", which has been ruled an acceptable alternative term for rayon by the US Federal Trade Commission (FTC).

The viscose method can use wood as a source of cellulose, whereas other routes to rayon require lignin-free cellulose as a starting material. The use of woody sources of cellulose makes viscose cheaper, so it was traditionally used on a larger scale than the other methods. On the other hand, the original viscose process generates large amounts of contaminated wastewater. Newer technologies use less water and have improved the quality of the wastewater. Rayon was produced only as a filament fiber until the 1930s when methods were developed to utilize "broken waste rayon" as staple fiber.

The physical properties of rayon remained unchanged until the development of high-tenacity rayon in the 1940s. Further research and development led to high-wet-modulus rayon (HWM rayon) in the 1950s. Research in the UK was centred on the government-funded British Rayon Research Association.

Industrial applications of rayon emerged around 1935. Substituting cotton fiber in tires and belts, industrial types of rayon developed a totally different set of properties, amongst which tensile strength and elastic modulus were paramount.

Modal

Modal is a type of rayon but made from particularly high-quality cellulose. Two forms are available: "polynosics" and "high wet modulus" (MWM). Modal is used alone or with other fibers (often cotton or spandex) in clothing and household items like pajamas, underwear, bathrobes, towels, and bedsheets. Modal can be tumble dried without damage due to its increased molecular alignment. The fabric has been known to pill less than cotton due to fiber properties and lower surface friction.

High wet modulus rayon (HWM) is a modified version of viscose that is stronger when wet. It also has the ability to be mercerized like cotton. HWM rayons are also known as "polynosic." Polynosic fibers are dimensionally stable and do not shrink or get pulled out of shape when wet like many rayons. They are also wearing resistant and strong while maintaining a soft, silky feel. They are sometimes identified by the 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 tire cord.

Lyocell

The Lyocell process relies on dissolution of cellulose products in a solvent, N-methylmorpholine N-oxide. The process starts with woody sources of cellulose and involves dry jet-wet spinning. It was developed at the now defunct American Enka and Courtaulds Fibres. Lenzing's Tencel is an example of a lyocell fiber.

Related materials

Related materials are not regenerated cellulose, but esters of cellulose.

Nitrocellulose

Nitrocellulose is a derivative of cellulose that is soluble in organic solvents. It is mainly used as an explosive or as a lacquer. Many early plastics were made from celluloid.

Acetate

Cellulose acetate shares many similarities with viscose rayon, and was formerly considered as the same textile. However, rayon resists heat while acetate is prone to melting. Acetate must be laundered with care either by hand-washing or dry cleaning, and acetate garments disintegrate when heated in a tumble dryer. The two fabrics are now required to be listed distinctly on garment labels.

Major fiber properties

Rayon is a versatile fiber and is widely claimed to have the same comfort properties as natural fibers, although the drape and slipperiness of rayon textiles are often more like nylon. It can imitate the feel and texture of silk, wool, cotton and linen. The fibers are easily dyed in a wide range of colors. Rayon fabrics are soft, smooth, cool, comfortable, and highly absorbent, but they do not always insulate body heat, making them ideal for use in hot and humid climates, although also making their "hand" (feel) cool and sometimes almost slimy to the touch.

The durability and appearance retention of regular viscose rayons are low, especially when wet; also, rayon has the lowest elastic recovery of any fiber. However, HWM rayon (high-wet-modulus rayon) is much stronger and exhibits higher durability and appearance retention. Recommended care for regular viscose rayon is dry-cleaning only. HWM rayon can be machine-washed.

Regular rayon has lengthwise lines called striations and its cross-section is an indented circular shape. The cross-sections of HWM and cupra rayon are rounder. Filament rayon yarns vary from 80 to 980 filaments per yarn and vary in size from 40 to 5000 denier. Staple fibers range from 1.5 to 15 denier and are mechanically or chemically crimped. Rayon fibers are naturally very bright, but the addition of delustering pigments cuts down on this natural brightness.

Acrylic fiber

Acrylic fibers are synthetic fibers made from a polymer (polyacrylonitrile) with an average molecular weight of -100,000, about 1900 monomer units. For a fiber to be called "acrylic" in the US, the polymer must contain at least 85% acrylonitrile monomer. Typical comonomers are vinyl acetate or methyl acrylate. DuPont created the first acrylic fibers in 1941 and trademarked them under the name Orlon. It was first developed in the mid-1940s but was not produced in large quantities until the 1950s. Strong and warm, acrylic fiber is often used for sweaters and tracksuits and as linings for boots and gloves, as well as in furnishing fabrics and carpets. It is manufactured as a filament, then cut into short staple lengths similar to wool hairs, and spun into yarn.

Modacrylic is a modified acrylic fiber that contains at least 35% and at most 85% acrylonitrile monomer. The comonomers vinyl chloride, vinylidene chloride or vinyl bromide used in modacrylic give the fiber flame retardant properties. End-uses of modacrylic include faux fur, wigs, hair extensions and protective clothing.

Production

The polymer is formed by free-radical polymerization in aqueous suspension. The fiber

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is produced by dissolving the polymer in a solvent such as N,N-dimethylformamide (DMF) or aqueous sodium thiocyanate, metering it through a multi-hole spinnerette 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. Acrylic fibers are produced in a range of deniers, usually from 0.9 to 15, as cut staple or as a 500,000 to 1 million filament tow. End uses include sweaters, hats, hand-knitting yarns, socks, rugs, awnings, boat covers, and upholstery; the fiber is also used as "PAN" precursor for carbon fiber. Production of acrylic fibers is centered in the Far East, Turkey, India, Mexico, and South America, though a number of European producers still continue to operate, including Dralon and Fisipe. US producers have ended production (except for specialty uses such as in friction materials, gaskets, specialty papers, conductive, and stucco), though acrylic tow and staple are still spun into yarns in the USA. Former U.S. brands of acrylic included Acrilan (Monsanto), and Creslan (American Cyanamid). Other brand names that are still in use include Dralon (Dralon GmbH) and Drytex (Sudamericana de Fibras, S.A.). In the late 1950s Courtaulds Ltd began investigating the production of an acrylic fibre later to be called "courtelle" by a process of solvent polymerisation. Methyl acrylate (6%) and acrylonitrile were polymerised in a 50% solution of sodium thiocyanate to produce a dope ready for spinning into a waterbath to produce "courtelle" fibre in various grades of denier. The sodium thiocyanate solution was reconcentrated and re used. The reaction was a continuous process with about 5% of reactants being recycled. This recycling process resulted in the build up of pollutants in the process as did the recycling of the solvent. A great deal of research in the Chemical engineering laboratory in Lockhurst Lane, Coventry, and on the pre production pilot plant at Little Heath overcame the recycling problems and resulted in the process becoming a commercial success at a new production plant in Grimsby.

Textile uses

Acrylic is lightweight, soft, and warm, with a wool-like feel. It can also be made to mimic other fibers, such as cotton when spun on short staple equipment. Some acrylic is extruded in colored or pigmented form; other is extruded in "ecru", otherwise known as "natural," "raw white," or "undyed." Pigmented fiber has the highest lightfastness. Its fibers are very resilient compared to both other synthetics and natural fibers. Some acrylic is used in clothing as a less expensive alternative to cashmere, due to the similar feeling of the materials. Some acrylic fabrics may fuzz or pill easily, though there are low-pilling variants. Acrylic takes color well, is washable, and is generally hypoallergenic. End-uses include socks, hats, gloves, scarves, sweaters, home furnishing fabrics, and awnings. Acrylic can also be used to make fake fur and to make many different knitted clothes.

As acrylic is a synthetic fiber, the larvae of clothes moths are unable to digest it. However, acrylic fibers that are blended with wool or soiled may be eaten as a consequence of having blended fibers.

Acrylic is the "workhorse" hand-crafting fiber for crafters who knit or crochet; acrylic yarn may be perceived as "cheap" because it is typically priced lower than its natural-fiber counterparts, and because it lacks some of their properties, including softness and propensity to felt. The fiber requires heat to "relax" or set the shape of the finished garment, and it isn't as warm when wet as alternatives like wool. Some hand-knitters also complain that the fiber "squeaks" when knitted, or that it is painful to knit with because of a lack of "give" or stretch in the yarn. On the other hand, it is machine-washable and extremely color-fast. This makes it useful in certain items, like garments for babies, which require constant washing. However it is much more flammable than its natural fiber counterparts, so caution should be used when making items for babies and children.

Microplastic

A team at Plymouth University in the UK spent 12 months analyzing what happened when a number of synthetic materials were washed at different temperatures in domestic washing machines, using different combinations of detergents, to quantify the microfibres shed. They found that acrylic was responsible for releasing nearly 730,000 tiny synthetic particles (microplastics) per wash, five times more than polyester-cotton blend fabric, and nearly 1.5 times as many as pure polyester. Research by ecologist Mark Browne showed synthetic fibre waste over coastlines at a global scale, with the greatest concentration near sewage outflows. Of the man-made material found on the shoreline, 85% were microfibers and matched the types of material (such as nylon and acrylic) used in clothing.

2.5 STUDENT ACTIVITY

1. What is **Natural Fibers**? Explain the **Man made Fibers**?

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2. What is **Textile**? Explain the Classification of **Textile Fibers and Properties of Cotton**?

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2.6 PROPERTIES AND END USES OF THE FIBERS

Fibers and Their Properties

Classification of Fibers

Fibers are broadly classified into natural fibers and man-made fibers:

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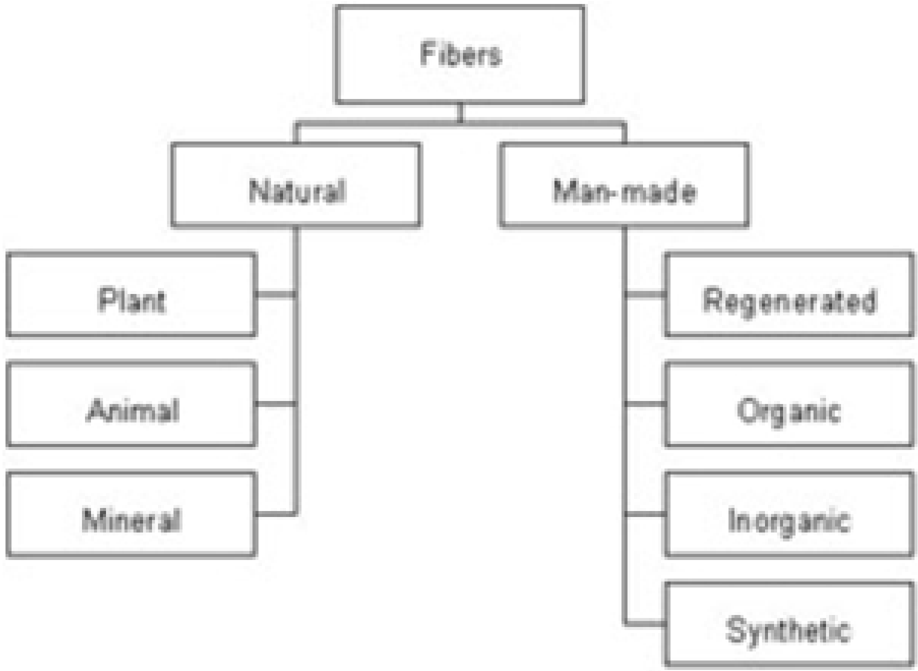

Figure: Classification of Fibers

Natural Fibers

Natural fibers are hair-like threads obtained directly from plants, animals, and mineral sources. Botanically, a natural fiber is a collection of cells having long length and negligible diameter. They are obtained as continuous filaments or discrete elongated pieces similar to thread. They can be spun or twisted into yarn such as cloth and can be converted into nonwoven fabrics, such as paper or felt. An example of a commonly used natural fiber is cotton. Other examples include wool, jute, silk, hair, fur, hemp, and linen.

The characteristics of natural fibers are:

- They can be spun or twisted into yarn to make cloth.
- They can be converted into nonwoven fabrics.
- They are strong and durable.
- They have high moisture absorbing capacity.
- They provide excellent look and feel.
- They are comfortable.

Natural fibers can be classified according to their origin into the following categories:

- Plant fibers
- Animal fibers
- Mineral fibers

Plant Fibers

Plant fibers are fibers that contain cellulose and can be extracted from the bast or stem, seed hair, leaf, or husk of a plant.

Plant fibers may be further categorized into:

- **Bast fibers:** Extracted from the bast or skin surrounding the stem of the plants such as kenaf, roselle, and coir. Due to their high tensile strength compared to other fibers, bast fibers are used for yarn and fabric production. They are durable when used...

Different types fiber & their uses

- **Introduction of Textile Fiber:** A textile is any object woven from natural or synthetic fibers. This also includes fabrics made by the interlacing of yarns or threads by knitting, braiding, netting or felting. The primary natural fibers are from animal sources (wool, silk and hair), vegetable sources (cotton, flax and hemp) and, less commonly, a mineral source (asbestos).

Synthetic fibers have been under development from the late 19th century. The first synthetic fibers are known as regenerated fibers and were of natural origin, such as cotton or wood pulp, dissolved in a solvent and extruded as a filament.

Rayon was first produced in the 1920s and is one of the important early natural based synthetics.

A fiber is defined as a unit of matter with a minimum length of 100 times its diameter, flexible, and capable of being woven. Within the militaries collecting field, the term textile generally means clothing such as jackets, shirts and headwear, but can also include some footwear, web equipment, insignia, maps, flags, and banners.

Animal Source Fibers

- **Wool:** Sheep are the primary source of wool in military textiles. Wool consists mainly of a protein called keratin, which is made up of amino acids. Keratin contains 3 – 4 % sulfur which is an insect attractant. Wool fibers absorb more moisture and accept dyes better than vegetable fibers. Wool is not a strong fiber and weakens considerably when wet.
- **Silk:** Silk is an animal (insect) fiber that is derived from the cocoon filament of the silkworm (Bombyx mori). Because it is basically protein, silk is easily affected by alkalis and various inorganic acids. Like wool, it easily absorbs moisture and will take dyes readily. These dyes, however, are not as light-fast as those on wool. Silk is as strong as a steel wire of the same diameter but is very light sensitive. Therefore, it will break down faster than wool when exposed to ultra-violet rays. The most commonly encountered military artifacts composed of silk are scarves, medal ribbons and escape maps.

Vegetable Source Fibers:

Cotton: Cotton is a vegetable fiber derived from lint on the cotton seed. It can survive in moderate alkaline conditions but is adversely affected by acids. Cotton does not transmit moisture like linen and is very absorbent in its processed state. It is this characteristic which allows cotton to take dyes well. Cotton has a very characteristic

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clockwise twist; for this reason, it is commonly spun in a 'Z' twist.

- **Linen:** Linen is a spun and woven vegetable-based fiber derived from flax stalks and branches. Linen fibers lie close together and are durable. They withstand moderate alkaline conditions because of their cellulose content, but are readily affected by acids. Moisture easily passes through the fibers of linen, causing the material to undergo dimensional and weight changes as well as changes in the overall strength. Linen does not take dye well and is usually left in a bleached or unbleached white state.

Agents of Deterioration

All textiles are deteriorated by light, insects, microorganisms, and air pollution which, alone or together, cause considerable loss of tensile strength and pliability. The oxygen in the atmosphere affects all organic substances to varying degrees. Prolonged exposure to normal atmospheric conditions will cause textiles to weaken and disintegrate. The speed of the deterioration varies according to environment and the nature of the fibers. The main factors that promote the decay of textiles can be categorized into three groups:

- **Organic:** All organic source textiles are subject to attack by molds, mildew and bacteria. The environments that favor the growth of these organisms are as damp heat, stagnant air, and dirty storage conditions. Animal source textiles are particularly susceptible to attack by insects and rodents.
- **Physical:** Excessive heat causes desiccation and embrittlement; exposure to ultra-violet light causes a type of deterioration known as "tendering," as well as the photochemical degradation of susceptible dyes. Environments that are too damp or too dry can lead to mold growth or desiccation of a textile. Improper handling or storage can cause stress on the fabric which leads to tearing or separation.
- **Chemical:** Exposure to gases from adhesives or paints can cause tendering. In some cases, these gases are converted to acids, a primary cause for the deterioration of some textiles. A coat of paint or layer of adhesive in a display case for example, may may produce fumes or "off gas" for months after it appears to be dry. In larger cities, air pollution may be a serious threat to textiles as well as human health.
- **Textile fiber:** Textile fiber is a thin hair like substance that length is thousands time higher than its diameter and it should have certain quality (strength, Flexibility, length)to spun into yarn.

Cotton Fiber

Among the seed and fruit fibres, cotton has grown in stature as the most important textile fiber in the world. In fact, cotton is the backbone and basic foundation of the world's textile trade and industry. Cotton is a natural vegetable fibre produced in the cotton plant in many countries of the world even in Bangladesh also.

Fig: Cotton fiber

Properties of Cotton Fibres

Properties of cotton fiber can be divided into two parts, one is according to physical structure and another is using process.

According to physical structure

Length of cotton fiber

Physically the individual cotton fibres consist of a single long tubular cell. Its length is about 1200-1500 times than its breadth. Length of cotton fibre varies from 16mm to 52 mm depending upon the type of cotton.

1. Indian cotton- 16-25 mm
2. American cotton- 20-30 mm
3. Sea Island- 38-52 mm
4. Egyptian cotton- 30-38 mm

Fineness of cotton fiber

Longer the fibre, finer the fibre in case of cotton fibre. It is expressed in term of decitex and it varies from 1.1 to2.3 decitex.

1. Indian = 2.2-2.3dtex
2. American = 2.1-2.2 dtex
3. Egyptian = 1.2-1.8 dtex
4. Sea Island = 1.0-1.1 dtex

Fineness may be more in case of immature fibre. So it is necessary to express maturity with fineness.

Strength and extension of cotton fiber

Cotton fibre is fairly among natural fibres in relation to tenacity which is 3-3.5g/dtex. Its tensile strength is between wool and silk fibre but disadvantage is low extension at break which is 5-7%.

Elastic properties of cotton

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Recovery from deformation of cotton fibre, yarn or fabric from applied load is very low. By applying heat it can't be achieved. This property can be achieved by -1.Chemical treatment to improve crease recovery, but the problem is the materials become harsher due to chemical treatment 2. blending or mixing of cotton with elastic fibre, e.g. polyester, blend ratio depends on the end use of the fabric. The initial modulus is fairly high=0

5 g/dtex (wool=0.25 g/dtex)

Cross-section

Cross-section of cotton fibre is some what ribbon like. The cell wall is rather thin and the lumen occupies about two-third of the entire breadth and shows up very prominent in polarized light. Fibre cross-section becomes round when mercerized.

Appearance

Cotton fibre is fairly short, fine and creamy white color. Color of the fibre depends on soil of growth. By adding chemicals in the soil, color of the cotton fibre may be varied.

Crimp

Cotton fibre is more or less twisted on its longitudinal axis which cab not be seen from out side is called convolution. The twist in the fibre does not to be continuous in one direction i.e. if at first right direction, then left direction. This property of cotton fibre helps in spinning.

According to using process

Comfortable

Cotton fiber has large amorphous portion and this is why the air can be in and out through cotton fiber. So, the fabric made by cotton fiber is quite comfortable to use.

Soft Hand

Cotton fiber is too much regular fiber and if properly ginned; this fibre can be the best soft hand feeling fibre amongst the others.

Absorbent

Cotton fiber has high absorbency power and this is why this fiber can be died properly and without any harassment.

Good Color Retention

If the printing is applied on cotton fiber, it seems it doesn't spread the color outside the design. So printing efficiency is good on cotton fibre.

Machine Washable & Dry Cleanable

It is seen that some fibers can't be dried or washed due to it's sensitivity and weak fastness properties but in case of Cotton fiber you will have large number of options to choose. You can easily wash the cotton made fabric by machines and even you will be able to dry this fiber by using electronic drier.

Good Strength

If you want to seek an average strength which might be enough for you; then cotton fiber can be your ultimate choice. The strength of cotton fiber is quite good.

Cotton Fibre Drapes Well

The drape-ability of cotton fibre is awesome. You can use the cotton fibre made fabric in any kind of wear which needs more flexibility and drapes.

Sewing & Handling Is Easy

The sewing efficiency on Cotton made fabric is easier and comfortable than other fiber. This is why the demand of cotton made fabric is higher in all over the world.

Uses of Cotton Fiber

Cotton fiber is a versatile fibre which has wide variety of uses. But the Cotton fibre is mostly used on the Apparel Industry to make the wearing cloth like Sweaters, Skirts, Shirts, Swimwear, Kids wear, Blouses, Pants, Hosiery and to make other type of dresses.

Groundnut protein fiber, its properties, and end use

The natural protein fibers Silk and Wool possess so many attractive properties that they have always served as quality fibers in the textile industries. Similarly the natural plant fibers like Cotton, Flax, and Ramie etc. have established their own importance in the textile industries. But nowadays regenerated fibers are getting importance in the textile industries like Viscose, Tencel, Modal, Casein, Soybean fiber etc. In the coming years, these fibers are going to occupy the leading positions in the textile manufacturing. As these fibers are having both the properties of natural and synthetic fibers, they are going to have an added advantage. They can easily be blended with both natural and synthetic fibers.

Vegetable protein fibers and groundnuts

The proteins from which these animal fibers are made come, in the first place, from proteins in the plants that are eaten by animals as food. These plant proteins differ from animal proteins in the detailed structure of their molecules. But all proteins are basically similar in chemical design. All protein molecules are in the form of long threads of atoms. Plant proteins, as well as animal proteins, are therefore able to satisfy the first requirement of a fiber-forming material.

In 1935, Prof Astbury and Prof Chibnall gave an idea to ICI, the UK that fibers can be made by dissolving vegetable proteins in urea and extruding the solution through spinnerets into coagulating baths. The regenerated protein fibers made in the mid-twentieth century were basically developed as a substitute for wool. For the production of protein fiber, the main emphasis was given to the commercial availability and their usefulness for the textile purpose. Theoretically, any protein containing substance may serve as a starting material, and the protein may be extracted from it.

There are four proteins, which are more important as the source for fiber formation.

1. Casein fiber from milk.
2. Zein fiber from maize.
3. Soya fiber (glycinin) from
4. Groundnut fiber (arachins) from groundnuts.
5. Ardil from

One of the most likely sources of vegetable protein for fiber production was groundnuts, which grow as a staple product in many of the hot, humid regions of the world.

Groundnuts (peanuts, monkey nuts) are used in large quantities as a source of the arachis oil required for making margarine. The meal remaining after removal of the oil contains a high proportion of protein. This protein was regarded as a potentially suitable source of vegetable protein. The nuts contain around 25 % protein and can be good and can be good and cheap resources for protein fiber.

Experiments were carried out and a process was developed for making the groundnut protein fiber which became known as 'Ardil'. The fiber was first made at Ardeer in Scotland. Commercial production started in 1951.

Production of groundnut fiber

Groundnuts are cultivated in India, China, West Africa, and southern states of U.S.A. After harvesting, the nuts are shelled or decorticated. The red skins are removed from the shelled nuts, together with foreign matter such as small stones and nails.

There are five main steps to produce Groundnut fiber.

1. **Extraction of oil to obtain oil-free meal:** The nuts, which contain about 50 % of oil, are crushed and pressed. About 80% of the available oil is squeezed out, leaving the oily groundnut meal which is reduced in breaker rolls and passed through flaking rolls. The thin flakes pass via a series of buckets on an endless chain into an extraction plant. As they pass through the plant, the buckets of the meal are subjected to a thorough washing with a solvent (Hexane) which removes the remainder of the Arachis oil.
2. **Extraction of protein:** The extracted meal is heated under low pressure in steam jacketed pans to remove residual solvent. It is then cooled, screened, weighed and bagged.

This special technique for removing oil from groundnut meal was devised to provide protein suitable for fiber production. The groundnut protein is extracted from the meal by dissolving it in caustic soda solution. The residue after extraction is a valuable cattle food. Then acidification of the protein solution precipitates the protein, which is the raw material from which fiber is spun.

3. **Preparation of spinning solution:** The spinning solution is prepared by dissolving the extracted protein in aqueous urea, ammonia, caustic soda and solutions of detergents. Caustic soda is used for dissolution. It is allowed to mature under controlled condition for 24 hours. During the maturation, the viscosity of the solution increases and attains the spinning characteristics. The solids content of the protein is between 12 -30 %.
4. **Fiber formation:** Groundnut fiber is formed by the wet spinning method. The solution of groundnut protein is filtered and pumped to spinnerets, through which it is extruded at a constant rate into an acid coagulating bath. The spinneret holes are typical of 0.07 – 0.10 mm diameter.

The coagulating liquor consists of a solution containing sulphuric acid, sodium sulfate, and auxiliary substances. It is maintained at a temperature between 12-40 deg c.

5. **After treatments:** As the filament is being spun, it is stretched to increase the alignment of the protein molecule. It coagulates to a filament that is weak and flabby when wet and brittle when dry. At this stage, the filament dissolves easily in dilute saline solution and in dilute acid and alkali. After leaving the coagulating bath it is treated with formaldehyde to harden and insolubilize it, and it is then dried and cut into staple fiber.

Properties of groundnut fiber

Table 1: Properties of groundnut fiber and its comparison with other major fiber

Properties	Groundnut	Silk	Wool	Cotton
Tenacity, g/den	0.7-0.9	1-1.5	1.5-2.0	2-5.5
Elongation ,%	40-60	25-45	25-40	6-10
Density, gm/cm3	1.31	1.34-1.38	1.33	1.50-1.54
Moisture regain, %	12-15	11.0	14-16	9
Acid resistance	Excellent	Excellent	Excellent	Bad
Alkali resistance	Bad	Good	Bad	Excellent
Resistance to moth/fungus	Resistance to fungus but not to moth	Resistance to fungus but not to moth	Resistance to fungus but not to moth	Resistance to moth but not to fungus
Refractive index	1.53	1.54	1.54	1.53
Flammability	Burns very slowly	Burns	Burns slowly	Burns

Groundnut fiber is having a circular cross-section and smooth, slightly striated surface. It is having tensile strength of 8-12 kg/mm2 (11,000-14,000 ib/in2). It does not soften or melt on heating. It chars at 250 deg c. It is degraded by sodium hypochlorite and sodium chlorite bleaches. Good resistance to organic solvents. Maybe dry cleaned without difficulty.

Groundnut protein fibers are generally similar to wool in that they are protein in structure. They do not have the rough scaly surface of wool fibers and do not undergo felting in the way that wool does.

Groundnut protein molecules carry many side chains, and they cannot pack so closely together as the molecules of silk. Groundnut protein yields a relatively weak fiber, which is much more sensitive to moisture than wool.

The blending of groundnut fiber: One of the outstanding characteristics of groundnut protein fiber is soft, wool-like handle. The price of groundnut protein fiber is half the cost of wool fiber. And it is used largely as a diluent fiber which provides wool-like characteristics at low cost. It is used in various worsted units along with wool and polyester. And it is also used with cotton and viscose in various proportions.

Chemical processing of groundnut fiber

Groundnut protein fiber has different physical and chemical construction from natural protein fiber, care is taken in the following steps.

1. **Scouring:** During scouring the alkali concentration should be less as compared to other textile fibers and the temperature should be less than 98 deg c. Wool type scouring conditions are suitable for 100 % groundnut protein fibers and kier type boiling should be avoided while processing groundnut blended fabrics.
2. **Bleaching:** It should be borne in mind that Sodium Hypochlorite and Sodium Chlorite cannot be used for bleaching of groundnut protein fiber because it causes degradation. Therefore Hydrogen peroxide is the preferred bleaching agent. The dosage has to be decided depending on the quality of Groundnut fiber.
3. **Dyeing:** Groundnut protein fiber is dyed with the same dyes used for dyeing of wool fiber like Acid dyes, Metal complex dyes, Chrome dyes and few Reactive dyes. Dyes are selected according to end uses of fibers and dyeing fastness. The dyeing method is just like dyeing of wool fiber. But the differences in protein structure result in different individual characteristics. In general, the affinity for dyes is higher than that of wool. It can be dyed in form of loose fiber, tops, yarn hank and fabric (both knitted and woven).

Uses of groundnut protein fiber (GPF)

In the 1950s ardil fiber (groundnut protein fiber) was intensively marketed for industrial and domestic uses. Dresses, suits and pajamas were promoted with the slogan 'Happy families wear clothes that contain Ardil'. Ardil fibers were used as garments, carpets or upholstery. Ardil/Wool blends were used for sweaters, blankets, underwear, carpets and felt. Blends with cotton were used for sports shirts, pajamas, dress fabrics, and blends with rayon for costume and dress fabrics, tropical clothing, sports shirts, and carpets. In course of time, these fibers were subsequently overshadowed by the successful synthetic fibers such as nylon and have been largely forgotten. However, presently more eco-friendly and biodegradable material has been given importance and so the manufacture of these fibers again getting momentum. Groundnut fiber is more commercialized now and it is expected that others will also follow.

2.7 SUMMARY

The use of natural fibres for textile materials began before recorded history. The oldest indication of fibre use is probably the discovery of flax and wool fabrics at excavation sites of the Swiss lake dwellers (7th and 6th centuries BCE). Several vegetable fibres were also used by prehistoric peoples. Hemp, presumably the oldest cultivated fibre plant, originated in Southeast Asia, then spread to China, where reports of cultivation date to 4500 BCE. The art of weaving and spinning linen was already well developed in Egypt by 3400 BCE, indicating that flax was cultivated sometime before that date. Reports of the spinning of cotton in India date back to 3000 BCE. The manufacture of silk and silk products originated in the highly developed Chinese culture; the invention and development of sericulture (cultivation of silkworms for raw-silk production) and of methods to spin silk date from 2640 BCE.

With improved transportation and communication, highly localized skills and arts connected with textile manufacture spread to other countries and were adapted to local needs and capabilities. New fibre plants were also discovered and their use explored. In the 18th and 19th centuries, the Industrial Revolution encouraged the further invention of machines for use in processing various natural fibres, resulting in a tremendous upsurge in fibre production. The introduction of regenerated cellulosic fibres (fibres formed of cellulose material that has been dissolved, purified, and extruded), such as rayon, followed by the invention of completely synthetic fibres, such as nylon, challenged the monopoly of natural fibres for textile and industrial use. A variety of synthetic fibres having specific desirable properties began to penetrate and dominate markets previously monopolized by natural fibres. Recognition of the competitive threat from synthetic fibres resulted in intensive research directed toward the breeding of new and better strains of natural-fibre sources with higher yields, improved production and processing methods, and modification of fibre yarn or fabric properties. The considerable improvements achieved have permitted increased total production, although natural fibres' actual share of the market has decreased with the influx of the cheaper, synthetic fibres requiring fewer man-hours for production.

Classification A nd Properties: Natural fibres can be classified according to their origin. The vegetable, or cellulose-base, class includes such important fibres as cotton, flax, and jute. The animal, or protein-base, fibres include wool, mohair, and silk. An important fibre in the mineral class is asbestos.

The vegetable fibres can be divided into smaller groups based on their origin within

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the plant. Cotton, kapok, and coir are examples of fibres originating as hairs borne on the seeds or inner walls of the fruit, where each fibre consists of a single, long, narrow cell. Flax, hemp, jute, and ramie are bast fibres, occurring in the inner bast tissue of certain plant stems and made up of overlapping cells. Abaca, henequen, and sisal are fibres occurring as part of the fibrovascular system of the leaves. Chemically, all vegetable fibres consist mainly of cellulose, although they also contain varying amounts of such substances as hemicellulose, lignin, pectins, and waxes that must be removed or reduced by processing.

Fig. Rope made from sisal.

The animal fibres consist exclusively of proteins and, with the exception of silk, constitute the fur or hair that serves as the protective epidermal covering of animals. Silk filaments are extruded by the larvae of moths and are used to spin their cocoons.

With the exception of mineral fibres, all natural fibres have an affinity for water in both liquid and vapour form. This strong affinity produces swelling of the fibres connected with the uptake of water, which facilitates dyeing in watery solutions.

Unlike most synthetic fibres, all natural fibres are nonthermoplastic; that is, they do not soften when heat is applied. At temperatures below the point at which they will decompose, they show little sensitivity to dry heat, and there is no shrinkage or high extensibility upon heating, nor do they become brittle if cooled to below freezing. Natural fibres tend to yellow upon exposure to sunlight and moisture, and extended exposure results in loss of strength.

All natural fibres are particularly susceptible to microbial decomposition, including mildew and rot. Cellulosic fibres are decomposed by aerobic bacteria (those that live only in oxygen) and fungi. Cellulose mildews and decomposes rapidly at high humidity and high temperatures, especially in the absence of light. Wool and silk are also subject to microbial decomposition by bacteria and molds. Animal fibres are also subject to damage by moths and carpet beetles. Termites and silverfish attack cellulose fibres. Protection against both microbial damage and insect attacks can be obtained by chemical modification of the fibre substrate; modern developments allow treatment of natural fibres to make them essentially immune to such damage.

2.8 GLOSSARY

Braid Angle : The acute angle measured from the axis of the fabric or rope to a braiding yarn.

Braided Fabric : A narrow fabric made by crossing a number of strands diagonally so that each strand passes alternately over or under one or more of the other strands.

Braiding : The interwinding of three or more strands to make a cord or narrow fabric.

Breaking Tenacity : The tensile stress at rupture of a specimen expressed as Newtons per Tex (cN/tex).

Broadcloth : A fabric so named because it is woven in widths exceeding 29 inches.

Broad Goods : Woven fabrics 18 inches or more in width.

Broken End : A broken, untied warp yarn in a fabric. Broken ends can result from: slubs, knots, improper shuttle alignment, shuttle hitting the warp shed, excessive warp tension, faulty sizing, and rough reeds, heddles, dropwires, or shuttles.

Broken Pick : A broken filling yarn in a fabric. Broken picks can result from: excessive shuttle tension, weak yarn, or filling coming in contact with a sharp surface.

Wether Wool : Wether wool is the one obtained from the sheep older than fourteen months. The shearing is not done for the first time and in fact these fleeces are obtained after the first shearing. These fleeces contain much soil and dirt.

Pulled Wool : Pulled wool is taken from animals originally slaughtered for meat. The wool is pulled from the pelt of the slaughtered sheep using various chemicals. The fibers of pulled wool are of low quality and produce a low-grade cloth.

Dead Wool : This is the wool obtained from the sheep that have died of age or accidentally killed. This type of wool fiber known should not be confused for pulled wool. Dead wool fiber is

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decidedly inferior in grade; it is used in low-grade cloth.

Cotty Wool : This type of wool is obtained from the sheep that are exposed to severe weather. As discussed; the severe weather conditions hamper the qualities of the fleece obtained. The cotty wool is of a poor grade and is hard and brittle.

Cabled Yarn : A yarn formed by twisting together two or more plied yarns.

Cabled Twist : A construction of thread, yarn, cord, or rope in which each successive twist is in the same direction opposite the preceding twists; i.e. an S/Z/S, or Z/S/Z construction.

Calender : A machine used in finishing to impart a variety of surface effects to fabrics. A calender essentially consists of two or more heavy rollers, sometimes heated, through which the fabric is passed under heavy pressure.

Calendering : A mechanical finishing process for fabrics used to produce special effects, such as high luster, glazing, moiré, and embossed effects.

Carbon Fiber : A high-tensile fiber or whisker made by heating rayon or polyacrylonitrile fibers or petroleum residues to appropriate temperatures. Fibers may be 7 to 8 microns in diameter and more than 90% carbonized.

Cloth : A generic term embracing all textile fabrics and felts. Cloth may be formed out of any textile fiber, wire, or material.

Coated Fabric : A fabric to which a substance such as lacquer, plastic, resin, rubber, or varnish has been applied in firmly adhering layers to provide certain properties, such as water impermeability.

Coating : The application of a semi-liquid material such as rubber, polyvinyl chloride, or polyurethane to one or both sides of the textile material. Once the coating has dried (cured) it forms a bond with the fabric.

Color Abrasion : Color changes in localized areas of a garment resulting from differential wear.

Colorfastness : Resistance to fading, i.e. the ability of a dye to retain its color when the dyed or printed textile material is exposed to conditions or agents such as light, perspiration, atmospheric gases, or washing that can remove color.

Distributed feedback (DFB) : A type of laser using an internal grating to reduce line width of the laser that may be used for analog applications, e.g., AM/FM/DWDM applications.

Duplex transmission : Transmission in both directions, either one direction at a time (half duplex) or both directions simultaneously (full duplex).

Dynamic range : For an optical instrument, defined as the ratio (in dB) of the smallest signal that can be observed at a specified wavelength separation in the presence of a strong, nearly-saturating signal.

E-band : The "extended" DWDM transmission band that uses the 1360 to 1460 nm wavelength range.

Electromagnetic interference (EMI): The frequency spectrum of electromagnetic radiation that extends from subsonic frequency to X-rays. This term should not be used instead of the term RFI.

Electro-optical switch : A solid-state optical switch with no moving parts and a very fast response time.

End finish : Surface condition at the optical conductor face.

End separation loss : The optical power loss caused by distance between the end of a fiber and a source, detector, or another fiber.

Erbium-doped fiber amplifier (EDFA): An optical amplifier that uses active erbium doped fiber and a pump source (laser) to boost or amplify the optical signal.

Etalon : Used in wavelength lockers, the etalon is a Fabry-Perot filter paired with a beamsplitter cube.

Ethernet : A data communications protocol originally developed for premises and local access networks (IEEE 802.3) operating at speeds from 10 Mbps to 10 Gbps. It was originally developed for peer-to-peer communications using shared media over relatively short distances. Ethernet features variable length packets that allow data to be sent with less overhead.

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Excess Loss : The amount of light lost in a coupler, beyond that inherent in the splitting to multiple output fibers.

Extinction Ratio : The ratio of the low or OFF optical power level to the high or ON optical power level.

Extrinsic Loss : Loss caused by imperfect alignment of fibers in a connector or splice such as lateral offset, angular misalignment, end separation, and end finish. Generally synonymous with insertion loss.

Eye Pattern : A diagram that shows the proper function of a digital system. The openness of the eye relates to the Bit Error Rate (BER) that can be achieved.

Fabry-Perot (FP) : A standard laser diode consisting of a semiconductor cleaved on each end forming a resonant chamber to create the lasing effect. Used in digital applications.

Fabry-Perot interferometer : An optical cavity similar to a laser but without the laser gain medium. It consists of two partially-transparent mirror aligned to be parallel so that they bounce light back and forth. Interference effects select wavelengths that resonate within the cavity.

Fall Time : Also called turn-off time. The time required for the trailing edge of a pulse to fall from 90% to 10% of its amplitude; the time required for a component to produce such a result.

2.9 REVIEW QUESTIONS

1. Understanding the **Natural Fibers.**
2. What is Animal sources **fiber?**
3. How to Use Plant fibers.
4. What are the different types of Natural fiber composites?
5. What is Nanocomposites?
6. Discuss the Properties of Cotton Products.
7. What kind of Cotton Ginning?
8. What are the various functions a Tussah silk?
9. Uses of Bombyxmori silk.
10. What is Jute trade?
11. How To Know What is Hemp?

12. What is Nylon?
13. What Is **Polyester Fiber Properties?**
14. Different types fiber & their uses.

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UNIT

3

YARN AND ITS TYPES

STRUCTURE

3.1 LEARNING OBJECTIVE

After studying this unit you should be able to:

- Describe the technology for modify of Classifications of Textile Yarn.
- Given the meaning and significance of Twist of Yarn
- Describe the Common materials used to make Yarn Count.
- The importance of Yarn Count Variation.
- Give meaning and significance of Spinning Yarn.
- Describe the Spinning (textiles).
- Explain the meaning and definition of Spinning (polymers).
- Describe the main responsibilities of a Mechanical for Cotton.

3.2 INTRODUCTION

Every day we use things made with textile yarn. Think about the shirt you wear and the carpet you walk on. Have you ever thought about how that yarn is made? Textile yarn is a strand of natural or synthetic fibers or filaments. A fiber is a small short piece of hair. A filament is a long strand of a single substance. In textile yarn, individual fibers or filaments are wound together to make threads.

Textile yarn can be made with natural fibers from substances such as wool from sheep, silk from silkworms, or cotton and linen from plants. It can also be made with synthetic, or man-made, fibers created from a variety of substances like nylon, acrylic, and polyester.

The process of making yarn is called spinning. Yarn can be spun by machine or by hand. Yarn used for weaving tends to have a tight twist, smooth surface, and lots of lengthwise strength. Yarn for knitting has a looser twist.

Fig. Brightly colored cotton yarn used for weaving. The surface of this yarn is tight and smooth.

Many specific production methods result in an endless variety of yarn. Textile yarn is made in a global industry that involves many specialized technical terms. We can't cover them all here, but for now, let's explore basic classifications and a few types of yarn.

Classifications of Textile Yarn: All textile yarn is classified according to structure, or how they are made. In general, there are three basic classifications. Let's look at each of them.

- Staple fiber yarns are made of many short staple fibers that are wound together to make yarn. This is the most basic classification of yarn. Most staple fiber yarns are made of natural materials.
- Ply yarns are made of one or more strands of staple fiber yarns. A single ply yarn is a single strand of staple fibers held together by twisting. Two- and three-ply yarns are made of two or three single yarns twisted together. Multiple-ply yarns are used for fabrics that might require more strength or fabrics that need a desired surface effect.
- Filament yarn is made of one or more continuous strands that run the entire length of the yarn. These are much longer than staple fibers. Silk is the only natural filament yarn. Most filament yarns tend to be made from synthetic materials created by mechanical or chemical processes.

CLASSIFICATION OF YARN: The yarn can be classified in two main categories:

1- Spun or staple yarn

2- Filament yarn

- **Spun yarn:** The yarn made of staple fibres by twisting together is called spun or staple yarn.

It can be classifies in various sub categories according to different bases:

According to the number of plys: on the basis of the number of ply, the yarn can be classified into two categories:

a) **Single ply yarn:** The spun or staple yarn having only one ply is called single ply yarn.

b) **Multi-plys yarn:** The spun or staple yarn consisting of more than one ply twisted together or grouped together only is called multi-plys yarn.

According to the direction of the twist: On the basis of the direction of twist the spun yarn can be classified into three categories:

1- S – twist yarn

2- Z – twist yarn

3- Zero twist or twist less yarn

1- **S – twist yarn:** Spun or staple yarn twisted in clock wise direction is called S – twist yarn. Inclination angle of fibres in this yarn makes the shape like S(English alphabet letter).

2- **Z – twist yarn:** Spun or staple yarn twisted in anti-clock wise direction is called Z – twist yarn. Inclination angle of fibres in this yarn makes the shape like Z(English alphabet letter).

3- **Zero-twist or twist less yarn:** This yarn is made by the wrapping of the soluble filament with untwisted staple fibres. Hot water soluble filaments are used for wrapping. After weaving, these filaments are dissolved in hot water during processing. Thus fabric having spun yarn looks like twist less therefore, it is called zero twist yarn.

According to the degree of the twist: On the basis of the degree of twist , the spun yarn can be classified in three categories:

1. **Low twist yarn:** This type of yarn contains less degree of the twist than standard. It has bulkiness and soft feel. It posses less strength than normal twist yarn. It shows poor lustre and less clearty in the structure. It looks coarser than normal twist yarn. Pilling properties of fabrics made of this yarn are poor.
2. **Normal twist yarn:** This type of yarn has a normal twist as per spinning norms and specification.
3. **High twist yarn:** This type of yarn contains a higher degree of twist than standard. This yarn has a rough feel. This yarn increases the clarity of the texture of the fabric. It posses higher strength than normal twist yarn. It shows good lustre in comparison of normal twist yarn. Yarn looks finer than normal twist yarn. It has better pilling properties.

According to the spinning process used: According to the spinning technology used, the spun yarn can be classified into two groups:

1- **Ring frame yarn:** The yarn being spun by the ring frame machine is called ring frame yarn.

It can be further divided in the following categories:

a) **Carded yarn:** In this yarn ordinary carding process is done and the yarn is manufactured on the ring frame machine. This yarn has short staple fibres in it. It contains dirt, broken seeds too. It has poor strength and yarn regularities.

b) **Super carded yarn:** This yarn is produced through special carding process and the yarn is manufactured on the ring frame machine. This yarn contains less dirt, broken seeds, and yarn regularities in comparison of carded yarn. It shows better strength and lower hairiness than carded yarn.

c) **Semi-combed yarn:** In this type of yarn, the combing process is done partially. The yarn is manufactured on the ring frame machine. Short fibres, dirt and broken seeds are removed partially from the yarn. Better evenness, hairiness and strength are achieved in this yarn.

d) **Fully combed yarn:** In this type of yarn, perfect combing process is adopted. The yarn is made on ring frame yarn. Most of the short fibres, dirt and broken seeds are eliminated from the yarn. This yarn shows excellent strength, and evenness. It has low hairiness in it. It shows good lustre and soft feel.

e) **Super combed yarn:** In this type of yarn special combing process is adopted. The yarn is manufactured on the ring frame machine. In this yarn, short fibres and dirt are removed completely. Broken seeds are removed upto optimum level. Fibres are straightened upto maximum level. It has excellent strength, evenness and hairiness level. This yarn contains minimum yarn irregularities.

f) **Compact yarn:** A special compact spinning device in the ring frame is used to manufacture this type of yarn. This yarn show the best strength, evenness,lurte and feel among all spun yarns. It has no short fibres and dirt. It has the best level of hairiness in it. It has the lowest level of irregularities among all spun yarns.

2- **Open end yarn:** This yarn is manufactured on an open-end machine(rottor spinning machine). The yarn is directly spun from sliver obtained from carding. Many processes of spinning are bypassed in this method of producing the yarn. Therefore yarn obtained from this process is cheaper than ring frame yarn. This type of yarn contains short fibres in it. It has poor strength. It contains more dirt and broken seeds than any ring frame spun yarn having the same mixing of fibres. It shows the poor level of hairiness, lustre and hand feel. This type of yarn contains many irregularities.

- Low twist yarn
- High twist yarn
- Normal twist yarn

Filament yarn: "The yarn consisting of long continuous filaments or fibres either twisted or only grouped together is called filament yarn". It may be man-made or synthetic both.

Filament yarns can be classified as follows:

1. Monofilament yarn
2. Multi-filament yarn

- **Monofilament yarn:** “The yarn consisting of only one long continuous filament is called monofilament yarn”. It is generally has the single coarse filament in it. This filament has good strength normally.
- **Multi-filament yarn:** “The yarn having more than one long continuous filament together is known as multi-filament yarn”. More than one filaments are grouped together. These filaments may be twisted or punched to prevent the fraying of filaments. Some times filaments are grouped together only.

The multifilament yarns further can be classified as follows:

a) **Twisted filament yarn:** The yarn consisting of more than of long continuous filaments grouped together and having the twist to stop the fraying of filaments is called twisted filament yarn.

b) **Rotto filament yarn:** The yarns consisting of more than one long continuous filaments grouped together and having punches in length at a regular interval of distance to prevent the fraying of filaments is called rotto yarn.

c) **Zero-twist filament yarn:** The yarn consisting of more than one long continuous filaments grouped together only is called zero-twist or twist less filament yarn.

Novelty yarn: It is typically consists of two or more stands. These yarns are produced to provide decorative surface effects. Based on the purpose, each strand is referred to as the base/core, effect, or binder. The base/core strand provides the structure and strength.

The effect strand creates decorative detail such as knots and loops. The binder is used to tie the effect yarn to the base yarn if the binding is necessary.

There is a wide variety of novelty yarns that are produced using different techniques and types of fibres and strands. The terminology as well as the classification for novelty yarns varies considerably. Some of the commonly used novelty yarn categories are included in this section.

- **Slub Yarn:** The yarn having fixed size thick places at regular interval of distance is called slub yarn. It may be either single ply or multi-plys yarn.
- **Flock/flake yarn:** “The yarn having small tufts of different coloured fibres added at intervals is called flock/flake yarn”. These tufts may be easily pulled out. Flock/flake yarns are generally single yarns.
- **Nub, knot, and spot yarn:** The plys yarn in which the effect yarn is twisted around the base yarn to produce a thicker area or a bump is called nub, knot or spot yarn.
- **Bouclé and loop yarn:** The plys made by using three sets of yarns – base or core yarn, effect yarn, and tie yarn and having the looped effect around the base or core yarn is called boucle or loop yarn. In this yarn, the effect yarn is tied with core yarn with help of binder yarn.
- **Spiral and corkscrew yarn:** These are ply yarns, in which one ply is soft and thick and the other is fine.
- **Chenille yarn:** These are pile yarns that are often made by slitting leno weave fabrics into narrow strips in the warp direction.

- **Textured yarn:** These are made of fully drawn filament fibres with a changed surface, shape and texture developed by using the new spinning techniques. Nylon and polyester are two main fibres that are textured. Textured yarns provide many variations in fabric properties. There are two main types of textured yarns:
- **Stretch yarn:** It is manufactured by using one of the following methods.

1. By using special heat setting treatment to thermoplastic filament fibres such as nylon and polyester
2. From elastomeric fibres.
3. From bi-component fibres
4. From bi-constituent fibres.
5. From chemically treated natural fibres.

- **Bulk Yarns:** These are softer and much pliable then tightly constructed twisted yarns. Bulk yarns are also have a better cover. They create a less transparent fabrics and are of two types:

1. High bulk yarns
2. Loop-bulk or airjet yarns

- **Hollow yarn (air rich yarn):** This yarn is made of staple fibers. Some quantity of PVA fibers is added with the main content. this PVA content is soluble in hot water and is eliminated completely after processing. Thus the hollow space (air space) is created in the yarn. this yarn becomes softer. the moisture absorbency of yarn is also increased.

3.3 TWIST OF YARN

Twisting, in yarn and rope production, process that binds fibres or yarns together in a continuous strand, accomplished in spinning or playing operations. The direction of the twist may be to the right, described as Z twist, or to the left, described as S twist.

Single yarn is formed by twisting fibres or filaments in one direction. Ply yarn is made by twisting two or more single yarns together, usually by combining singles twisted in one direction with a ply twist in the opposite direction. Twine, cord, or rope can be made with a cable twist, each twist in the opposite direction of the preceding twist (S/Z/S or Z/S/Z), or with a hawser twist, the single yarns and the first ply twist in one direction and the second ply twist in the opposite direction (S/S/Z or Z/Z/S). The number of turns per unit of length in a yarn affects the appearance and durability of fabric made from that yarn. Yarns used for soft-surfaced fabrics have less twist than those used for smooth-surfaced fabrics. Yarns made into crepe fabrics have maximum twist.

Twist is the spiral arrangement of the fibres around the axis of the yarn. The twist binds the fibres together and also contributes to the strength of the yarn. The amount of twist inserted in a yarn defines the appearance and the strength of the yarn. The number of twists is referred to as turns per inch.

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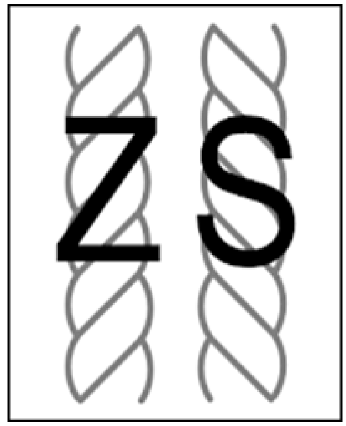

Yarn twist

There are different definitions given to twist of the yarn. Some of the definitions given are as follows:

Yarn twist is defined as the spiral deposition of the components of a twist is the measure of the spiral turns given to a yarn in order to hold the constituent fibres or threads together – Skinkle.

When a strand is twisted the component fibres tend to take on a spiral formation, the geometric perfection of which depends on their original formation – Morton.

Twist may be defined as the rotation about the yarn axis of any line drawn on the yarn which was originally, before twisting parallel to the yarn axis – Wool Res. Vol. 3.

Twist may also be defined as thread which is usually the result of relative rotation of the two ends.

Twist direction

The direction of the twist at each stage of manufacture is indicated by the use of letters S or Z in accordance with the following convention:

A single yarn has S twist if, when it is held in the vertical position, the fibres inclined to the axis of the yarn conform in the direction of the slope to the central portion of the letter S. Similarly the yarn has Z twist if the fibres inclined to the axis of yarn conform in the direction of slope to the central portion of the letter Z.

The Amount of Twist: In B.S. 946: 1952 it is stated that the amount of twist in a thread at each stage of manufacture is denoted by a figure giving the number of turns of twist per unit length at that stage. It affects the characteristics and properties of a yarn including appearance, behaviour and durability.

The amount of twist is an important factor in finished consumer goods. It determines the appearance as well as the durability and serviceability of a fabric. Fine yarns require more twist than coarser yarns. Warp yarns, which are used for the length wise threads in a woven fabric, are given more twist than filling yarn which is used for cross wise threads.

The amount of twist also depends upon the type of the fabric to be woven:

1. Yarns intended for soft surfaced fabric are given slack twist. They are called as soft twisted yarns.
2. Yarns intended for smooth surfaced fabrics are given optimum twists. Such twisted yarns contribute strength, smoothness and elasticity.
3. Yarns intended for crepe fabrics are given maximum amount of twists.

Types of Twist

- S-twist
- Z-twist

Twist Principle

One end will be fixed and another end will be turned this is the twist principle.

Definition Of Twist

The process by which fibres are arranged around the axis of yarn is called yarn twist. It imparts strength to the yarn.

Higher the twist more the yarn strength, till optimum twist is reached. But due to property of 'fabric assistance' even less than optimum twist will produce fabrics of maximum strength.

It also costs money. The circular threads in cloth become elliptical in shape due to flattening. High twisted thread resists flattening, size penetration and their covering power is reached. Spun threads are invariably irregular and hairy and both these specialties help to hide minor weaving faults.

A cotton fibre has about 50 crimps per cm which help a lot in spinning. Voil and crepe threads are purposely hard twisted for producing an open structure cloth. In voil it is 25-30 TPI and in crepe 40-60 TPI. Crepe threads are twisted to a degree when no compactness occurs on further twisting. On wetting, threads swell and contract, producing a low profiled wavy structure. Only hydrophilic fibres swell. Silk and viscose are the best crepers. Yarn's irregularity may be short, medium or long term, depending upon whether it is 10, 100, or 1000 times, the average fibre length.

Twist In Yarns

All staple threads need to be twisted in direct proportion to the square root of thread count.

It varies according to the type of spinning machinery used and end use of the thread. Filling or weft threads are generally given lower twist than warp, as they do not bear shedding and other tensions or reed friction.

Pot spun threads need more twist than ring or flyer spun threads. Up to a certain stage, twist beyond which a reduction in strength takes place. As it costs money and reduces production; yarns are seldom-twisted full. Due to the property of "Fabric assistance" a cloth woven with lesser twisted yarns or threads, is as strong as that woven with optimum twisted threads. But voil and crepe threads are purposely hard twisted. Threads needed for knitting or weaving women's wear are soft twisted.

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It is then is termed soft, medium, medium hard or hard. For crepon or sheersucker effect and for cord effect, threads are made hard twisted. It can be S, left handed (regular or open hand) or Z right handed (reverse or cross hand).

A hard twisted thread becomes wiry, resists liquid penetration and flattens with difficulty. It also acquires a certain amount of elasticity and a tendency to snarl and resist change. An mf yarn is as strong without twisted condition as in twisted condition. It disturbs parallel configuration of monofilaments and their load sharing capacity. A certain amount of twist helps in weaving of mf yarns. Terms, twist per meter and twist per inch are used in continuous filaments and staple spun yarns respectively. A certain amount of lengthwise contraction occurs in yarns with increase in twist, but the amount is quite small. Yarns for American Georgette are given up to 3500 TPM. Polyester filament such as 75/34/0 and 150/30/0 are used as filling in shirtings and suitings without twist.

3.4 YARN COUNT

Some people try to count sheep when they go to bed. For others, however, a good night's sleep only comes from thinking about yarn count. Before any textile, including bed sheets, can be made, the manufacturers have to produce the yarn. The quality of a sheet depends on its yarn count, which is a numerical value that tells you how fine or coarse a yarn is. In technical terms, it's the value of the linear density (the diameter) to which that yarn was spun. When helping you fall asleep, this is the count that will matter.

Calculating Yarn Count

The yarn count can tell you a lot about a yarn's durability, strength, and comfort. It's an important number, and that means it's one that you don't want to estimate. You can probably guess where this is going. We're going to have to talk about math and in a textiles course, no less.

In its most basic sense, the yarn count represents either the mass per unit length, or length per unit mass of the spun yarn. Let's look at two different ways to calculate this number, both of which can ultimately tell us how fine or coarse the yarn is but involve different routes of getting there.

Direct System

Let's start with the first method for calculating yarn count: the direct system, which calculates the weight of a yarn by treating the length of the yarn as the constant in the formula. Basically, it helps you answer the question, 'How much does a consistent length of yarn weigh?' That's what the yarn count represents. In this system, a higher yarn count represents a heavier and, therefore, coarser yarn.

The basic formula for the direct system looks like this:

N = (W/l) / (L/w)

In this formula, N is the Yarn Count, W is the weight of a sample of yarn, l is the unit of length, L is the length of the sample, and w is the unit of weight. W and L come from the specific yarn being used, but what about w and l? These numbers come from the metric we're using to calculate yarn count. Here are three units we often use in the direct system:

1. Tex: Grams per 1000m (1 km) of yarn
2. Denier: Grams per 9000m (9 km) of yarn
3. Pounds per Spindle: Pounds per 14,400 yards of yarn

For example, a Tex would be the weight in grams in one kilometer of yarn. In our formula for the direct system, the unit of length would be one kilometer, and the unit of weight would be a gram. From there, all we need is the actual weight and length of the sample, and we can calculate the yarn count.

Types of Yarn Count:

Direct Count System

The weight of a fixed length of yarn is determined. The weight per unit length is the yarn count! The common features of aII direct count systems are the length of yarn is fixed and the weight of yarn varies according to its fineness.

The following formula is used to calculate the yarn count:

N= (W×l) / L

Where,

N =Yarn count or numbering system

W =Weight of the sample at the official regain in the unit of the system

L=Length of the sample

l=Unit of length of the sample

Numbering System	Unit of Length (l)	Unit of Weight(w)
Tex system, Tt	1000 metres	No. of Grams
Denier, D or Td	9000 metres	No. of Grams
DeciTex, dtex	10 000 metres	No. of Grams
Millitex, mtex	1000 metres	No. of Milligrams
Kilotex, ktex	1000 metres	No. of Kilograms
Jute count	14, 400 yards	No. of Pounds (lb)

In brief, definition of the above Systems is as follows:

1. Tex system ....NO. of grams per 1000 meters
2. Denier ....No. of Grams per 9000 meters
3. Deci Tex ....No. of grams per 10,000 metres

4. Millitex ....No. of milligrams per 1000 metres

5. Kilotex............................... .No. of kilograms per 1000 metres.

6. Jute count........................No. of lb per 14,400 yds

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The Tex of a yarn indicates the weight in grammes of 1000 metres yarn. So that 40 Tex means 1000 meters of yarn weigh 40gm.

From above discussion it is concluded that, higher the yarn number(count) coarser the yarn and lower the number finer the yarn.

Indirect Count System

The length of a fixed weight of yarn is measured. The length per unit weight is the yarn count. The common features of all indirect count systems are the weight of yarn is fixed and the Length of yarn varies according to its fineness.

The following formula is used to calculate they are count:

N = (L×w) / W×l

Where,

N =Yarn count or numbering system

W =Weight of the sample at the official regain in the unit of the system

L=Length of the sample

l=Unit of length of the sample

w = Unit of weight of the sample.

Numbering System	Unit of Length (l)	Unit of Weigt (w)
English cotton count, N_e (N_eB)	840 yards (yds)	1 pound (lb)
Metric count, N_m	1000 metres / 1km	1 kg
Woollen count (YSW)	256 yards	1 pound (lb)
Woollen count (Dewsbury)	1 yard	1 ounce (oz)
Worsted count, N_eK	560 yards	1 pound (lb)
Linen count, N_eL	300 yards	1 pound (lb)

1. Ne: No of 840 yards yarn weighing in One pound

2. Nm: No of one kilometer yarn weighing in One Kilogram

The Ne indicate show many hanks of 840 yards length weigh one English pound. So that 32 Ne Means 32 hanks of 840yards i.e.32x840 yards length weigh one pound.

For the determination of the count of yarn, it is necessary to determine the weight of a known length of the yarn. For taking out known lengths of yarns, a wrap-reel is used. The length of yarn reeled off depends upon the count system used. One of the most important requirements for a spinner is to maintain the average count and count variation within control.

Yarn Count Variation

The term count variation is generally used to express variation in the weight of a lea and this is expressed as C.V.%. The number of samples and the length being considered for count checking affects this. While assessing count variation, it is very important to test adequate number of leas. After reeling the appropriate length of yarn, the yarn is conditioned in the standard atmosphere for testing before it's weight is determined.

Yarn Count: Definition And Types

Yarn count

The yarn count is a numerical expression which defines its fineness or coarseness. It also expresses weather the yarn is thick or thin. A definition is given by the textile institute – "Count is a number which indicates the mass per unit length or the length per unit mass of yarn."

Types of yarn count

- **Indirect system-** English, Metric, Worsted.
- **Direct system-** Tex, Denier, Lbs/Spindle.

Indirect count

The count of yarn expresses the number of length units in one weight unit. Thus higher the count, finer the yarn. The system is generally used for cotton, worsted, linen (wet spun), etc.

Indirect count: $N = \frac{w \times L}{W \times l}$

Where, W = The weight of the sample.

w = The unit weight of the system.

L = The length of the sample.

l = The unit length of the sample.

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Direct count

The count of yarn expresses the no. of weight units in one length unit. Thus higher the count, coarser the yarn. The system is generally used for synthetic fibre, jute, silk, etc.

Direct count: $N = \frac{W \times l}{w \times L}$

Where,

N = The yarn number or, count.

W = The weight of the sample.

w = The unit weight of the sample.

L = The length of the sample.

l = The unit length of the sample.

In Details:

English system: It is defined as the number of hanks (840 yds) per pound. count.

English count $N = \frac{\text{Length (yds)}}{\text{840 yds}} \times \frac{\text{1 pound}}{\text{Weight (Pound)}}$

Metric system: It is defined as the number of hanks (1000m) per kg.

Metric count $= \frac{\text{Length (m)}}{\text{1000m}} \times \frac{\text{1 kg}}{\text{Weight (kg)}}$

Worsted system: It is defined as the number of hanks (540yds) per pound.

Worsted count $= \frac{\text{Length (yds)}}{\text{560 (yds)}} \times \frac{\text{1 Pound}}{\text{Weight (Pound)}}$

Tex system or Lea count: It is defined as the weight in grams of 1000 m.

Tex count $= \frac{\text{Weight (gm)}}{\text{1 gm}} \times \frac{\text{1000m}}{\text{Length (m)}}$

Denier: The number or, count in the denier system is the weight in grams of 9000 m.

Denier count $= \frac{\text{Weight (gm)}}{\text{1 gm}} \times \frac{\text{9000m}}{\text{Length}}$

Pounds per spindle (Jute system): Count in the pound per spindle system is the weight in pounds of 14400 yards of yarn.

3.5 STUDENT ACTIVITY

1. What is Yarn? Explain the Classifications of Textile Yarn?

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....
....

2. What is Twist of Yarn? Explain the Yarn Count?

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....
....

3.6 SPINNING- DRY, WET, MELT

Textiles are all around us. We wear them, use them when we sleep, and decorate our homes with them. But, have you ever thought about how they are made? One important step is spinning the yarn. Spinning is the process of taking textile fibers and filaments and making them into yarn. For thousands of years, people spun natural fibers into yarn by hand. Today, spinning involves many methods and different machines, depending on what kind of yarn is being made.

Before we discuss how spinning works, let's review some basics. Fibers are short, natural hairs that come from plants like cotton and animals like sheep. Filaments are long continuous single strands. Silk is a natural filament, but most filaments are synthetic or man-made materials, like polyester and nylon. Converting fibers and the substances that form synthetic filaments into yarn involves different methods of spinning.

Basic Process of Spinning Yarn

First, let's look at the basics of spinning, which can be done with very simple tools. To make a natural yarn, you gather cleaned and prepared natural fibers like wool or cotton. Using a tool called a spindle, a rounded stick with tapered ends, you pull the fibers by hand onto it as the spindle twists. To aid the process, the spindle is weighted by something called a whorl, a small, round stone or piece of wood which allows the spinning to be maintained at a regular speed. The process of pulling and twisting results in a piece of yarn.

Spinning Natural Fibers

This basic spinning process was used for natural fibers. It's how the process worked for thousands of years. Then, advances in tools and technology made spinning more efficient. In 1828, a machine was invented that allowed a method called ring spinning to mechanize the process. During this process, hundreds of spindles are mounted vertically on a machine that spins fibers into yarns.

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Ring spinning is still the way many fibers are turned into yarn, but in the 20th century another method was invented. Today, some yarns are made through rotor or open-ended spinning. In this method, the fibers are fed into a rotor and blown with air into a system that turns them into yarn without using a spindle. Yarns created by rotor spinning tend to be bulkier and heavier than those made by ring spinning.

Spinning (textiles)

Spinning is the twisting technique where the fiber is drawn out, twisted, and wound onto a bobbin.

Explanation of spinning process

The yarn issuing from the drafting rollers passes through a thread-guide, round a traveller that is free to rotate around a ring, and then onto a tube or bobbin, which is carried on to a spindle, the axis of which passes through a center of the ring. The spindle is driven (usually at an angular velocity that is either constant or changes only slowly), and the traveller is dragged around a ring by the loop of yarn passing round it. If the drafting rollers were stationary, the angular velocity of the traveller would be the same as that of the spindle, and each revolution of the spindle would cause one turn of a twist to be inserted in the loop of yarn between the roller nip and the traveller. In spinning, however, the yarn is continually issuing from the rollers of the drafting system and, under these circumstances, the angular velocity of the traveller is less than that of the spindle by an amount that is just sufficient to allow the yarn to be wound onto the bobbin at the same rate as that at which it issues from the drafting rollers.

Each revolution of the traveller now inserts one turn of twist into the loop of yarn between the roller nip and the traveller but, in equilibrium, the number of turns of twist in the loop of yarn remains constant as the twisted yarn is passing through the traveller at a corresponding rate.

Types of fibre

Artificial fibres are made by extruding a polymer through a spinneret into a medium where it hardens. Wet spinning (rayon) uses a coagulating medium. In dry spinning (acetate and triacetate), the polymer is contained in a solvent that evaporates in the heated exit chamber. In melt spinning (nylons and polyesters) the extruded polymer is cooled in gas or air and sets. All these fibres will be of great length, often kilometers long.

Natural fibres are from animals (sheep, goat, rabbit, silkworm), minerals (asbestos), or plants (cotton, flax, sisal). These vegetable fibres can come from the seed (cotton), the stem (known as bast fibres: flax, hemp, jute) or the leaf (sisal). Many processes are needed before a clean even staple is obtained. With the exception of silk, each of these fibres is short, only centimetres in length, and each has a rough surface that enables it to bond with similar staples.

Artificial fibres can be processed as long fibres or batched and cut so they can be processed like a natural fibre.

Methods

Ring spinning is one of the most common spinning methods in the world. Other systems include air-jet and open-end spinning, a technique where the staple fiber is blown by air into a rotor and attaches to the tail of formed yarn that is continually being drawn out of the chamber. Other methods of break spinning use needles and electrostatic forces.

The processes to make short-staple yarn (typically spun from fibers from 0.75 to 2.0") are blending, opening, carding, pin-drafting, roving, spinning, and—if desired—plying and dyeing. In long staple spinning, the process may start with stretch-break of tow, a continuous "rope" of synthetic fiber. In open-end and air-jet spinning, the roving operation is eliminated. The spinning frame winds yarn around a bobbin. Generally, after this step the yarn is wound to a cone for knitting or weaving.

In a spinning mule, the roving is pulled off bobbins and sequentially fed through rollers operating at several different speeds, thinning the roving at a consistent rate. The yarn is twisted through the spinning of the bobbin as the carriage moves out, and is rolled onto a cop as the carriage returns. Mule spinning produces a finer thread than ring spinning. Spinning by the mule machine is an intermittent process as the frame advances and returns. It is the descendant of a device invented in 1779 by Samuel Crompton, and produces a softer, less twisted thread that is favored for fines and for weft.

The ring was a descendant of the Arkwright water frame of 1769 and creates yarn in a continuous process. The yarn is coarser, has a greater twist, and is stronger, making it more suitable for warp. Ring spinning is slow due to the distance the thread must pass around the ring. Similar methods have improved on this including flyer and bobbin and cap spinning.

The pre-industrial techniques of hand spinning with a spindle or spinning wheel continue to be practiced as handicraft or hobby and enable wool or unusual vegetable and animal staples to be used.

History and economics

Hand spinning was an important cottage industry in medieval Europe, where the wool spinners (most often women and children) would provide enough yarn to service the needs of the men who operated the looms or to sell on in the putting-out system. After the invention of the spinning jenny water frame the demand was greatly reduced by mechanization. Its technology was specialized and costly and employed water as motive power. Spinning and weaving as cottage industries were displaced by dedicated manufactories, developed by industrialists and their investors; the spinning and weaving industries, once widespread, were concentrated where the sources of water, raw materials, and manpower were most readily available, particularly West Yorkshire. The British government was very protective of the technology and restricted its export. After World War I the colonies where the cotton was grown started to purchase and manufacture significant quantities of cotton spinning machinery. The next breakthrough was with the move over to break or open-end spinning, and then the adoption of artificial fibres. By then most production had moved to Asia.

During the Industrial Revolution, spinners, doffers, and sweepers were employed in spinning mills from the 18th to 20th centuries. Many mill owners preferred to employ children due to their small size and agility.

Melt Spinning , Dry spinning and Wet Spinning Method

Melt Spinning, Dry spinning and Wet Spinning Method

Man-made fibers are manufactured by spinning the polymer. There are three major types of spinning process. They are-

- Melt Spinning (It is used for polymers that can be melted easily.)
- Dry Spinning (It involves dissolving the polymer into a solution that can be evaporated.)
- Wet Spinning (It is used when the solvent can't be evaporated and must be removed by chemical means.)

Melt Spinning

Melt spinning uses heat to melt the polymer to a viscosity suitable for extrusion. This type of spinning is used for polymers that are not decomposed or degraded by the temperatures necessary for extrusion. This method is used by 70% of the fibers.

Spinning process:

- In melt spinning, polymer is heated and it melts to form a liquid spinning solution or dope.
- Chips of polymers are fed to a hopper which is heated. There is a grid (sieve) at the base which permits only molten liquid to pass through.
- Then the solution is purified by filter.
- The molten polymer is extruded at high pressure and constant rate through a spinneret into a relatively cooler air stream that solidifies the filaments.
- Finally the filament yarn either is immediately wound onto bobbins or is further treated for certain desired characteristics or end use.

Example: Melt spinning is used for the production of polyester, nylon, olefin, saran and glass fibers.

Advantages:

►High speed (275 to 1500 yds/min); (4000 yds/min spin draw)

►No solvents

►No purification problems

Disadvantages:

►Separate drawing step (unless spin draw)

Dry spinning

Dry spinning is used for polymers that need to be dissolved in a solvent. Solvent spinning (dry spinning and wet spinning) are used by 30% of the fibers.

Spinning process:

- In dry spinning, a volatile solvent is used to dissolve the raw materials and form a salutation.
- Then the solution is purified by filter.
- The solution is extruded through a spinneret into a warm air chamber where the solvent evaporates, solidifying the fine filaments.
- Finally the filament yarn either is immediately wound onto bobbins or is further treated for certain desired characteristics or end use.

Example: Dry spinning is used in the production of acetate, triacetate, and some acrylic, modacrylic, spandex, and vinyon (PVC,PVA) fibers.

Advantages:

►Yarn does not require purification

Disadvantages:

►Flammable solvent hazards

►Solvent recovery

►Slow (200-400 yds/min)

Wet Spinning

This is the oldest, most complex and also the most expensive method of man-made yarn manufacture. This type of spinning is applied to polymers which do not melt and dissolve only in non-volatile or thermal unstable solvents.

Spinning process:

- In wet spinning, a non-volatile solvent is used to convert the raw material into a solution.
- The solvent is extruded through the spinneret either by simply washing it out or by a chemical reaction between the polymer solution and a reagent in the spinning bath.
- After extrusion, the solvent is removed in a liquid coagulation medium.
- Finally the filament yarn either is immediately wound onto bobbins or is further treated for certain desired characteristics or end use.

Example: Wet spinning is used in the production of aramid, Lyocell, PVC, Vinyon

(PVA), viscose rayon, spandex, acrylic and modacrylic fibers.

Advantages:

- ► Large tows can be handled

Disadvantages:

- ► Slow (70-150 yds/min)
- ► Washing to remove impurities
- ► Solvent and chemical recovery

Spinning (polymers)

Spinning is a manufacturing process for creating polymer fibers. It is a specialized form of extrusion that uses a spinneret to form multiple continuous filaments. There are many types of spinning: wet, dry, dry jet-wet, melt, gel, and electrospinning.

Process

First, the polymer being spun must be converted into a fluid state. If the polymer is a thermoplastic then it can be simply melted, otherwise it is dissolved in a solvent or chemically treated to form soluble or thermoplastic derivatives. The molten polymer is then forced through the spinneret, then it cools to a rubbery state, and then a solidified state. If a polymer solution is used, then the solvent is removed after being forced through the spinneret.

Wet spinning

Wet spinning is the oldest of the five processes. This process is used for polymers that need to be dissolved in a solvent to be spun. The spinneret is submerged in a chemical bath that causes the fiber to precipitate, and then solidify, as it emerges. The process gets its name from this "wet" bath. Acrylic, rayon, aramid, modacrylic, and spandex are produced via this process.

A variant of wet spinning is dry jet-wet spinning, where the solution is extruded into air and drawn, and then submerged into a liquid bath. This method is used in Lyocell spinning of dissolved cellulose.

Dry spinning

A solution consisting of a fiber-forming material and a solvent is extruded through a spinneret. A stream of hot air impinges on the jets of solution emerging from the spinneret, the solvent evaporates, and solid filaments are left behind. Solution blow spinning is a similar technique where polymer solution is sprayed directly onto a target to produce a nonwoven fiber mat.

Melt spinning

Melt spinning is used for polymers that can be melted. The polymer solidifies by cooling after being extruded from the spinneret. Nylon, olefin, polyester, saran, and sulfar are produced via this process.

Extrusion spinning

Pellets or granules of the solid polymer are fed into an extruder. The pellets are compressed, heated and melted by an extrusion screw, then fed to a spinning pump and into the spinneret.

Direct spinning

The direct spinning process avoids the stage of solid polymer pellets. The polymer melt is produced from the raw materials, and then from the polymer finisher directly pumped to the spinning mill. Direct spinning is mainly applied during production of polyester fibers and filaments and is dedicated to high production capacity (>100 ton/day).

Gel spinning

Gel spinning, also known as dry-wet spinning, is used to obtain high strength or other special properties in the fibers. The polymer is in a "gel" state, only partially liquid, which keeps the polymer chains somewhat bound together. These bonds produce strong inter-chain forces in the fiber, which increase its tensile strength. The polymer chains within the fibers also have a large degree of orientation, which increases strength. The fibers are first air dried, then cooled further in a liquid bath. Some high strength polyethylene and aramid fibers are produced via this process.

Electrospinning

Electrospinning uses an electrical charge to draw very fine (typically on the micro or nano scale) fibres from a liquid - either a polymer solution or a polymer melt. Electrospinning shares characteristics of both electrospraying and conventional solution dry spinning of fibers. The process does not require the use of coagulation chemistry or high temperatures to produce solid threads from solution. This makes the process particularly suited to the production of fibers using large and complex molecules. Melt electrospinning is also practiced; this method ensures that no solvent can be carried over into the final product.

Drawing

Finally, the fibers are drawn to increase strength and orientation. This may be done while the polymer is still solidifying or after it has completely cooled.

Types of Spinning

There are different types of spinning. Such as:

Dry Spinning

Dry spinning is also used for fiber-forming substances in solution. However, instead of precipitating the polymer by dilution or chemical reaction, solidification is achieved by evaporating the solvent in a stream of air or inert gas.

The filaments do not come in contact with a precipitating liquid, eliminating the need for drying and easing solvent recovery. This process may be used for the production of acetate, triacetate, acrylic, modacrylic, PBI, spandex, and vinyon.

Wet Spinning

Wet spinning is the oldest process. It is used for fiber-forming substances that have been dissolved in a solvent. The spinnerets are submerged in a chemical bath and as the filaments emerge they precipitate from solution and solidify.

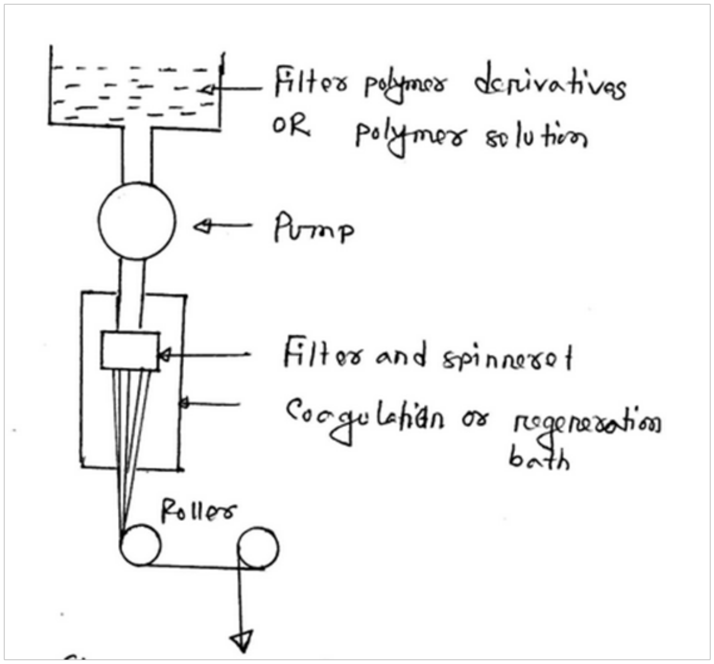

Fig: Principle of wet spinning

Because the solution is extruded directly into the precipitating liquid, this process for making fibers is called wet spinning. Acrylic, rayon, **aramid**, modacrylic and spandex can be produced by this process.

Melt Spinning

In melt spinning, the fiber-forming substance is melted for extrusion through the spinneret and then directly solidified by cooling. Nylon, olefin, polyester, saran and sulfar are produced in this manner.

Melt spun fibers can be extruded from the spinneret in different cross-sectional shapes (round, trilobal, pentagonal, octagonal, and others). Trilobal-shaped fibers reflect more light and give an attractive sparkle to textiles.

Pentagonal-shaped and hollow fibers, when used in carpet, show less soil and dirt. Octagonal-shaped fibers offer glitter-free effects. Hollow fibers trap air, creating insulation and provide loft characteristics equal to, or better than, down.

Gel Spinning

Gel spinning is a special process used to obtain high strength or other special fiber properties. The polymer is not in a true liquid state during extrusion. Not completely separated, as they would be in a true solution, the polymer chains are bound together at various points in liquid crystal form.

This produces strong inter-chain forces in the resulting filaments that can significantly increase the tensile strength of the fibers. In addition, the liquid crystals are aligned along the fiber axis by the shear forces during extrusion. The filaments emerge with an unusually high degree of orientation relative to each other, further enhancing strength. The process can also be described as dry-wet spinning, since the filaments first pass through air and then are cooled further in a liquid bath. Some high-strength polyethylene and aramid fibers are produced by gel spinning.

3.7 MECHANICAL FOR COTTON

Cotton Harvesting

As the technology for combines for wheat and corn developed, demand increased for combination harvesters for all crops. One of the most important of those crops was cotton and the development of a mechanical harvester had far-reaching social consequences.

In 1914, the U.S. grew two-thirds of the cotton used in the world. That amounted to more than 16 million bales of raw cotton – each bale weighing 600 pounds – that were processed into thread, woven into cloth and then sewn into clothing or other fabric items.

Throughout U.S. history, cotton has been an extremely labor intensive crop to produce. The labor required to grow cotton was one of the reasons that slavery (before the Civil War) and the share cropper system (after the Civil War) existed. In the 20th century, both World Wars lured many black share croppers out of the fields and to defense jobs in the North. In fact, between 1940 and 1950, the rural black population in the South declined by 21 percent.

As a result, cotton growers in the South, Southwest and California were all clamoring for a combine to harvest their crops.

The first attempts at a mechanical cotton picker or combine were patented as early as 1850. Over the next 100 years, there were over 1,800 different patents issued for cotton harvesting schemes – and none of them were successful until International Harvester built the Model "H-10-H" in 1942 in the middle of the war. Because of restrictions on steel, IH couldn't begin producing its cotton combine in quantity until 1948. By then, they had come up with an updated model dubbed the "M-12-H."

Before IH's success, inventers and engineers tried various techniques to pull the cotton fibers from the mature boll, but the plant itself made it hard. Traditionally, cotton fields had to be picked by hand three and four times each harvest season. The bolls on the plants would mature at different rates. Growers could not simply leave the early-maturing bolls on the plant until all had matured because the quality of

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the cotton deteriorated as soon as the bolls opened. So, human pickers would move through the fields trailing 10 foot long sacks that would weigh up to 100 pounds when full. Their hands would end up bloody from the sharp spikes on the cotton plants. And they would have to come back through two or three more times during the harvest season.

Early on, some mechanical engineers tried to pick the cotton with pneumatic mechanisms that acted like giant vacuum cleaners. Others tried to adapt grain threshing machines to cotton. Others tried static electricity. Others tried mechanical fingers or prongs to remove the cotton lint fibers to be spun into cloth. All of these early prototypes either didn't harvest enough of the cotton or damaged the plants, making a second pass through the field impossible.

The design that held the most promise was an adaptation of a spindle mechanism, much like the spindle on an antique spinning wheel. The plants would pass over a series of spindles that were turning at fairly high speed. When the spindle encountered an open boll, the cotton fibers would wrap around the spindle. The spindle would then move around to a "doffer" where the spindle would rotate the opposite direction and the doffer would pull the fibers off to be cleaned and transported to a hopper.

But the spindles didn't capture enough of the fibers – until one self-trained agricultural engineer named John D. Rust from Texas remembered something. When he was a kid picking cotton by hand, he remembered how the dew caused the cotton to stick to his fingers, and how his grandmother moistened the spindle on her spinning wheel to get the cotton to adhere. He quickly designed a machine that added water to his spindles, and that approach was the one that IH used in their cotton combines.

Around the same time, cotton plant breeders were able to develop hybrid varieties that produced bolls that were higher off the ground, so that the combine could pick them more easily. They were also able to produce varieties that ripened uniformly so that the harvester had to only make one pass through the field. And finally, herbicides were developed that would defoliate the plants, causing them to drop their leaves just before the harvester came through producing a cleaner harvest.

Between 1948 and the late 1960s, mechanical harvesting of the cotton crop went from essentially zero to 96 percent of the crop. The machines reduced the man-hours required to produce a cotton crop from 125 hours per acre to 25. It's estimated that each two-row cotton combine replaced about 80 share croppers and farm workers. In a sense, the cotton combine completed the exodus of blacks from the rural South to the urban North.

Ironically, the same war that hastened the development of the cotton combine also severely limited cotton's worldwide market. Armies needed lightweight fabrics for their airborne parachute troops, but the supplies of silk from the Far East was cut off. So, scientists developed nylon and other man-made fibers. After the war, cotton was no longer the dominant fabric for clothing.

Mechanical measures for cotton insect -pest

1. **Topping:** Removal of terminals of cotton crop ("Topping") at 80-90 days of growth should be made to reduce Helicoverpa oviposition and also to encourage sympodial branching which bears more fruiting bodies.
2. **Bird perches:** Erection of bird perches (@ 10 / ha) encourages the predation by carnivorous birds.
3. **Hand picking of larvae:** Hand picking of grown up larvae should be done in the morning between 6.30 to 10.0 am and in the evening hours. It will eliminate the possible development of insecticide resistance. It also helps to minimize heavy build up of future population.
4. **Scouting, monitoring and crop protection decisions:** Regular field scouting / monitoring is a vital component of any pest management programme because it is the only way by which reliable information can be obtained to decide if and when pest reaches the economic threshold level. It will determine the pest density and damage levels through the use of standardized sampling techniques. Control measures should be taken in time when pest population reaches a level at which further increases would have resulted in losses beyond sustainable level.
5. **Pheromone monitoring:** A sex pheromone released by one sex only triggers off a series of behavioral patterns in the other sex of the species. It is referred to as sex attractant or sex lure. Generally females produce sex pheromone which attracts males. The sex pheromones are specific in their biological activity, the males responding only to a specific pheromone of the female of the same species. Males of the American bollworm respectively. Pheromone traps @ 5 / ha help to identify the brood emergence for synchronization of insecticide application and release of parasites.

Textile Finishing

Textile Finishing is a process used in manufacturing of fiber, fabric, or clothing. In order to impart the required functional properties to the fiber or fabric, it is customary to subject the material to different type of physical and chemical treatments. For example wash and wear finish for a cotton fabric is necessary to make it crease free or wrinkle free. In a similar way, mercerising, singeing, flame retardant, water repellent, water proof, antistatic finish, peach finish etc are some of the important finishes applied to textile fabric.

Broadly it can be classified into following classes,which are used individually or in combination with each other. (other terms are also used such as wet finishing, dry finishing, durable finishes and non durable finishes)

Fig: Textile finishing

Mechanical Finishing:

Involving the application of physical principles such as friction, temperature, pressure, tension and many others.

Calendering

Calendering is a process of passing cloth between rollers (or "calendars"), usually under carefully controlled heat and pressure, to produce a variety of surface textures or effects in fabric such as compact, smooth, supple, flat and glazed. The process involves passing fabric through a calendar in which a highly polished, usually heated, steel bowl rotates at a higher surface speed than the softer (e.g. cotton or paper packed) bowl against which it works, thus producing a glaze on the face of the fabric that is in contact with the steel bowl. The friction ratio is the ratio of the peripheral speed of the faster steel bowl to that of the slower bowl and is normally in the range 1.5 to 3.0. The normal woven fabric surface is not flat, particularly in ordinary quality plain weave fabrics, because of the round shape of the yarns, and interlacings of warp and weft at right angles to each other. In such fabrics it is more often seen that even when the fabric is quite regular, it is not flat. During calendering, the yarns in the fabric are squashed into a flattened elliptical shape; the intersections are made to close-up between the yarns. This causes the fabric surface to become flat and compact. The improved planeness of surface in turn improves the glaze of the fabric. The calender machines may have several rollers, some of which can be heated and varied in speed, so that in addition to pressure a polishing action can be exerted to increase lustre.

Compacting

Durable finish imparted on man-made fibres and knitted fabrics by employing heat and pressure to shrink them to produce a crêpey and bulky texture.

Embossing

This particular type of calendering process allows engraving a simple pattern on the fabric.To produce a pattern in relief by passing fabric through a calendar in which a heated metal bowl engraved with the pattern works against a relatively soft bowl, built up of compressed paper or cotton on a metal centre.

Sueding

Sueding finishing process is carried out by means of a roller coated with abrasive material. The fabric has a much softer hand and an improved insulating effect thanks to the fibre end pulled out of the fabric surface.

Raising or Napping

The raising of the fibre on the face of the goods by means of teasels or rollers covered with card clothing (steel wires) that are about one inch in height. Action by either method raises the protruding fibres and causes the finished fabric to provide greater warmth to the wearer, makes the cloth more compact, causes the fabric to become softer in hand or smoother in feel; increase durability and covers the minute areas between the interlacings of the warp and the filling. Napped fabrics include blankets, flannel, unfinished worsted, and several types of coatings and some dress goods. Other names for napping are Gigging, Genapping, Teaseled, Raised.

Wool Glazing

This is done on a special machine, which is used to perform functional finishing on wool fabrics after raising.

Shearing

Shearing is an important preparatory stage in the processing of cotton cloth. The objective of "Shearing" is to remove fibres and loose threads from the surface of the fabric, thus improving surface finish.

Stabilization

A term usually referring to fabrics in which the dimensions have been set by a suitable preshrinking operation

Decating

Also called Decatizing. A finishing process applied to fabrics to set the material, enhance lustre and improve the hand.Fabric wound onto a perforated roller is immersed in hot water or has steam blown through it.

Steaming and Heat setting

It is done by using high temperatures to stabilize fabrics containing polyester, nylon, or triacetate but not effective on cotton or rayon.it may be performed in fabric form or garment form it may cause shade variation from side-to-side if done prior to dyeing; may change the shade if done after dyeing

Sanforizing or Pre Shrinking

Sanforizing is a process where by the fabric is run through a sanforizer; a machine that has drums filled with hot steam. This process is done to control the shrinkage of the fabric.The fabric is given an optimum dimensional stability by applying mechanic forces and water vapour.

Fulling

The structure, bulk and shrinkage of wool are modified by applying heat combined with friction and compression.

Chemical Finishing

The finishes applied by means of chemicals of different origins, a fabric can receive properties otherwise impossible to obtain with mechanical means.

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Softening

Softening is carried out when the softness characteristics of a certain fabric must be improved,always carefully considering the composition and properties of the substrate.

Elastomeric Finishes

Elastomeric finishes are also referred to as stretch or elastic finishes and are particularly important for knitwear. These finishes are currently achieved only with silicone-based products. The main effect is durable elasticity, because not only must extensibility be enhanced, but recovery from deformation is of crucial importance. After all stresses and disturbing forces have been released, the fabric should return to its original shape.

Crease Resistant or Crease Proofing

Crease Resistant Finishes are applied to cellulose fibres (cotton, linen and rayon) that wrinkle easily. Permanent Press fabrics have crease resistant finishes that resist wrinkling and also help to maintain creases and pleats throughout wearing and cleaning.

Soil Release Finishes

These finishes attract water to the surface of fibres during cleaning and help remove soil.

Flame Retardant Treatment

Are applied to combustible fabrics used in children's sleepwear, carpets and curtains and prevent highly flammable textiles from bursting into flame.

Peach finish

Subjecting the fabric (either cotton or its synthetic blends) to emery wheels, makes the surface velvet like. This is a special finish mostly used in garments.

Anti Pilling

Pilling is a phenomenon exhibited by fabrics formed from spun yarns (yarns made from staple fibres). Pills are masses of tangled fibres that appear on fabric surfaces during wear or laundering. Fabrics with pills have an unsightly appearance and an unpleasant handle. Loose fibres are pulled from yarns and are formed into spherical balls by the frictional forces of abrasion. These balls of tangled fibres are held to the fabric surface by longer fibres called anchor fibres.

Anti pilling finish reduces the forming of pills on fabrics and knitted products made from yarns with a synthetic-fibre content, which are inclined to pilling by their considerable strength, flexibility and resistance to impact. Anti pilling finish is based on the use of chemical treatments which aim to suppress the ability of fibres to slacken and also to reduce the mechanical resistance of synthetic fibre.

Non Slip Finish

A finish applied to a yarn to make it resistant to slipping and sliding when in contact with another yarn.The main effect of non-slip finishes is to increase the adhesion between fibres and yarns regardless of fabric construction, the generic term for these finishes would be fibre and yarn bonding finishes. Other terms that can be used include anti-slip, non-shift and slip-proofing finishes.

Stain and Soil Resistant Finishes

Prevent soil and stains from being attracted to fabrics. Such finishes may be resistant to oil-boure or water-bourne soil and stains or both. Stain and soil resistant finishes can be applied to fabrics used in clothing and furniture. Scotchgard is a stain and soil resistant finish commonly applied to carpet and furniture.

Oil and Water Proofing

Waterproof Finishes -Allows no water to penetrate, but tend to be uncomfortable because they trap moisture next to the body. Recently, fabrics have been developed that are waterproof, yet are also breathable

Water-Repellent Finishes

Water-repellent finishes resist wetting. If the fabric becomes very wet, water will eventually pass through. Applied to fabrics found in raincoats, all-weather coats, hats, capes, umbrellas and shower curtains.

Absorbent Finishes

Increase fibres' moisture holding power. Such finishes have been applied to towels, cloth diapers, underwear, sports shirts and other items where moisture absorption is important.

Anti Static Finish

Reduce static electricity which may accumulate on fibres. The most common type of anti-static finishes are fabric softeners.

Anti Mildew

In certain ambient (humidity and heat) conditions, cellulose can be permanently damaged. This damage can be due to depolymerisation of the cellulose or to the fact that certain microoganisms (mildews) feed off it. The situation is worsened, during long storage periods, by the presence of starch finishing agents.This damage can be prevented by the use of antiseptics, bacteria controlling products containing quaternary ammonium salts, and phenol derivatives. Dyestuffs containing heavy metals can also act as antiseptics. Permanent modification of the fibre (cyanoethylation) is another possibility.

Mothproofing Finishes

Protect protein-containing fibres, such as wool, from being attacked by moths, carpet beetles and other insects.

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Antibacterial Finish

The inherent properties of textile fibres provide room for the growth of micro-organisms. The structure and chemical process may induce the growth, but it is the humid and warm environment that aggravates the problem further. Antimicrobial finish is applied to textile materials with a view to protect the wearer and textile substrate itself.

Antimicrobial finish provides the various benefits of controlling the infestation by microbes, protect textiles from staining, discoloration, and quality deterioration and prevents the odor formation.Anti-microbial agents can be applied to the textile substrates by exhaust, pad-dry-cure, coating, spray and foam techniques. The application of the finish is now extended to textiles used for outdoor, healthcare sector, sports and leisure.

UV ProtectionFabric treated with UV absorbers ensures that the clothes deflect the harmful ultraviolet rays of the sun, reducing a person's UVR exposure and protecting the skin from potential damage. The extent of skin protection required by different types of human skin depends on UV radiation intensity and distribution with reference togeographical location, time of day, and season. This protection is expressed as SPF (Sun Protection Factor), higher the SPF value better is the protection against UV radiation.

Colorfastness Improving Finish

Colour fastness is the resistance of a material to change in any of its colour characteristics, to the transfer of its colourants to adjacent materials or both. Fading means that the colour changes and lightens. Bleeding is the transfer of colour to a secondary, accompanying fibre material. This is often expressed as soiling or staining meaning that the accompanying material gets soiled or stained.

The physical and chemical principles involved in the performance of the fastnessnimproving finishes concern either the interaction with the dyestuff or with the fibre or both.

The finishes are applied to

a.Improve the colorfastness to washing

b.Improve the colorfastness to crocking

c.Improve the colorfastness to light

d.Improve the colorfastness to weathering

e.Improve the colorfastness to chemicals washes such as mild bleaching , dry cleaning and commercial washing.

Plasma finish

Plasma treatment is a surface modifying process, where a gas (air, oxygen, nitrogen, argon,carbon dioxide and so on), injected inside a reactor at a pressure of approximately 0.5 mbar, is ionised by the presence of two electrodes between which is a high-frequency electric field. The need to create the vacuum is justified by the necessity to obtain a so-called cold plasma with a temperature no higher than 80 °C. This, with the same energy content that can be reached at atmospheric pressure at a temperature of some thousands of degrees C, permits the treatment of fabrics even with a low melting point such as polypropylene and polyethylene, without causing any form of damage.The fabric, sliding through the electrodes, is subject to a true bombardment from the elements that constitute the plasma (ions, electrons, UV radiation and so on) and which come from the decomposition of gas and contain a very high level of kinetic energy. The surface of the fabric exposed to the action of the plasma is modified, both physically (roughness), as well as chemically, to remove organic particles still present and to prepare for the successive introduction of free radicals and new chemical groups inside the molecular chain on the surface of the material. The mechanical properties remain, on the other hand, unaltered, as the treatment is limited to the first molecular layers.

Enzyme Finishing

Bio polishing, also called bio-finishing, is a finishing process applied to cellulosic textiles that produces permanent effects by the use of enzymes. Bio-finishing removes protruding fibres and slubs from fabrics, significantly reduces pilling, softens fabric hand and provides a smooth fabric appearance, especially forknitwear and as a pretreatment for printing.

Sewing Thread Finishing

Apart from many of the above said finishes which can be applied to sewing threads also, A variety of finishes are used to improve the sewability of sewing thread,for example

1. Lubricants reduce friction and improve the lubricity of the thread.Lubricity refers to the frictional characteristics of thread as it passes through the sewing machine and into the seam. Good lubricity characteristics will minimize thread breakage and enhance sewability.
2. Glazing increases strength and abrasion resistance.Glaze Finish refers to a finish put on 100% cotton threads or cotton-polyester core spun thread made from starches, waxes or other additives. This coating is then brushed to give the thread a smooth surface. A glaze finish protects the thread during sewing giving better ply security and abrasion resistance.
3. Bonding to increase strength and surface smoothness. Bonded Finish refers to a finish applied to continuous filament nylon and polyester threads which coats the fibers, giving the thread better ply security and abrasion resistance.

3.8 SUMMARY

Yarns can be described as single, or one-ply; ply, plied, or folded; or as cord, including

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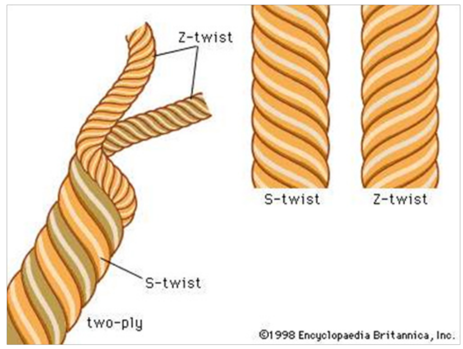
cable and hawser types.

- **Single yarns:** Single, or one-ply, yarns are single strands composed of fibres held together by at least a small amount of twist; or of filaments grouped together either with or without twist; or of narrow strips of material; or of single synthetic filaments extruded in sufficient thickness for use alone as yarn (monofilaments). Single yarns of the spun type, composed of many short fibres, require twist to hold them together and may be made with either S-twist or Z-twist. Single yarns are used to make the greatest variety of fabrics.



S- and Z-twist yarns (Left) S- and (right) Z-twist yarns.Encyclopædia Britannica, Inc.

- **Ply yarns:** Ply, plied, or folded, yarns are composed of two or more single yarns twisted together. Two-ply yarn, for example, is composed of two single strands; three-ply yarn is composed of three single strands. In making ply yarns from spun strands, the individual strands are usually each twisted in one direction and are then combined and twisted in the opposite direction. When both the single strands and the final ply yarns are twisted in the same direction, the fibre is firmer, producing harder texture and reducing flexibility. Ply yarns provide strength for heavy industrial fabrics and are also used for delicate-looking sheer fabrics.
- **Cord yarns:** Cord yarns are produced by twisting ply yarns together, with the final twist usually applied in the opposite direction of the ply twist. Cable cords may follow an SZS form, with S-twisted singles made into Z-twisted plies that are then combined with an S-twist, or may follow a ZSZ form. Hawser cord may follow an SSZ or a ZZS pattern. Cord yarns may be used as rope or twine, may be made into very heavy industrial fabrics, or may be composed of extremely fine fibres that are made up into sheer dress fabrics.

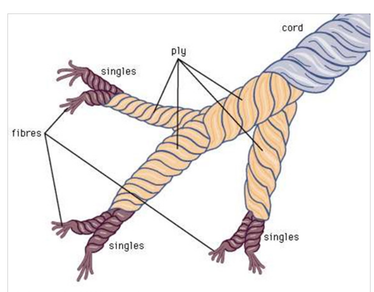
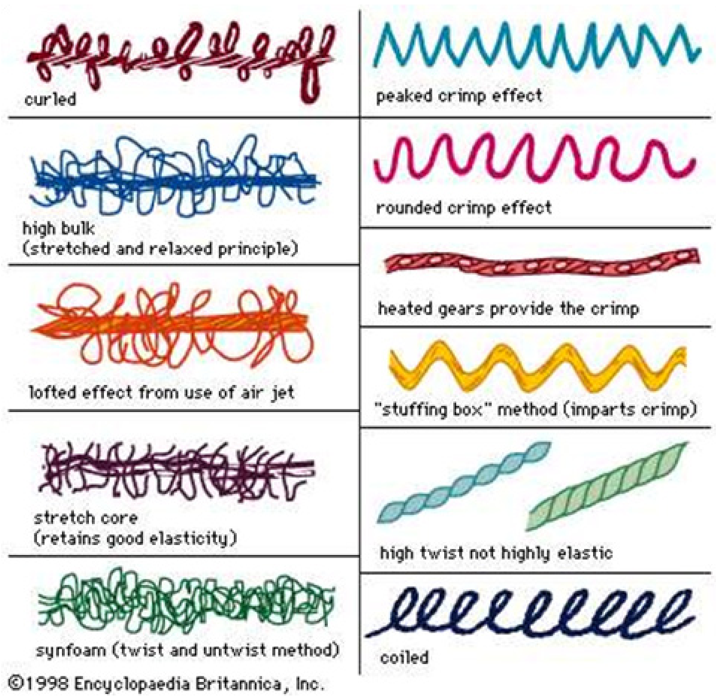


Fig. Single, ply, and cord yarns.Encyclopædia Britannica, Inc.

- **Novelty yarns:** Novelty yarns include a wide variety of yarns made with such special effects as slubs, produced by intentionally including small lumps in the yarn structure, and synthetic yarns with varying thickness introduced during production. Natural fibres, including some linens, wools to be woven into tweed, and the uneven filaments of some types of silk cloth are allowed to retain their normal irregularities, producing the characteristic uneven surface of the finished fabric. Synthetic fibres, which can be modified during production, are especially adaptable for special effects such as crimping and texturizing.
- **Textured yarns:** Texturizing processes were originally applied to synthetic fibres to reduce such characteristics as transparency, slipperiness, and the possibility of pilling (formation of small fibre tangles on a fabric surface). Texturizing processes make yarns more opaque, improve appearance and texture, and increase warmth and absorbency. Textured yarns are synthetic continuous filaments, modified to impart special texture and appearance. In the production of abraded yarns, the surfaces are roughened or cut at various intervals and given added twist, producing a hairy effect.



examples of textured yarnsExamples of textured yarns.Encyclopædia Britannica, Inc.

Bulking creates air spaces in the yarns, imparting absorbency and improving ventilation. Bulk is frequently introduced by crimping, imparting waviness similar to the natural crimp of wool fibre; by curling, producing curls or loops at various intervals; or by coiling, imparting stretch. Such changes are usually set by heat application, although chemical treatments are sometimes employed. In the early 1970s bulky yarns were most frequently produced by the "false twist" method, a continuous process in which the filament yarn is twisted and set and then untwisted and heated again to either stabilize or destroy the twist. The "stuffing box" method is often applied to nylon, a process in which the filament yarn is compressed in a heated tube, imparting a zigzag crimp, then slowly withdrawn. In the knit-de-knit process, a synthetic yarn is knitted, heat is applied to set the loops formed by knitting, and the yarn is then unraveled and lightly twisted, thus producing the desired texture in the completed fabric.

Bulk may be introduced chemically by combining filaments of both high and low shrinkage potential in the same yarn, then subjecting the yarn to washing or steaming, causing the high shrinkage filaments to react, producing a bulked yarn without stretch. A yarn may be air bulked by enclosing it in a chamber where it is subjected to a high-pressure jet of air, blowing the individual filaments into random loops that separate, increasing the bulk of the material.

- **Stretch yarns:** Stretch yarns are frequently continuous-filament synthetic yarns that are very tightly twisted, heat-set, and then untwisted, producing a spiral crimp giving a springy character. Although bulk is imparted in the process, a very high amount of twist is required to produce yarn that has not only bulk, but also stretch.

Spandex is the generic term for a highly elastic synthetic fibre composed mainly of segmented polyurethane. Uncovered fibres may be used alone to produce fabrics, but they impart a rubbery feel. For this reason, elastomeric fibre is frequently used as the core of a yarn and is covered with a nonstretch fibre of either natural or synthetic origin. Although stretch may be imparted to natural fibres, other properties may be impaired by the process, and the use of an elastic yarn for the core eliminates the need to process the covering fibre.

- **Metallic yarns:** Metallic yarns are usually made from strips of a synthetic film, such as polyester, coated with metallic particles. In another method, aluminum foil strips are sandwiched between layers of film. Metallic yarns may also be made by twisting a strip of metal around a natural or synthetic core yarn, producing a metal surface.
- **Fabric construction yarns:** Almost any textile yarn can be used to produce such interlaced fabrics as woven and knitted types. In weaving, the warp, or lengthwise, yarns are subjected to greater stress and are usually stronger, smoother, and more even and have tighter twist than the weft, or crosswise, yarns. A sizing (stiffening) material such as starch may be applied to warp yarns, increasing their strength to withstand the stresses of fabric construction operations. Weft yarns, subjected to little stress during weaving, may be quite fragile.

Warp and weft threads used in the same fabric may be of differing diameter, producing such special effects as ribbing or cording in the fabric. Special effects may also be obtained by combining warp and weft yarns of fibre from differing origin, or with different degrees of twist, or by introducing metallic threads into weaves composed of other fibres.

Yarns for machine knitting are usually loosely twisted because softness is desired in knit fabrics.

- **Yarns used in handwork:** Yarns used in hand knitting are generally of two or more ply. They include such types as fingering yarns, usually of two or three plys, light to medium in weight and with even diameter, used for various types of apparel; Germantown yarns, soft and thick, usually four-ply and of medium weight, frequently used for sweaters and blankets; Shetland yarns, fine, soft, fluffy, and lightweight, frequently two-ply, used for infants' and children's sweaters and for shawls; worsted knitting yarn, highly twisted and heavy, differing from worsted fabric by being soft instead of crisp, and suitable for sweaters; and zephyr yarns, either all wool, or wool blended with other fibres, very fine and soft, with low twist, and used for lightweight garments.

Embroidery floss, used in hand embroidery, generally has low twist, is of the ply or cord type, and is made of such smooth filaments as silk and rayon. Yarn used for crocheting is frequently a loose cotton cord type; and darning yarns are usually loosely spun.

- **Sewing thread:** Sewing threads are tightly twisted ply yarns made with strands having equally balanced twist, producing a circular cross section. Thread for use in commercial or home sewing machines and for hand sewing should allow easy movement when tension is applied and ease in needle threading; should be smooth, to resist friction during sewing; should have sufficient elasticity to avoid the breaking of stitches or puckering of seams; and should have sufficient strength to hold seams during laundering or dry cleaning and in use.

Threads for special uses may require appropriate treatment. Garments made of water-repellent fabrics, for example, may be sewn with thread that has also been made water-repellent. Thread is usually subjected to special treatment after spinning and is then wound on spools. Thread size is frequently indicated on the spool end, and systems for indicating degree of fineness vary according to the textile measurement system used locally.

Silk thread has great elasticity and strength combined with fine diameter. It can be permanently stretched in sewing, and is suitable for silks and wools. Buttonhole twist is a strong, lustrous silk about three times the diameter of normal sewing silk, and is used for hand-worked buttonholes, for sewing on buttons, and for various decorative effects.

Cotton thread is compatible with fabric made from yarn of plant origin, such as cotton and linen, and for rayon (made from a plant substance), because it has similar shrinkage characteristics. It is not suitable for most synthetics, which do not shrink, or for fabrics treated to reduce shrinkage. Its low stretch is useful for woven fabrics, but not for knits, which require more stretch.

Nylon thread is strong, with great stretch and recovery, does not shrink, and is suitable for sheers and for very stretchy knits. Polyester thread has similar characteristics, and is appropriate for various synthetic and preshrunk fabrics, and for knits made of synthetic yarns.

- **Measurement systems:** Yarn measurements are expressed as yarn number, count, or size, and describe the relationship of length and weight (or approximate diameter). Because methods of measurement were developed in various areas of the world, there has been a lack of uniformity in such systems.

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- **Indirect systems:** Indirect measuring systems are those employing higher number to describe finer yarns and are based on length per unit weight. Most countries measure yarns made from staple fibres according to the weight of a length of yarn. If one pound is used as a standard unit, for example, a very fine yarn will have to be much longer than a coarser yarn to weigh a pound, so higher counts indicate finer yarns. The size number is an indication of the length of yarn needed to reach a weight of one pound.

In the United States, the system is based on the number of hanks per pound, with a hank of 840 yards for cotton and spun silk, 300 yards (a lea) for linen, 256 yards for woollen yarns, and 560 yards for worsted yarns. A widely used Continental system is based on the number of hanks of 1,000 metres (one kilometre) required to reach a weight of one kilogram.

- **Denier system:** The denier system is a direct-management type, employed internationally to measure the size of silk and synthetic filaments and yarns, and derived from an earlier system for measuring silk filaments (based on the weight in drams of 1,000 yards). Denier number indicates the weight in grams of 9,000 metres of filament or filament yarn. For example, if 9,000 metres of a yarn weigh 15 grams, it is a 15-denier yarn; if 9,000 metres of a yarn weigh 100 grams, it is a 100-denier yarn and much coarser than the 15-denier yarn. Thus, a smaller number indicates a finer yarn. This system is not convenient for measurement of staple yarns because their greater weight would require the use of very large numbers.

Tex system: The tex system, originally devised in 1873, is a universal method developed for the measurement of staple fibre yarns and is also applicable to the measurement of filament yarns. It is based on the weight in grams of one kilometre (3,300 feet) of yarn.

3.9 GLOSSARY

Crocking : The rubbing-off of dye from a fabric as a result of insufficient dye penetration of fixation, the use of improper dyes or dyeing methods or insufficient washing and treatment after the dyeing operation. Crocking can occur under either wet or dry conditions.

Center Wavelength : In a laser, the nominal value central operating wavelength. It is the wavelength defined by a peak mode measurement where the effective optical power resides.

Channel : A communications path or the signal sent over that path. Through multiplexing several channels, voice channels can be transmitted over an optical channel.

Chirp : In laser diodes, the shift of the lasers center wavelength during single pulse durations.

Chromatic dispersion (CD) : The variation in the velocity of light (group velocity) as a function of wavelength. It causes pulses of a modulated laser source to broaden when traveling within the fiber, up to a point where pulses overlap and bit error rate increases. CD is a limiting factor in high-speed transmission and must be properly compensated, which implies proper testing.

Circulator, optical : The optical circulator allows for optical add/drop multiplexing in conjunction of integrating a fiber Bragg grating (FBG) and is commonly used in long haul, metropolitan area networks and networks. In a circulator, the internal passive components are arranged so that light passes from port 1 to 2, from port 2 to 3 and from port 3 to 4 while preventing it from traveling in the opposite direction. Because each level of the circulator is identical, the steps can be repeated as many times as necessary.

Cladding : Material that surrounds the core of an optical fiber. Its lower index of refraction compared to that of the core causes the transmitted light to travel down the core.

Coarse wavelength division multiplexing (CWDM) : Applies to greater separation of wavelengths than DWDM. In the case of single-mode applications CWDM defines 20-nm separation from 1270nm to 1610nm, with 1470nm to 1610nm the most commonly used wavelengths. With multimode fibers, the wavelengths are 778, 800, 825 and 850 nm.

Coating : The material surrounding the cladding of a fiber. Generally a soft plastic material that protects the fiber from damage.

Density : Mass per unit volume usually expressed as grams per cubic centimeter (g/cc). Also known as specific gravity.

Denier : The weight, in grams, of 9000 meters of yarn. The lower the denier number the finer the size of yarn, and the higher the number the larger the size of yarn. In countries other than the USA, Denier is replaced by the Tex system.

Denier per filament (dpf) : The denier of an individual continuous filament or an individual staple fiber if it were continuous.

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Yarn Denier : The denier of filament yarn. It is the product of the denier per filament and the number of filaments in the yarn.

Total Denier : The product of the denier per filament and the number of filaments in the tow.

Denier Variation : Usually variation in diameter, or other cross-sectional dimension, along the length of a filament or bundle of filaments. Malfunction or lack of process control in fiber manufacturing causes denier variation.

Dent : On a loom, the space between the wires of a reed.

Dimensional Stability : The ability of textile material to maintain or return to its original geometric configuration.

Dobby : A mechanical attachment on a loom that controls the harness to permit the weaving of geometric figures.

Doff : A set of full packages, bobbins, spools, etc. produced by one machine.

Doffing : The operation of removing full packages, bobbins, spools, etc. from a machine and replacing them with empty ones.

Double End : Two ends woven as one in a fabric. It may be intentional or accidental.

Drape : A term to describe the way a fabric falls while it hangs; the suppleness and ability of a fabric to form graceful configurations.

Drawing-in : In weaving the process of threading warp ends through the eyes of the heddles and the dents of the reed.

Drop Wires : A stop-motion device utilizing metal wires suspended from warp or creeled yarns. When a yarn breaks, the wire drops, activating a switch that stops the machine.

3.10 REVIEW QUESTIONS

1. Understanding the Yarn.
2. What is Spun yarn?
3. How to Calculating Yarn Count.

4. What is Direct Count System?
5. Discuss the Indirect Count System.
6. What Is Yarn Count?
7. What kind of Wet spinning?
8. What are the various functions a Dry Spinning?
9. Uses of Melt Spinning.

NOTES

UNIT

4

FABRIC MANUFACTURING TECHNIQUES

STRUCTURE

4.1 LEARNING OBJECTIVE

After studying this unit you should be able to:

- Describe the technology for modify of Woven.
- Given the meaning and significance of Types of Weaves.
- Describe the Common materials used to make Loom and its Parts.
- The importance of Types of Fabrics.
- Give meaning and significance of Weaves Structures.
- Describe the Fabric Weave Patterns.
- Explain the meaning and definition of Power looms.

4.2 INTRODUCTION

Weaving is a textile production method which involves interlacing a set of vertical threads (called the warp) with a set of horizontal threads (called the weft). This is done on a machine known as a loom, of which there are a number of types. Some weaving is still done by hand, but the vast majority is mechanised.

Knitting and crocheting involve interlacing loops of yarn, which are formed either on a knitting needle or on a crochet hook, together in a line. The two processes are different in that knitting has several active loops at one time, on the knitting needle waiting to interlock with another loop, while crocheting never has more than one active loop on the needle.

Braiding or plaiting involves twisting threads together into cloth. Knotting involves tying threads together and is used in making macrame.

Lace is made by interlocking threads together independently, using a backing and any of the methods described above, to create a fine fabric with open holes in the work. Lace can be made by either hand or machine.

Carpets, rugs, velvet, velour, and velveteen, are made by interlacing a secondary yarn through woven cloth, creating a tufted layer known as a nap or pile.

Felting involves pressing a mat of fibers together, and working them together until they become tangled. A liquid, such as soapy water, is usually added to lubricate the fibers, and to open up the microscopic scales on strands of wool.

Treatments Woven tartan of Clan Campbell, Scotland.Textiles are often dyed, with fabrics available in almost every colour. Coloured designs in textiles can be created by weaving together fibres of different colours (tartan or Uzbek_Ikat), adding coloured stitches to finished fabric (embroidery), creating patterns by resist dyeing methods, tying off areas of cloth and dyeing the rest (tie-dye), or drawing wax designs on cloth and dyeing in between them (batik), or using various printing processes on finished fabric. Woodblock printing, still used in India and elsewhere today, is the oldest of these dating back to at least 220AD in China.

Textiles are also sometimes bleached. In this process, the original colour of the textile is removed by chemicals or exposure to sunlight, turning the textile pale or white.

Textiles are sometimes finished by starching, which makes the fabric stiff and less prone to wrinkles, or by waterproofing, which makes the fabric slick and impervious to water or other liquids. Since the 1990s, finishing agents have been used to strengthen fabrics and make them wrinkle free.

- **Weaving Process:** Weaving is a major process of making fabric or cloth . In it, two distinct sets of yarns called the warp and the filling or weft are interlaced with each other to form a fabric. Yarn is a long continuous length of interlocked fibers. The lengthwise yarns which run from the back to the front of the loom are called the warp. The crosswise yarns are the filling or weft. A loom is a device for holding the warp threads in place while the filling threads are woven through them. Yarns made from natural fibers like cotton, silk, and wool and synthetic fibers such as nylon and Orlon are commonly used for weaving textile. But other fibers can also be used for weaving. Yarn intended for the warp goes through operations such as spooling, warping and slashing to prepare them to withstand the strain of the weaving process.
- **Knitting Process:** Knitted fabric is a textile that results from knitting. Its properties are distinct from woven fabric in that it is more flexible and can be more readily constructed into smaller pieces, making it ideal for seats.

Its properties are distinct from nonwoven fabric in that it is more durable but takes more resources to create, making it suitable for multiple uses.

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It is a known fact that the main material for fabric construction is yarn. Knitting is the second most frequently used method, after weaving, that turns yarns or threads into fabrics. It is a versatile technique that can make fabrics having various properties such as wrinkle-resistance, stretchability, better fit, particularly demanded due to the rising popularity of home furnishings. The yarn in knitted fabrics follows a meandering path , forming symmetric loops or stitches. When the interlocking loops run lengthwise, each row is called a wale. A wale can be compared with the warp in weaving. When the loops run across the fabric, each row is called a course. A course corresponds to the filling, or weft. There are two major varieties of knitting: weft knitting and warp knitting. In weft knitting, one continuous yarn forms courses across the fabric. In warp knitting, a series of yarns form wales in the lengthwise direction of the fabric.

- **Nonwoven Fabrics:** Nonwoven fabrics are made by bonding or interlocking fibers or filaments by Mechanical, Thermal, Chemical or Solvent means. For making Staple non-woven, fibers are first spun, cut to a few centimeters length, and put into bales. These bales are then scattered on a conveyor belt, and the fibers are spread in a uniform web by a wet laid process or by carding. These nonwovens are either bonded thermally or by using resin. The Spun laid non-wovens are made in one continuous process. Fibers are spun and then directly dispersed into a web by deflectors or with air streams. Melt blown nonwovens have extremely fine fiber diameters but are not strong fabrics. Spun laid is also bonded either thermally or by using resin. Both staple and spun bonded non-wovens would have no mechanical resistance without the bonding step.
- **Foam Lamination:** The lamination of foam to different substrates is either achieved using either adhesive lamination or flame lamination.

In adhesive foam lamination, as the name implies, adhesives are used to attach the foam to the substrate.

In flame foam lamination a flame front is used to attach the foam to the substrate. One example of flame laminated foam would be the lamination of foam to a fabric substrate in the production of headliners for automobiles.

In either case, foams can be attached to substrates to form bi- or tri-laminates.

- **Coating:** "A material composed of two or more layers, at least one of which is a textile fabric and at least one of which is a substantially continuous polymeric layer."

This Polymeric layer is applied in liquid form in a solvent or water base, which evaporates off to leave the polymer behind, applied to one or both surfaces. Dependant upon the application method the liquid may require thickening so it does not soak through the fabric, or an anti-foaming agent to aid processing. The thickness of the coating, or amount of product applied is controlled. Bonding occurs either through the drying process (evaporation) or through a curing process, required to provoke crosslinking.

- **Flame Retardants:** Textile Finishes for Flame Resistant Fabrics: As the whole environment is going highly technical and risky, the demand for specially treated textile such as flame resistant fabric has grown significantly. In the process of meeting with these demands, synthetic fiber has played a significant role. Simply defined, flame retardants are materials that have the quality of inhibiting or resisting the spread of fire. Textile is highly ignitable and contribute to rapid fire spread. However, the ignitable property of a textile can be considerably reduced by any one of the three methods- by using inorganic materials such as Asbestos, Glass etc; by chemically treating the textile with flame retardant chemicals; and by modifying the polymer.

- **Scotchgard fabric (Water Repellant):** Protect the things you love with Scotchgard protected Fabric. Whether it's a brand-new seats, or your little wall, Scotchgard protected Fabric helps repel liquids and block stains without changing the look and feel of the fabric. That means you can wipe the surface clean before the mess sinks in for beautiful, long-lasting using. So host a family get-together, or your sofa with confidence knowing that Scotchgard protected fabric is your secret defender from life's little mishaps.

4.3 WOVEN

Woven fabric

Woven fabric is any textile formed by weaving. Woven fabrics are often created on a loom, and made of many threads woven on a warp and a weft. Technically, a woven fabric is any fabric made by interlacing two or more threads at right angles to one another.

Qualities

Woven fabrics only stretch diagonally on the bias directions (between the warp and weft directions), unless the threads used are elastic. Woven fabric cloth usually frays at the edges, unless techniques are used to counter it, such as the use of pinking shears or hemming.

Fabrics that are woven do not stretch as easily as knitted fabrics, which can make them advantageous for many uses.

Weaving is a method of fabric production in which two distinct sets of yarns or threads are interlaced at right angles to form a fabric or cloth. Cloth is usually woven on a loom, a device that holds the warp threads in place while filling threads are woven through them.

The way the warp and filling threads interlace with each other is called the weave. Woven cloth can be plain (in one colour or a simple pattern), or can be woven in decorative or artistic designs.

Types of weaves

The majority of woven products are created with one of four basic weaves: ***plain weave, basket weave, satin weave, or twill.***

Plain Weave

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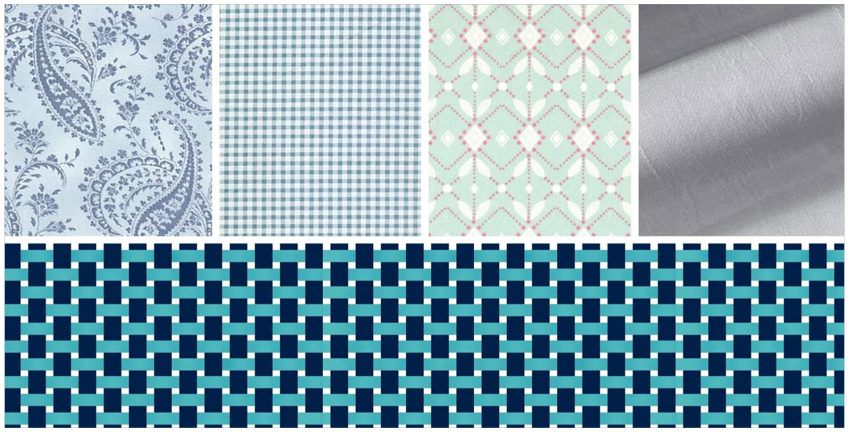
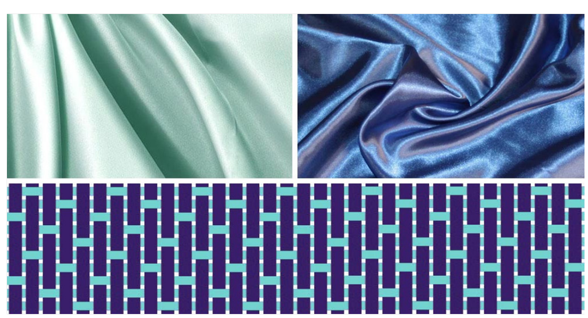


The most basic form of fabric construction, plain weave is a one-to-one overlap of Warp and Weft threads (the weft threads go over, then under, the warp threads). Also, they are inexpensive to produce & durable.

Basket Weave

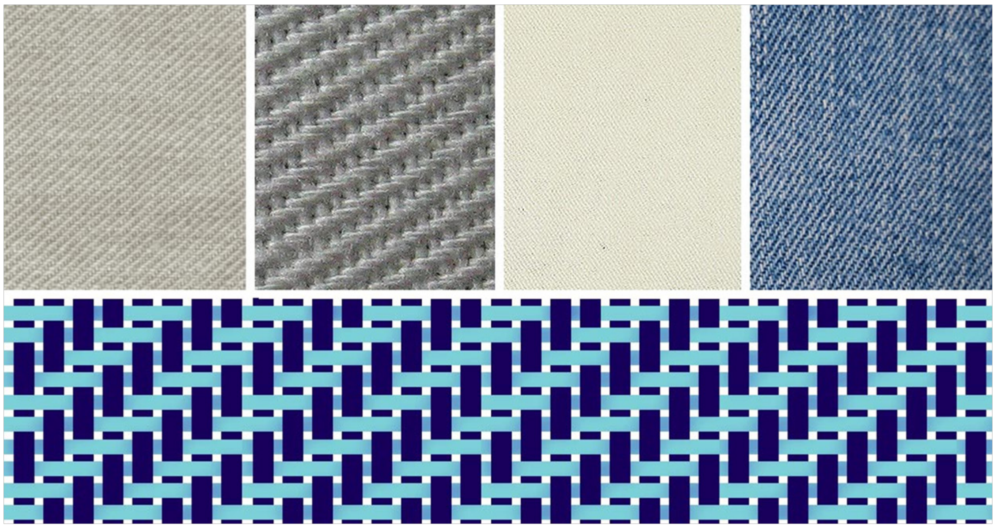
This is a simple variation of Plain Weave. In this version, the criss-cross pattern uses more than one thread, but the number of threads is consistent throughout. The result resembles a checkerboard, because the criss-crossing strands are more pronounced than in the Plain Weave

Satin Weave



Satin is known as a soft and smooth fabric that drapes wonderfully. To create this weave, one thread (either the Warp or the Weft) is 'floated' over four or more opposite threads. It then goes under one thread, and repeats the pattern. 'Float' is the term for spaces between interlacing – where a thread rests on top of the opposite thread. The large distance between interlacing is what creates the smooth and glossy surface on this fabric.

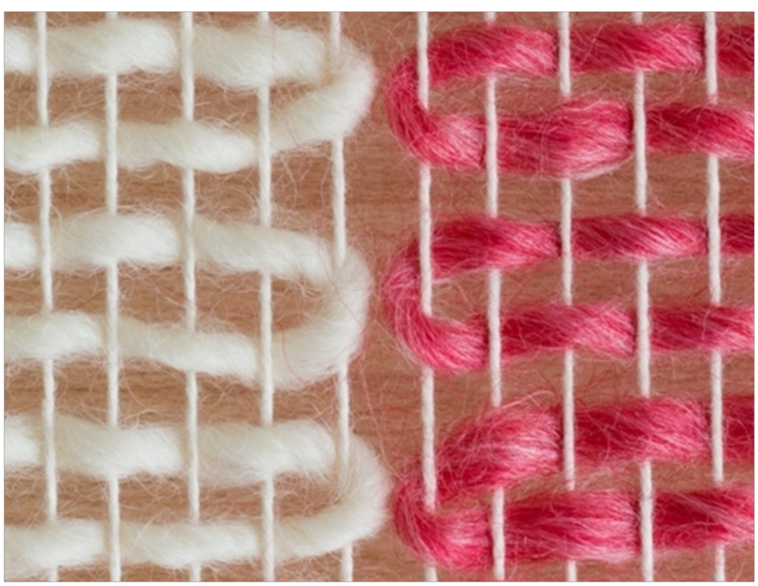
Twill



Twill weaves are easy to spot since they create diagonal lines. The Weft thread is passed through the warp thread in groups of two or more. Each row of threads starts on the next line in a progression, creating a distinct diagonal line. This is generally rougher in texture , so they aren't great for soft pillows or comforters.

Weaving Techniques

1. **Straight Sit**



2. **Diagonal Sit**

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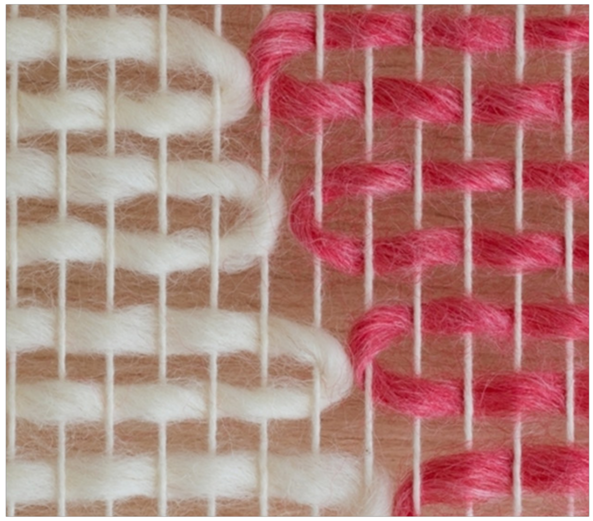
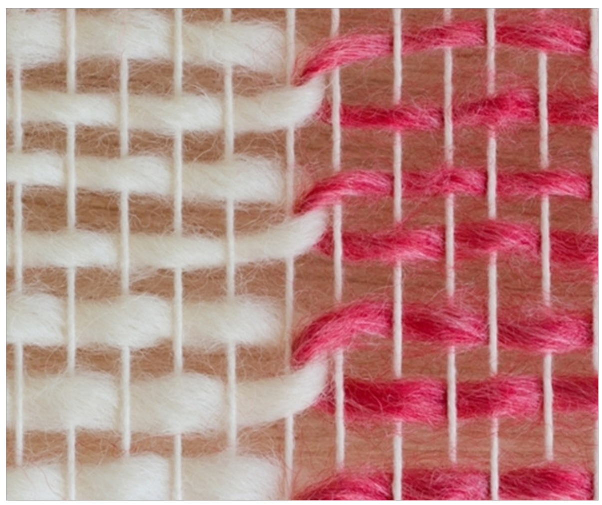
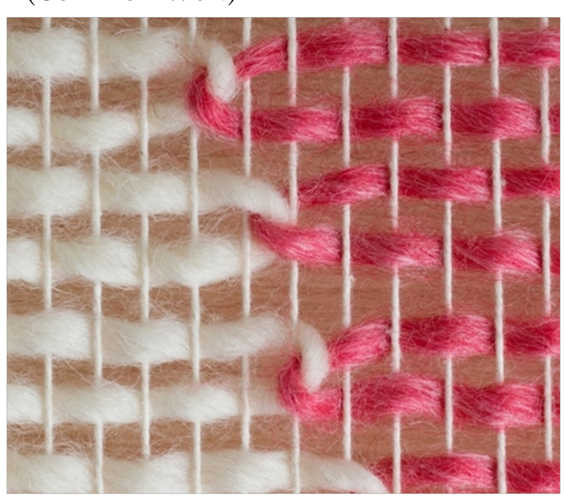


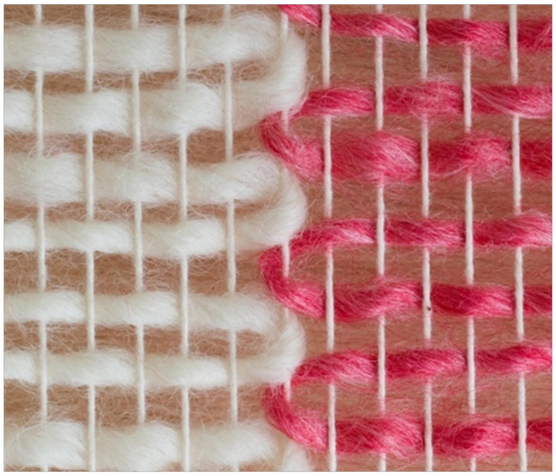
3. **Straight Interlock (Common Weft)**



4. Diagonal Interlock (Common Weft)



5. **Straight Interlock (Common Warp)**



6. **Diagonal Interlock (Common Warp)**

Applications in Home textiles

1.**Cushions**

NOTES

2. **Tablecloth**

3. **Comforters**

4. **Table Runners**

Plain weave

Plain, or tabby, weave, the simplest and most common of all weaves, requires only two harnessses and has two warp and weft yarns in each weave unit. To produce it, the warp yarns are held parallel under tension while a crosswise weft yarn is shot over and under alternate warps across the width of the web. The weave unit is completed at the end of the second row, when the weft has been inserted over and under the opposite set of warps, thus locking the previous weft in place. Fabric length is increased with the insertion of each succeeding weft yarn. When warp and weft yarns are approximately equal in size and quantity, the finished fabric is balanced and potentially stronger than cloth made of the same kind and number of warp and weft yarns in any other basic weave. Tabby woven with different-sized warp and weft yarns results in such fabrics as taffeta and poplin, in which many fine warps are interlaced with proportionately fewer thick weft yarns to form cloths with crosswise ridges or ribs.

The term extended tabby describes any weave in which two or more warps or wefts, or both, are interlaced as a unit. The group includes fabrics with basketry effects and fabrics with ribs formed by groups of warps or wefts in each shed.

Tapestry weave is a tabby in which a variety of coloured weft yarns is interlaced with the warp to form patterns. It is usually an unbalanced weave, with wefts completely covering a proportionately low number of warps. These cloths are sturdy and compact. Although they are flat and generally do not drape well, they have been used for centuries to make ceremonial and decorative dress and costumes.

Twill weave

Twill weave is distinguished by diagonal lines. The simplest twill is that created by the weft crossing over two warp yarns, then under one, the sequence being repeated in each succeeding shot (pick), but stepped over, one warp either to the left or right. Twills with more warps than wefts floating on the fabric's face are called warp faced; those with wefts predominating, weft faced. The angle of the twill can also vary.

Twills can be varied by changing the relative number of warps and wefts in each repeat (2:1, 2:3, 3:1, 6:2, etc.); by stepping the repeat in one direction; by breaking the direction of the diagonals formed by the twill at regular intervals; by reversing the direction of the diagonal at regular intervals to form chevrons or lozenges; or by combining several twills or modifying them to create a pattern.

Twills drape better than plain weaves with the same yarn count because twills have fewer interlacings. Twill weaves have been used throughout history in many weights and textures, from wool serges mentioned in medieval French manuscripts to English diapered (diamond patterned) table linens, patterned bed coverlets, and Indian shawls.

Satin weave

Although satin-weave drafts superficially resemble those of twills, satin weave does not have the regular step in each successive weft that is characteristic of twills. Thus, there is no strong diagonal line, and the fabric is smooth faced, with an unbroken surface made up of long floating warp yarns. A true satin must have at least five warp and weft yarns in each complete weave repeat and thus requires at least five harnesses. Most satin fabrics are made of smooth, lightly twisted yarns that heighten the effect of light unbroken by visible crosswise bindings. The limited number of interlacings allows the weaver to use a proportionately large number of warp yarns and thus produce a heavy textured cloth that can be arranged in smooth, shadowed folds. Satins, having long floats, are susceptible to the wear caused by rubbing and snagging and are, therefore, generally regarded as luxury fabrics.

Among the variations of satin weave are damask and sateen, a weft-faced satin. Damask is the most important variation of basic satin weave. Classic damask is a patterned solid-coloured fabric with figures in warp-faced satin and background in weft-faced satin weave. The pattern is created by the difference in light reflection between the warp-faced and weft-faced areas. Silk damasks probably originated in China and came to Europe through Italy, the centre of European silk manufacture between the 13th and 17th centuries. During this period drawloom weavers from the Netherlands and Belgium also developed the art of linen damask weaving. Pictorial linen damasks, unlike most silk damasks of the time, often consisted of a single large repeat, picturing biblical scenes, contemporary events, or the arms of nobles and kings.

Complex weaves

Complex weaves include multiple plane, pile, inlaid, Jacquard, dobby, and gauze (or leno) weaves.

Multiple plain weave

Reversible double-woven cloth is produced by multiple plain weaving. It is woven in two layers, which may be completely independent, may be joined at one or both selvages, may be held together along the edges of a pattern, or may be united by a separate binding weft. Though often tabby weave is employed on both surfaces, any of the basic weaves may be used, depending on the intended use of the fabric.

Double-woven cloths have been used for clothing, but, though warm, they tend to be heavy and to drape poorly. They are most often used as bedcovers or wall hangings. German 18th-century Beiderwand is an example of antique double-woven cloth consisting of two layers of tabby weave joined only along the edges of the pattern. A dark-coloured pattern in one layer is set against the light-coloured ground of the other layer; the pattern is seen in negative or the reverse side of the cloth.

Nonreversible cloth with two or more sets of warp and sometimes of weft can also be produced. These cloths have an intricately patterned face, and all warps and wefts that do not appear on the face are carried along and bound into the web on the reverse side. This class includes important historic textiles, such as early Persian and Byzantine figured fabrics, as well as more recent Jacquard-woven imitation tapestries and a wide range of imitation brocaded fabrics.

Pile weave

Pile weaves have a ground fabric plus an extra set of yarns woven or tied into the ground and projecting from it as cut ends or loops. A great range of textures is included in this binding system, from terry pile toweling and corduroy to silk velvets and Oriental rugs.

In warp-pile fabrics the pile is formed by an extra set of warp yarns. To create such a fabric, first one set (sheet) of ground warps is raised, and the weft makes its first interlacing with the ground warp. Next, pile warps are raised, and a rod is inserted through the entire width of the web. The remaining ground warps are raised to form the third shed; then the ground weft is shot across again. This sequence is repeated several times; then the rods are slipped out, leaving a warp pile. To form cut-pile velvet, a knife on the end of the rod cuts the pile warps it passes, creating two fine rows of cut pile. Although the system has many technical variations, the same basic process can be applied to most warp-pile weaving.

If the pile is not cut when the rod is removed, a loop pile fabric results. In weaving terry pile fabrics, the ground warp is under tension, and the pile warp stays slack. When wefts are beaten in, the slack yarns are pushed into loops on both sides of the cloth.

To make velvets by double-cloth construction, two layers of cloth are woven simultaneously face-to-face, with long pile warp yarns connecting the two layers. After the cloth is woven, a knife slices the two layers apart.

Corduroy and velveteen are weft-pile constructions. Weft yarns having long floats are inserted between ground-weave picks. The floats are slit longitudinally after the fabric is completed, thus forming a ribbed surface of cut pile. In manufacture of velveteen the floats are formed over the whole surface of the fabric and cut evenly to imitate velvet.

Hand-knotted Oriental and Scandinavian rugs are constructed on a tabby-weave ground, with each row of knots followed by tightly beaten-in wefts. The pile of fine Oriental rugs may contain 160 knots per inch, thus completely obscuring the knots in the rug's foundation.

Inlaid weave

In all of the fabrics of this class, designs are created by inserting pattern warp or weft yarns between ground warps or wefts.

Brocaded fabric has a pattern of coloured or metallic threads, or both, set in low relief against the ground weave. The ground weave can be any basic weave, since the brocaded pattern is merely inserted between ground wefts and is bound by ground warps. Until the advent of the Jacquard mechanism in the early 19th century, brocaded fabrics were woven by drawloom weavers who inserted the pattern wefts by hand. These weft yarns were wound on small brocading shuttles that travelled across the width of each pattern repeat, a separate shuttle being used for each colour in the repeat. Generally, these extra wefts were found only in the area in which the pattern was located and usually formed long floats on the reverse side of the fabric.

A mechanical process closely corresponding to hand brocading is called swivel, a system of figuring fabrics by using mechanically controlled pattern shuttles. The figures, inserted between ground-weft picks, interlace with the warp. The lappet system produces figured fabrics resembling those made by swivel figuring, but the pattern yarns are extra warps (rather than wefts) brought into play from separate warp beams. Lappet weaving is generally confined to coarse pattern yarns and can be distinguished from swivel by its interlacing with weft rather than with warp yarns.

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Jacquard weave

The Jacquard weave, used to make allover figured fabrics such as brocades, tapestries, and damasks, is woven on a loom having a Jacquard attachment to control individual warps. Fabrics of this type are costly because of the time and skill involved in making the Jacquard cards, preparing the loom to produce a new pattern, and the slowness of the weaving operation. The Jacquard weave usually combines two or more basic weaves, with different weaves used for the design and the background.

Dobby weaves

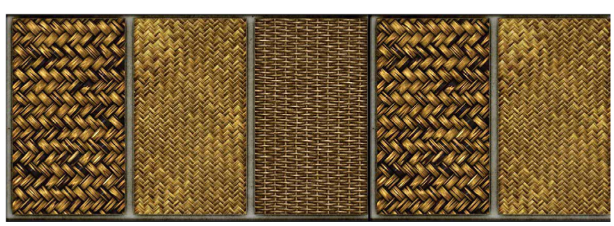
Dobby weaves also produce allover figured fabrics. They are made on looms having a dobby attachment, with narrow strips of wood instead of Jacquard cards. Dobby weaves are limited to simple, small geometric figures, with the design repeated frequently, and are fairly inexpensive to produce.

Gauze or leno weave

Gauze weaving is an open weave made by twisting adjacent warps together. It is usually made by the leno, or doup, weaving process, in which a doup attachment, a thin hairpin-like needle attached to two healds, is used, and the adjacent warp yarns cross each other between picks. Since the crossed warps firmly lock each weft in place, gauze weaves are often used for sheer fabrics made of smooth fine yarns. Although gauze weaving, with its multitude of variations, has been adapted to modern production, it is an ancient technique.

4.4 TYPES OF WEAVES

Different types of weaves



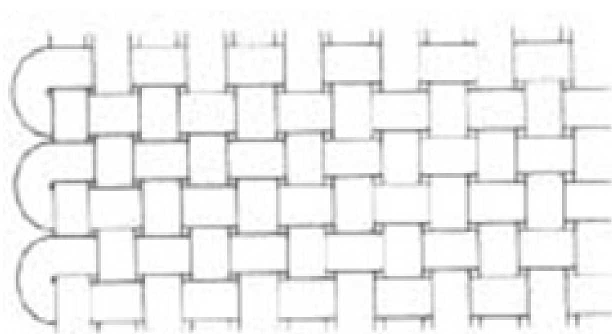
Fabric are manufactured in wide varieties and design. And the different design and effect is produced on the fabric with the help for various mechanism which is helpful to from different weaves and lots of design which enhances the look of apparels. The present paper was aimed at investigating the different types of weaves and also overview the fabrics come under the different weave categories.

Types of Weaves

Plain Weave

Most simple and most common type of construction Inexpensive to produce, durable, Flat, tight surface is conducive to printing and other finishes. The simplest of all patterns is the plain weave. Each weft yarn goes alternately over and under one warp yarn. Each warp yarn goes alternately over and under each weft yarn. Some examples of plain weave fabrics are crepe, taffeta, organdy and muslin. The plain weave may also have variations including the following:

- **Rib weave:** the filling yarns are larger in diameter than the warp yarns. A rib weave produces fabrics in which fewer yarns per square centimeter are visible on the surface.
- **Matt Weave or Basket weave:** Here, two or more yarns are used in both the warp and filling direction. These groups of yarns are woven as one, producing a basket effect.
- **Method of Construction:** Each filling yarn goes alternately under and over the warp yarns
- **Household Uses**: Draperies, tablecloths, upholstery.



Different types of Fabric Come under this Category:

- **Chiffon:** A very soft and filling plain woven Silk texture consisting of the Finest Singles which are hard twisted and woven in the gum condition. The cloth is afterward degummed.
- **Georgette:** A cotton Crepe fabric made in imitation of silk georgette, with hard twisted warp and weft yarn. A good Cloth is woven plain with right and left twist thread arranged in 2 and 2 order in warp and weft.
- **Shantung:** Coarse Silk fabric with Slubs. Mostly Tussah Silk but can be Polyester, nylon and viscose.
- **Seersucker:** It is created by holding some warp yarns at tight tension, some

at slack tension. Those at Slack Tension puff up to form a sort of Blis-ter-effect, often slack and tight yarn of different colour.

NOTES

Basket Weave

A variation of the plain weave usually basket or checkerboard pattern Contrasting colors are often used Inexpensive, less durable than plain weave. Basket weave is the amplification in height and width of plain weave. Two or more yarns have to be lifted or lowered over or under two or more picks for each plain weave point. When the groups of yarns are equal, the basket weave is termed regular, otherwise it is termed irregular.

There two types of weave come under this category i.e. regular and irregular weave.

a) **Regular Basket Weave:** This is commonly used for edges in drapery, or as a bottom in very small weave repeats, because the texture is too loose-fitting for big weave repeats; moreover, yarns of different groups can slip, group and overlap, spoiling the appearance. This is why only basket weaves 2-2, 3-3 and 4-4 exist.

b) **Irregular Basket Weave:** This is generally a combination of irregular warp and weft ribs.

Method of Construction: Two or more warps simultaneously interlaced with one or more fillings.

Household Uses: Wall hangings, pillows.

Example of Basket weave:

- **Monks cloth:** Heavy cotton Cloth in a coarse basket weave, chiefly used for draperies.
- **Oxford;** Oxford weave fabric consists of two, thin warp yarns woven to very soft, thicker yarn in the filling direction. The unbalanced construction of the fabric causes the thin yarns to break and leave tiny holes. The primary use of oxford weave fabric is in cotton shirting. It is also used in other forms of apparel.

Twill Weave

Creates a diagonal, chevron, hounds tooth, corkscrew, or other design. The design is enhanced with colored yarn is strong and may develop a shine. Twill weave is characterized by diagonal ridges formed by the yarns, which are exposed on the surface. These may vary in angle from a low slope to a very steep slope. Twill weaves are more closely woven, heavier and stronger than weaves of comparable fiber and yarn size. They can be produced in fancy designs.

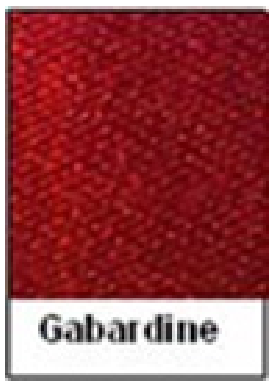
Method of Construction: Three or more shafts; warp or filling floats over two or more counterpart yarns in progressive steps right or left

Household Uses: Upholstery, comforters, pillows.

Types of Fabrics

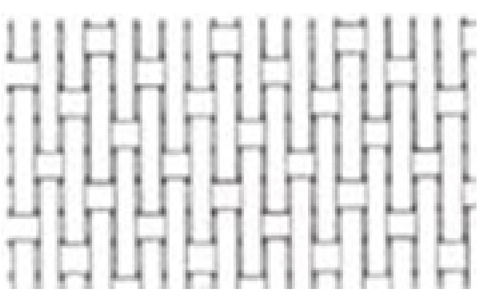
Denim: A Strong Warp Face Cotton Cloth used for overall, Jeans skirts etc. Largely made in 3/1 twill weave. Generally warp yarn is dyed brown or blue and crossed with white weft.

- **Gabardine:** A Warp Face cloth mostly woven 2/2 twill, 27/2 tex warp, 20/2 tex cotton weft. Here cotton weft is yarn dyed but the wool warp may be dyed in piece.



Satin

- Smooth, soft luster
- Excellent drapability
- Floats snag easily



Method of Construction:

- Floats one warp yarn over four or more weft yarns, then tied down with one thread, resulting in a smooth face.
- **Common Fabrics:** Satin, satin-weave fabrics out of fabrics such as cotton & Charmeuse

Household Uses: Draperies, quilts

Examples of Fabric:

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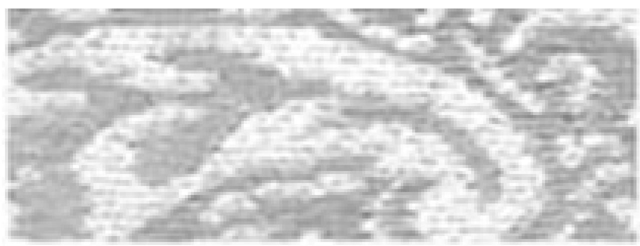
- **Satin:** Used for ribbons, trimmings, dresses, linings etc, and originally was an all silk fabric with a fine rich glossy surface formed in a warp satin weave. The warp is much finer and more closely set than the weft, and the latter which only shows on the under side is frequently composed of cotton. Double faced Satins are made on the reversible warp backed principle, with one side differently colour from the other.
- **Sateen:** A cotton fabric is made in 5 thread weft face sateen, and woven like cotton. It is sold in bleached, mercerized or printed condition.
- **Charmeuse:** It is a light weight fabric woven with a satin weave ,where the warp threads cross over three or more of the backing (weft) threads. The front side of the fabric has a satin finish-lustrous and reflective-whereas the back has a dull finish.



Jacquard

Jacquard patterns, when carefully analyzed, may be seen to contain combinations of plain, twill, and satin weaves, even in the same crosswise yarn. Many decorative fabrics are made by the jacquard technique. Yarns woven into unlimited designs, often intricate, multicolor effect. Expensive, but the design dont fade or wear out. Durability depends on the fiber used. The Jacquard loom was invented by Joseph Marie Jacquard.

Method of Construction:

Warp is individually controlled with each pick passage creating intricate designs

Household Uses:

Upholstery, wall hangings

Types of Jacquard fabric:

- **Brocade:** Originally a heavy rich silk fiber ornaments with raised figures formed by extra threads or by embroidery. Mostly used for upholstery fabrics and draperies.
- **Damask:** Fabric with a weft sateen figures on a warp satin, twist or plain grained, made of silk, cotton, rayon and linen yarns Damasks are reversible.

Cotton and linen damasks are made either with four yarn float or a seven yarn float in the satin weave. The Longer floats are more lustrous, but the shorter floats are more durable.

Leno or Gauze

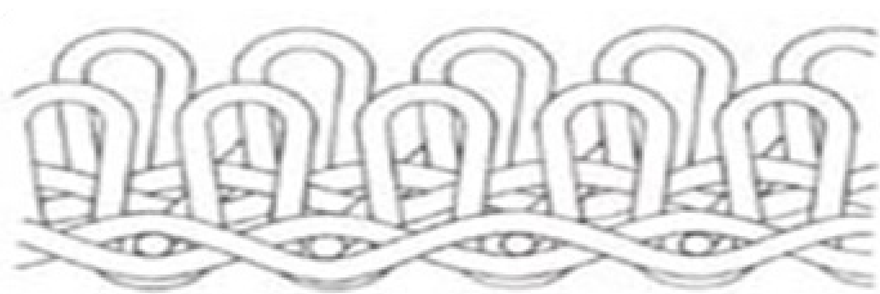
In leno or gauze weave pairs of warps are twisted over each other with each passing of filling yarn. The leno weave is the modern descendant of a technique called twining that was used thousands of years ago for making fabrics. In leno-weave fabrics, the warp yarns are paired. A special attachment, the doup or leno attachment, crosses or laps the paired warp yarns over each other, while the filling passes through the opening between the two warp yarns. Leno-weave fabrics are made in Open, gauzelike constructions.

- **Method of Construction:** A pair of warp threads is twisted over each other with each passing of filling yarn in a figure or an hourglass twist, creating a geometric pattern
- **Household Uses:** Thermal Blankets, curtains

Pile Fabric

Extra sets of warps or fillings are woven over ground yarns of plain or twill weave to form loops. Pile fabrics have been defined as fabrics(s) with cut or uncut loops which stand up densely on the surface Pile fabrics may be created by weaving or through other construction techniques, such as tufting, knitting, or stitch through. To create the loops that appears on the surface of woven pile fabrics, the weaving process.

Piled fabric are classified as Uncut pile and Cut Pile Fabric



Uncut Pile

- Loops are possible on both sides of fabric
- Soft and absorbent, relatively inexpensive
- Can snag if loops are caught

Method of Construction (Wire Method or double cloth Method): Generally a plain or twill weaves with a third dimension--additional warp yarn or filling yarn is introduced into the basic structure and forms a loop at regular intervals.

- **Common Fabrics:** Frieze, terry cloth

- **Household Uses:** Upholstery, towels, carpet, area rugs

Cut Pile:

NOTES

- Soft and warm, resilient, absorbent
- May have a nap that must be matched
- May be expensive and need professional cleaning
- Method of Construction:
- Similar to uncut pile, but loops have been cut

Household uses: Upholstery, stage draperies.

Different types of Cut pile Fabric

- **Corduroy:** Corded velveteen Structures in which a weft pile forms longitudinal lines or chords, strong heavy clothes being used for trouser-rings, smoking jackets and lighter fabrics for dress materials.
- **Velvet:** A cut warp pile fabric with a short, soft, dense pile.
- **Velveteen:** A Short heavily wefted cotton fabric uniformly covered with a short dense pile of fibers which formed after the cloth has been woven by cutting certain picks of weft that float somewhat loosely on the surface.

Different Types of Basic Weaves Structures

Basic Weave Structures

Weave is the interlacing pattern warp and weft yarns, in order to produce a woven fabric. Weave structures is the design by which fabric is produced. Fabric are manufactured in wide varieties and design. The great variety of weaves found in the textiles of today are modifications of a few fundamental weaves invented in the earliest times. The basic weaves are plain, twill, and satin. All the others are derivatives of these basic weaves or their combination.

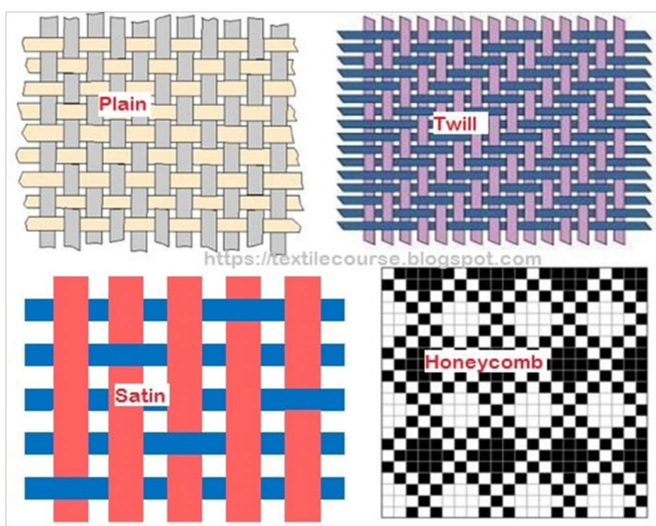


Figure: Different basic weaves structures

Different Types Of Weaves and Their Names:

1. Plain Weave
2. Twill Weave
3. Satin/Sateen
4. Honey Comb Weave
5. Huck a Back Weave
6. Crepe Weave
7. Bedford Cord Weave
8. Welts and Pique
9. Mock Leno Weave

All types of basic weaves are descrived briefly.

Plain Weave

Plain is the simplest weave, in which warp and weft threads interlace in alternate manner, giving maximum number of inter¬lacements. This maximum interlacement imparts firmness and stability to the structure. In trade, the special names like broadcloth, taffeta, shantung, poplin, calico, tabby, and alpaca are applied to plain weave. At least two ends and two picks are required to weave its basic unit. A minimum of two heald frames are required for this weave, but more than two (multiple of basic weave) heald frames can be used to weave this construction. It is used in cambric, muslin, blanket, canvas, dhothi, saree, shirting, suiting, etc.

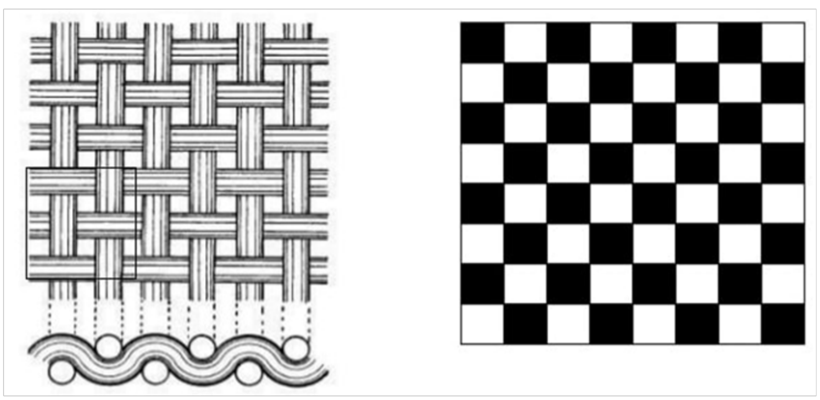


Figure: Plain weave structure

Plain weaves are basically three types. They are:

Warp rib

Warp ribs are a modified form of plain weave. It has 1/1 interlacements in the filling direction, which differs from the simple plain weaves. This modified interlacement results in the formation of cords, ridges, or texture across the warp direction of the fabric. These cords or ridges are formed due to the group¬ing of the filling yarns. The repeat of warp rib is always on two warp yarns. The first warp yarn follows the formula, while the second warp yarn is in the oppo¬site direction of the first one. It requires two heald frames at least, but multiple of these can also be employed. The number of weft yarns in a repeat unit of this weave is equal to the sum of the digits in formula of warp rib. For example, 2/2 warp rib requires 2 warp yarns and 4 weft yarns. Design of the above-stated warp rib. Warp rib is also known as ottoman.

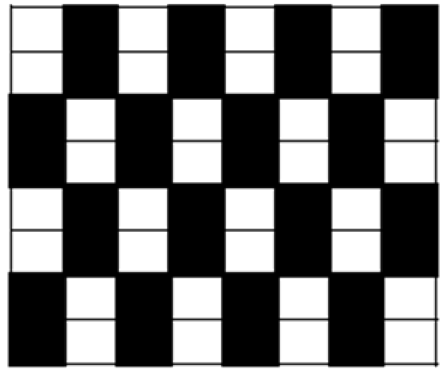


Figure: Warp rib (2/2).

Warp rib are two types:

1. Regular Warp Rib
2. Irregular Warp Rib

Weft rib

Weft ribs are another modified form of plain weaves. It has 1/1 interlace¬ments in the warp direction, which differs from the simple plain weaves. This modified interlacement results in the formation of cords, ridges, or tex¬ture across the weft direction of the fabric. These cords or ridges are formed due to the grouping of the warp yarns. The repeat of weft rib is always on two weft yarns. The first weft yarn follows the formula, while the second weft yarn is in the opposite direction of the first one. It requires two heald frames at least, but multiple of these can also be employed. The number of warp yarns in a repeat unit of this weave is equal to the sum of the digits in formula of warp rib. For example, 2/2 weft rib requires 2 weft yarns and 4 warp yarns. Design of the above-stated warp rib. Weft rib is also known as half panama.

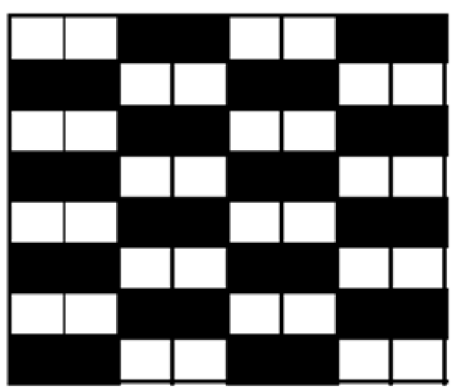


Figure: Weft rib (2/2).

Weft rib are two types:

1. Regular Weft Rib
2. Irregular Weft Rib

Matt weave

This type of weave is constructed by extending the plain weave in warp and weft directions at the same time so that two or more threads work alike in both directions. In this weave, the same size of squares appear on both sides of the fabric showing the same number of warp and weft yarns on front and back of the fabric. Matt weave is also commercially known as basket, hop¬sack, or full panama. This weave requires a minimum of two heald frames. Design of the 2/2 matt weave. The matt weaves can be extended further to give more prominence but restricted due to loose struc¬ture and modified in several ways. In matt weave, the warp ends that work alike tends to twist around each other. To avoid this twisting of the yarns, warp ends that work alike are drawn from different slits of the reed.

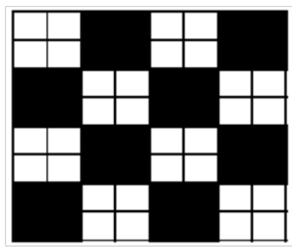


Figure: Matt weave (2/2).

Matt weave are three types:

1. Regular Matt Weave
2. Irregular Matt Weave
3. Fancy Matt Weave

Twill Weave

Twill weave is another basic weave which is well known for its diagonal line formation in the fabric due to its interlacing pattern. This weave and its derivatives are used for the ornamental purposes. Twill has closer setting of yarns due to less interlacement imparting greater weight and good drape as compared to the plain weave. In simple twill, the outward and upward movement of the interlacing pattern is always one that imparts a diagonal line to this design. The direction of the propagation of twill line classifies twill into right-hand or left-hand twill. Twill weaves find a wide range of application such as drill cloth, khakhi uniforms, denim cloth, blankets, shirtings, hangings and soft furnishings.

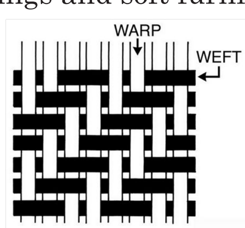


Figure: Twill weave

NOTES

There are various types of twill weave:

1. Warp faced twill
2. Weft faced twill
3. Balanced twill
4. Pointed Twill
5. Horizontal Pointed Twill
6. Vertical Pointed Twill
7. Herringbone Twill
8. Horizontal Herringbone Twill
9. Vertical Herringbone Twill
10. Skip Twill
11. Diamond Weave
12. Pointed Twill Base Diamond
13. Herringbone Twill Base Diamond
14. Combination Twill
15. Combined Twill
16. Broken Twill
17. Elongated Twill
18. Transposed Twill

Satin/Sateen

Satin/sateen is a basic weave that does not have any regular pattern like twill. The surface of the fabric is either warp or weft faced. Satin is warp faced, which means that all the surface of the fabric will show the warp threads except for the one thread interlacement with other series of yarn. If it is weft faced, then it will be known as sateen, which means that fabric surface will show the weft threads mostly. The unique in this weave is the single inter¬lacement of warp thread and weft thread in a single repeating unit. These weaves have the least interlacement points among the basic weaves. Due to this reason, it gives the surface of fabric more luster and smoothness. Along with these properties, more close packing of the threads is possible, which gives the maximum achievable cover factor in this weave. With this weave it is possible to use a cotton warp and silk filling, having most of the silk appear on the surface of the fabric.

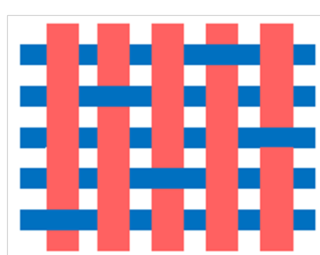


Figure: Satin weave

Honey Comb Weave

This name is given to this weave due to its honey bee web-like structure. It makes ridges and hollow structures which finally give a cell-like appear¬ance. In this weave, both warp and weft threads move freely on both sides, which coupled with rough structure. The fabric made by this weave has longer float all over the fabric. Due to this reason, it is radially absorbent of moisture. This property made these weaves useful for towels, bed covers, and quilts. This weave is further divided into three types which are explained below. Most commonly, these weaves are constructed on repeats which are multiple of four in ends and picks.

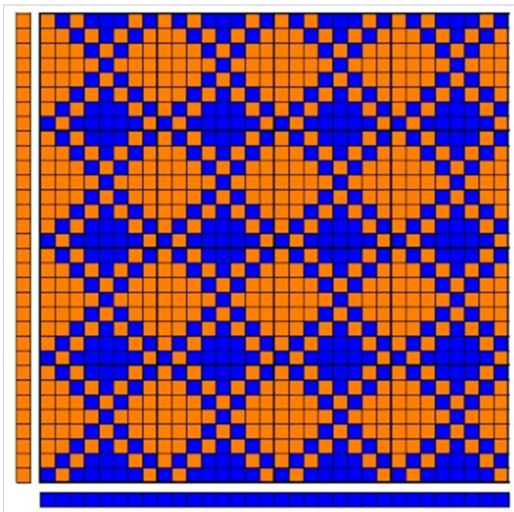


Figure: Honeycomb weave

Honey comb weave are three types:

- Single-Ridge Honey Comb
- Double-Ridge Honey Comb
- Brighton Honey Comb

Huck a Back Weave

This weave is largely used for cotton towel and linen cloth. It has longer floats in two quadrants, which make them more moisture absorbent so employed in towels. This weave is combination of longer floats of symmetric weaves in two quadrants and plain weaves in the remaining two quadrants. Plain weave gives firmness to the structure, while longer float weave increases the absor¬bency of fabric, making it suitable for the above-stated purpose. Special draft is employed for this weave. The draft is arranged in such a way that odd ends are drawn in two front heald frames and the even threads are drawn from back two heald frames. The purpose of this special draft is to weave plain fabric without redrawing of beam. For this purpose, heald frame one and two are coupled together, and heald frames three and four are coupled together. Sometimes, longer float symmetric weaves are used in combination of plain weaves in huck a back weave, which is also termed as honey comb huck a back weaves.

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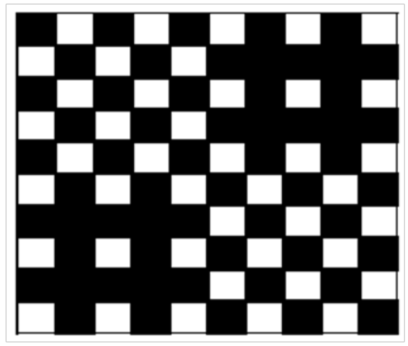

Figure: Huck a back weave

Crepe Weave

Crepe weave refers to those weaves that do not have any specific pattern. These weaves may contain a little bit appearance of twills, but they do not have the prominence. They make small patterns or minute spots and seed-like appearance all over the fabric surface. These weaves may be used separately or in combination with other weaves. Crepe weaves are frequently employed in making the ground of the figured fabrics. In simple words, crepe weave is used to make a rough appearance. If we make crepe weaves with crepe yarns, this combination will give more remarkably pebbly or puckered appearance. Crepe weaves can be drawn in several ways, but the most common methods are given below.

- Sateen Method
- 1/4 Turn Method
- Reversing Method
- Super Imposed Method
- Plain Method

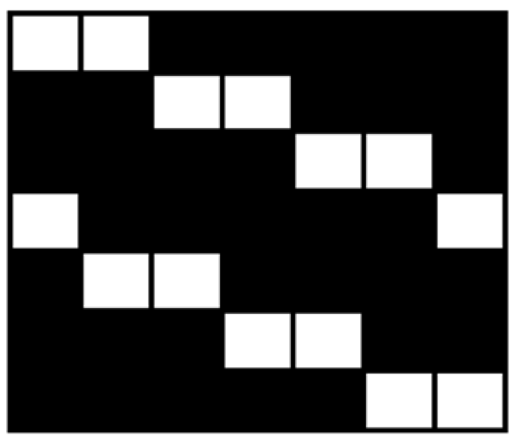

Figure: Crepe (sateen based), 7 end.

Bedford Cord Weave

This is a special class of weave that forms longitudinal warp lines in fabric with fine sunken lines in between. This fabric is used in suiting for orna¬mental purposes.

The method to construct this weave is simple. The repeat of the weave is calculated by multiplying the cord ends by two. The resultant value will be the total number of ends of the weave repeat. The pick repeat is four for this weave. The weave repeat (warp ends) is divided into two halves to construct it. The first and last ends of both the halves are treated as cutting ends. Plain weave is inserted on these cutting ends. These plain ends behave as sunken ends in the Bedford cord.

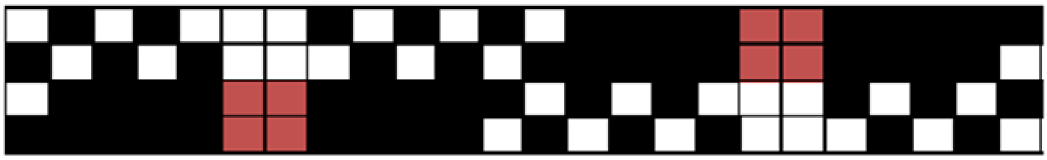

Figure: Bedford cord weave, 10 threads cord with 2 waded ends

Welts and Pique

A pique weave consists of plain face fabric which is composed of a series of warp and weft threads along with a series of stitching threads. This weave is unique due to the formation of horizontal lines (weft wise). This weave requires two beams, one for the plain weave threads and the other for stitching ends. The word "welt" is concerned to the pique construction, when the indenta¬tions make deep or hollow (sunken) lines appear in the cloth.

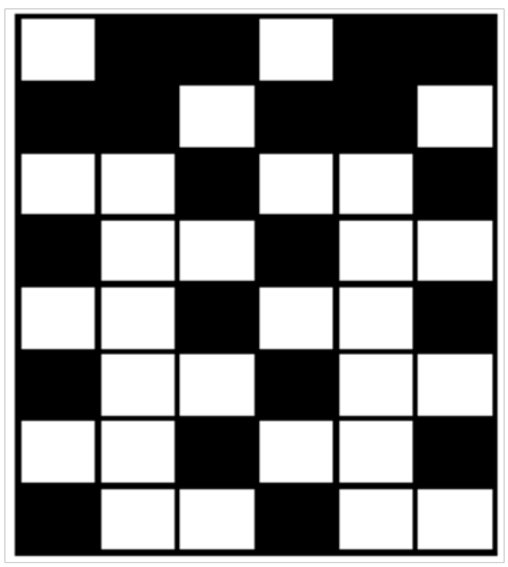

Figure: Welts and pique weave

Mock Leno Weave

This weave is much similar to a gauze-type fabric. The weave is constructed in four quadrants. The first and third quadrants have symmetric weave, and the second and fourth quadrants have opposite weave to the symmetric weave. The perforated fabrics are made by this type of weave. This effect is achieved by reversing the symmetric unit of the weave in the alternate quadrants. So, these weaves are produced in sections that oppose each other. The fabric appearance can be improved or obscured by the system of denting that is employed in this weave. The tendency of threads to run together is counteracted if the last end of one group is passed through the same split as the first end of the next group.

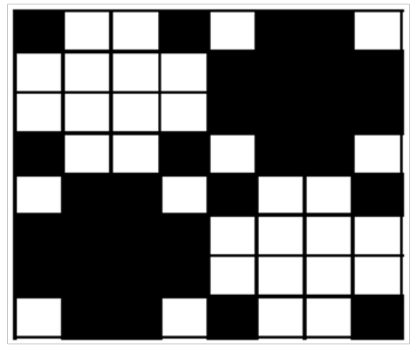

Figure: Mock leno weave

Classification of Fabric Weave Patterns

List of fabric weave patterns | type of fabric weave patterns 1 fabric weave pattern names

In the simplest weaving arrangement, alternate warp yarns are over or under the shuttle as it moves in one direction and the warp yarn positions are reversed for the return stroke of the shuttle. This weave can be made on a loom with only two harnesses. In other arrangements, several warp yarns may be moved upward or downward together, or several filling picks may take place before the warp yarns change position.

The two major categories based on the types of weaves are Basic or Simple weave and Compound or complex weaves which are further categorized into the following categories:

Basic/Simple Weaves

1. Plain Weave
2. Twill Weave
3. Satin Weave

Compound/Complex/Novelty Weaves

1. Dobby Weave
2. Jacquard Weave
3. Double Cloth & Double Weave
4. Pique
5. Pile Fabrics
6. Surface Figure Weaves

Basic/Simple Weaves

Plain Weave

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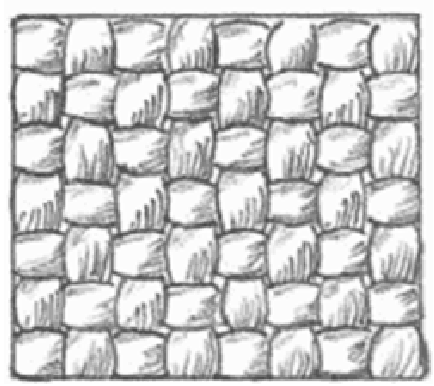
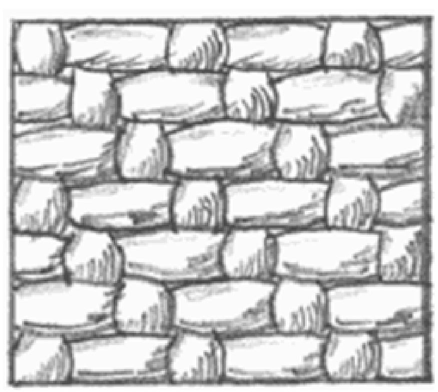


Plain weave, also called taffeta. Filling yarns pass over and under alternate warp yarns. Other plain weaves are broadcloth, muslin, batiste, percale, seersucker, organdy, voile, and tweed.

Simplest weave requiring a 2 harness loom, formed by yarns at right angles whereby each warp yarn interlaces with each weft yarn Properties: least expensive to produce, reversible unless surface design, wrinkles more, firm & wears well, less absorbent, abrasion resistant, used as background for printing/ embroidery

- **Rib Weave fabrics:** Rib effect is produced by using heavy yarns in the filling direction or by more warp than
- filling yarns per inch. Eg Bengaline, ottoman, faille, poplin, broadcloth, taffeta.
- **Basket Weave fabrics:** Basketweave is made by treating two or more yarns as one in either the warp or weft or
- both the directions and interlacing them in plain weave. It is not as firm as plain weave, have more yarn slippage, shrinks easily. Eg 2X1, 2X2, 2X4, 3X2, 4X4. Oxford cloth is 2X1 & monk cloth is 4X4. Flat duck, hopsacking, Panama are other examples.

Twill Weave



Twill weave. Filling yarns pass over two warp yarns and under a third, and repeat the sequence for the width of the fabric. The next filling yarn repeats the sequence but shifts one warp yarn sideways, creating a diagonal pattern. Herringbone, serge, jersey, foulard, gabardine, worsted cheviot, and drill are twill weaves.

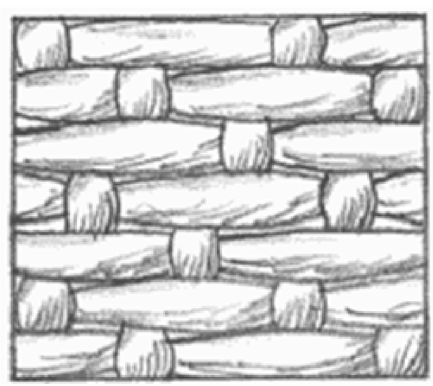
NOTES

Each warp or weft yarn floats across two or more weft or warp yarns with a progression of interlacing by one to the right or to the left, forming a distinct diagonal line or wale.

The direction of diagonal may be formed from right to left, from left to right or a combination of both. Soil resistant, softer & pliable, good wrinkle recovery, durable & wears well. The direction of the twill on the back of the cloth is opposite to the twill line on the face. 3 harness is required for twill weave.

- **Right Hand Twill** – diagonals run upwards to the right
- **Left Hand Twill** – diagonals run upwards to the left.
- **Balanced Twill** – the same number of warp pass over filling yarns. It is reversible. 2X2, 4X4
- **Unbalanced Twill** – have an uneven warp or filling yarn. It has a right or wrong.
- **Broken Twill** – combines right or left-hand twills
- **Herringbone Twill** – a series of inverted V's are formed resembling the backbone of the
- herringbone fish. Most commonly used in suiting fabrics.
- **Twill Angles** – according to the angles of the diagonal line, Regular twill – 45° °
- **Reclining twill** – with smaller angles, Steep twill – with larger angles. E.g.: denim, herringbone, houndstooth

Satin Weave



Satin weave. Filler yarns pass over a number of warp yarns, four in this illustration, and under the fifth. Damask, sateen, and crepe satin are satin weaves. Exposed yarns reflect light and give the weave its sheen.

Each warp/ filling yarn floats over 4 filling/ warp yarns & interlaces with 5th filling/ warp yarn, with a progression of interlacing by 2 to right or left (warp-faced/ weft faced). Luster (long floats), firm, durable (yarns packed closely together), pliable, wrinkle resistant,

yarn slippage. Satin is warp faced. Sateen is weft-faced. 5 harness is required for a satin weave.

Compound/Complex/Novelty Weaves/ Figure/ Decorative weave

Dobby Weave

Small figured designs (floral or geometrical) woven repeatedly throughout the fabric, produced by a combination of two or more basic weaves, using a dobby attachment on the loom. Weaving pattern controlled by a plastic tape with punched holes that control
the raising & lowering of warp yarns. It uses up to 32 harnesses.

Jacquard Weave

Characteristics: highly intricate large designs using colored yarns and multi-weaves produced on a loom with jacquard attachment. Incorporates all 3 basic weaves & their combination. Each warp yarn is controlled separately by punched cards that are laced together in a continuous strip. Are more expensive. Used for home furnishing, apparel, elaborate & decorative fabrics. Eg Brocade, Damask, tapestry, brocatelle, matelasse

Surface Figure /Extra Yarn Weaves

Extra warp or weft yarn introduced in fabric to produce designs at regular intervals.
Between 2 motifs, extra yarn floats across the back of the fabric.

- **Clipped / unclipped Spot** – embroidery-like design is achieved through either extra warp or weft yarn. Long floats on the back when a cut is called Clipped Spot.
- **uncut** – Unclipped Spot.
- **Swivel** – contains extra filling yarns. In this weave, the extra yarn is interlaced with the background at different places to avoid pulling. These are stronger than Spot weave.
- **Lappet** – contains extra warp yarns.

Pique

Lightweight to heavyweight cotton fabric with a raised woven design. Lengthwise wales or cords on the face of fabric (formed by extra warp yarns) that are held in place by crosswise weft floats on the back of the fabric. Extra warp yarns (stuffer yarns) do not show on the face of the fabric. They are not interwoven but laid under the cords to emphasize the quilted effect. Made of dobby or jacquard loom. Eg waffle, huck toweling, granite, honeycomb, bedcord, pique

Double Cloth

They are made with 3, 4 or 5 sets of yarn. Two fabrics are woven together on the same loom, one above the other & laced together with an extra set of warp or weft yarns called binder yarns (5 sets of yarns). Pile fabrics are commonly prepared by this method. Produces a variety of fabrics, reversible, stable, may have different color or design on the two sides. Used for upholstery, drapery, and heavy apparels.

Other Special Weaves

Crepe Weave

Crinkled or pebbly surface. Irregular, indistinct pattern utilizing both plain and satin weave using dobby attachment are made. Few crepe weave fabric is available.

Other crepe fabrics are created using crepe yarn which is highly twisted (up to 65 tpi).

Textured yarns, bicomponent yarns (uneven shrinkage), embossing, stamping crepe like effect are being used. In all these plain weaves, synthetic fibers and thermoplastic property are used.

Leno Weave

It is the form of weaving in which two adjacent warp yarns cross each other between the picks. The warp yarns are paired. With a special leno or doup, attachment warp yarns are crossed/ twisted over each other in pairs around each pick, firmly holding the filling yarn. Leno fabrics are open and gauge like. Leno weave is useful in reducing yarn slippage, greater firmness & strength than plain weave. Uses-curtain, gauge, marquisette, grenadine, fruit sacks, rice net, mosquito net, mesh.

Colour & Weave Effect

A pattern produced in a fabric by using a certain weave and a certain arrangement of differently colored yarns in both warp and filling.

Hound's tooth – 2 up, 2 down, 45° left-hand twill, and a group of 4 yarns of one color are arranged in both warp & filling followed by the other color.

Lappet weave

This is the type of weave in which floating threads are carried on the surface of the fabric and introduced at intervals to form the patterns. The floats are not long and the patterns are usually geometric, i.e. zigzag stripes in white yarn on a colored plain weave ground.

Novelty weave

Any weave which varies or combines the basic weaves, plain, satin and twill.

Swivel weaving

A fabric in which figure is achieved by the introduction of additional weft threads into base fabric to produce small clipped woven-in-spot effects. The figuring yarn is fed from a series of shuttles mounted over the top of the weaving surface.

Tablet Weaving

It is a method of making woven plain or patterned narrow fabrics, where the warp is controlled by tablets made of thin, stiff material, e.g. cardboard, plastic, bone, etc. Tablets are usually about 5 to 10 cm square, although other shapes, e.g. triangles, hexagons, etc. are also used. Each tablet has a hole at each corner through the warp yarns are threaded. Rotating the tablets controls the rise and fall of the warp yarns.

Woven Pile Fabrics

3-dimensional fabrics, utilizing 3 sets of yarns, warp & weft to form base fabric & extra set of warp or weft yarns to form pile or loop surface. Extra set of yarns forming the pile may be cut to produce an erect pile on the face of fabric – Cut Pile – velvet or left uncut to form loops on one or both sides of fabric- Uncut pile – terry.

- **Warp pile fabric –** velvet, plushes, terry, velour.
- **Weft pile fabric –** velveteen, corduroy

Triaxial Fabric

Triaxial fabrics have 3 set of yarns, 2 warp & 1 filling. The warp yarns are placed diagonally to each other by special attachments, through which the filling yarn is interlaced. It is an ancient weave used in basket weaving. Stability against stretching in all direction even bias, strong resistance, resistance to shear forces & raveling. Lighter, longer life & less material required than biaxial fabrics. Three major weaves – basic triaxial weave, basic basket triaxial weave & biplane weave.

Uses – aerospace, industrial fabrics, sailcloth, balloon, truck covers, uniforms & outerwear.

Terry Fabric

A warp pile fabric in which loops are created, without positive assistance, by varying the relative positions of the fell and the reed. A high tension is applied to the ground warp and a very low tension to the pile warp.

Narrow Fabric

This is the type of any textile fabric made by interlacing fibers or yarns which does not exceed 45 cm (in the U. K.) and does not exceed 30 cm (in the U. S. A. and other countries). Narrow fabrics are characterized by the edges, which are the essential feature.

4.5 STUDENT ACTIVITY

1. What is Woven and Weaving Process? Explain the Types of Weaves?

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2. What is Loom? Explain Loom and its Parts?

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4.6 LOOM AND ITS PARTS

A **loom** is a device used to weave cloth and tapestry. The basic purpose of any loom is to hold the warp threads under tension to facilitate the interweaving of the weft threads. The precise shape of the loom and its mechanics may vary, but the basic function is the same.

Types of looms

Back strap loom

Woman weaving a silk rebozo on a backstrap loom at the Taller Escuela de Rebocería in Santa Maria del Rio, San Luis Potosí

The back strap loom is a simple loom that has its roots in ancient civilizations. The Andes Textiles, still made today with the back strap loom, originated thousands of years ago with the same back strap loom process. It consists of two sticks or bars between which the warps are stretched. One bar is attached to a fixed object and the other to the weaver, usually by means of a strap around the back. The weaver leans back and uses her body weight to tension the loom. On traditional looms, the two main sheds are operated by means of a shed roll over which one set of warps pass, and continuous string heddles which encase each of the warps in the other set. To open the shed controlled by the string heddles, the weaver relaxes tension on the warps and raises the heddles. The other shed is usually opened by simply drawing the shed roll toward the weaver.

Both simple and complex textiles can be woven on this loom. Width is limited to how far the weaver can reach from side to side to pass the shuttle. Warp faced textiles, often decorated with intricate pick-up patterns woven in complementary and supplementary warp techniques are woven by indigenous peoples today around the world. They produce such things as belts, ponchos, bags, hatbands and carrying cloths. Supplementary weft patterning and brocading is practiced in many regions. Balanced weaves are also possible on the backstrap loom. Today, commercially produced backstrap loom kits often include a rigid heddle.

Warp-weighted loom

The warp-weighted loom is a vertical loom that may have originated in the Neolithic period. The earliest evidence of warp-weighted looms comes from sites belonging to the Starčevo culture in modern Serbia and Hungary and from late Neolithic sites in Switzerland. This loom was used in Ancient Greece, and spread north and west throughout Europe thereafter. Its defining characteristic is hanging weights (loom weights) which keep bundles of the warp threads taut. Frequently, extra warp thread is wound around the weights. When a weaver has reached the bottom of the available warp, the completed section can be rolled around the top beam, and additional lengths of warp threads can be unwound from the weights to continue. This frees the weaver from vertical size constraint.

Drawloom

A drawloom is a hand-loom for weaving figured cloth. In a drawloom, a "figure harness" is used to control each warp thread separately. A drawloom requires two operators, the weaver and an assistant called a "drawboy" to manage the figure harness. The earliest confirmed drawloom fabrics come from the State of Chu and date c. 400 BC. Most scholars attribute the invention of the drawloom to the ancient Chinese, although some speculate an independent invention from ancient Syria since drawloom fabrics found in Dura-Europas are thought to date before 256 AD. The draw loom for patterned weaving was invented in ancient China during the Han Dynasty. Chinese weavers and artisans used foot-powered multi-harness looms and jacquard looms for silk weaving and embroidery; both of which were cottage industries with imperial workshops. The Chinese-invented drawloom enhanced and sped up the production of silk and play a significant role in Chinese silk weaving. The loom was later introduced to Persia, India, and Europe.

Handloom

A handloom is a simple machine used for weaving. In a wooden vertical-shaft looms, the heddles are fixed in place in the shaft. The warp threads pass alternately through a heddle, and through a space between the heddles (the shed), so that raising the shaft raises half the threads (those passing through the heddles), and lowering the shaft lowers the same threads — the threads passing through the spaces between the heddles remain in place. This was a great invention in the 13th century.

Flying shuttle

Hand weavers could only weave a cloth as wide as their armspan. If cloth needed to be wider, two people would do the task (often this would be an adult with a child). John Kay (1704–1779) patented the flying shuttle in 1733. The weaver held a picking stick that was attached by cords to a device at both ends of the shed. With a flick of the wrist, one cord was pulled and the shuttle was propelled through the shed to the other end with considerable force, speed and efficiency. A flick in the opposite direction and the shuttle was propelled back. A single weaver had control of this motion but the flying shuttle could weave much wider fabric than an arm's length at much greater speeds than had been achieved with the hand thrown shuttle.

The flying shuttle was one of the key developments in weaving that helped fuel the Industrial Revolution. The whole picking motion no longer relied on manual skill and it was just a matter of time before it could be powered.

Haute-lisse and basse-lisse looms

Looms used for weaving traditional tapestry are classified as haute-lisse looms, where the warp is suspended vertically between two rolls. In basse-lisse looms, however, the warp extends horizontally between the two rolls.

Traditional looms

Several other types of hand looms exist, including the simple frame loom, pit loom, free-standing loom, and the pegged loom. Each of these can be constructed, and provide work and income in developing economies.

The earliest evidence of a horizontal loom is found on a pottery dish in ancient Egypt, dated to 4400 BC. It was a frame loom, equipped with foot pedals to lift the warp threads, leaving the weaver's hands free to pass and beat the weft thread.

Power looms

Edmund Cartwright built and patented a power loom in 1785, and it was this that was adopted by the nascent cotton industry in England. The silk loom made by Jacques Vaucanson in 1745 operated on the same principles but was not developed further. The invention of the flying shuttle by John Kay was critical to the development of a commercially successful power loom. Cartwright's loom was impractical but the ideas behind it were developed by numerous inventors in the Manchester area of England where, by 1818, there were 32 factories containing 5,732 looms.

Horrocks loom was viable, but it was the Roberts Loom in 1830 that marked the turning point. Incremental changes to the three motions continued to be made. The problems of sizing, stop-motions, consistent take-up, and a temple to maintain the width remained. In 1841, Kenworthy and Bullough produced the Lancashire Loom which was self-acting or semi-automatic. This enables a youngster to run six looms at the same time. Thus, for simple calicos, the power loom became more economical to run than the hand loom – with complex patterning that used a dobby or Jacquard head, jobs were still put out to handloom weavers until the 1870s. Incremental changes were made such as the Dickinson Loom, culminating in the Keighley-born inventor Northrop, who was working for the Draper Corporation in Hopedale producing the fully automatic Northrop Loom. This loom recharged the shuttle when the pirn was empty. The Draper E and X models became the leading products from 1909. They were challenged by synthetic fibres such as rayon. By 1942, faster, more efficient, and shuttleless Sulzer and rapier looms had been introduced. Modern industrial looms can weave at 2,000 weft insertions per minute.

Weft insertion

Different types of looms are most often defined by the way that the weft, or pick, is inserted into the warp. Many advances in weft insertion have been made in order to make manufactured cloth more cost effective. There are five main types of weft insertion and they are as follows:

- **Shuttle:** The first-ever powered looms were shuttle-type looms. Spools of weft are unravelled as the shuttle travels across the shed. This is very similar to projectile methods of weaving, except that the weft spool is stored on the shuttle. These looms are considered obsolete in modern industrial fabric manufacturing because they can only reach a maximum of 300 picks per minute.

- **Air jet:** An air-jet loom uses short quick bursts of compressed air to propel the weft through the shed in order to complete the weave. Air jets are the fastest traditional method of weaving in modern manufacturing and they are able to achieve up to 1,500 picks per minute. However, the amounts of compressed air required to run these looms, as well as the complexity in the way the air jets are positioned, make them more costly than other looms.
- **Water jet:** Water-jet looms use the same principle as air-jet looms, but they take advantage of pressurized water to propel the weft. The advantage of this type of weaving is that water power is cheaper where water is directly available on site. Picks per minute can reach as high as 1,000.
- **Rapier loom:** This type of weaving is very versatile, in that rapier looms can weave using a large variety of threads. There are several types of rapiers, but they all use a hook system attached to a rod or metal band to pass the pick across the shed. These machines regularly reach 700 picks per minute in normal production.
- **Projectile:** Projectile looms utilize an object that is propelled across the shed, usually by spring power, and is guided across the width of the cloth by a series of reeds. The projectile is then removed from the weft fibre and it is returned to the opposite side of the machine so it can get reused. Multiple projectiles are in use in order to increase the pick speed. Maximum speeds on these machines can be as high as 1,050 ppm.

Shedding

Dobby looms

A dobby loom is a type of floor loom that controls the whole warp threads using a dobby head. Dobby is a corruption of "draw boy" which refers to the weaver's helpers who used to control the warp thread by pulling on draw threads. A dobby loom is an alternative to a treadle loom, where multiple heddles (shafts) were controlled by foot treadles – one for each heddle.

Jacquard looms

The Jacquard loom is a mechanical loom, invented by Joseph Marie Jacquard in 1801, which simplifies the process of manufacturing textiles with complex patterns such as brocade, damask and matelasse. The loom is controlled by punched cards with punched holes, each row of which corresponds to one row of the design. Multiple rows of holes are punched on each card and the many cards that compose the design of the textile are strung together in order. It is based on earlier inventions by the Frenchmen Basile Bouchon (1725), Jean Baptiste Falcon (1728) and Jacques Vaucanson (1740). To call it a loom is a misnomer, a Jacquard head could be attached to a power loom or a hand loom, the head controlling which warp thread was raised during shedding. Multiple shuttles could be used to control the colour of the weft during picking. The Jacquard loom is the predecessor to the computer punched card readers of the 19th and 20th centuries.

Different Parts of Loom and Their Functions

Textile Weaving Machine Parts

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Weaving is the process of interlacement between the weft and warp in fabric according to a design of fabric. This process is done by using weaving machine or loom machine. This chapter has presented all the parts of loom machine or weaving machine with their functions.

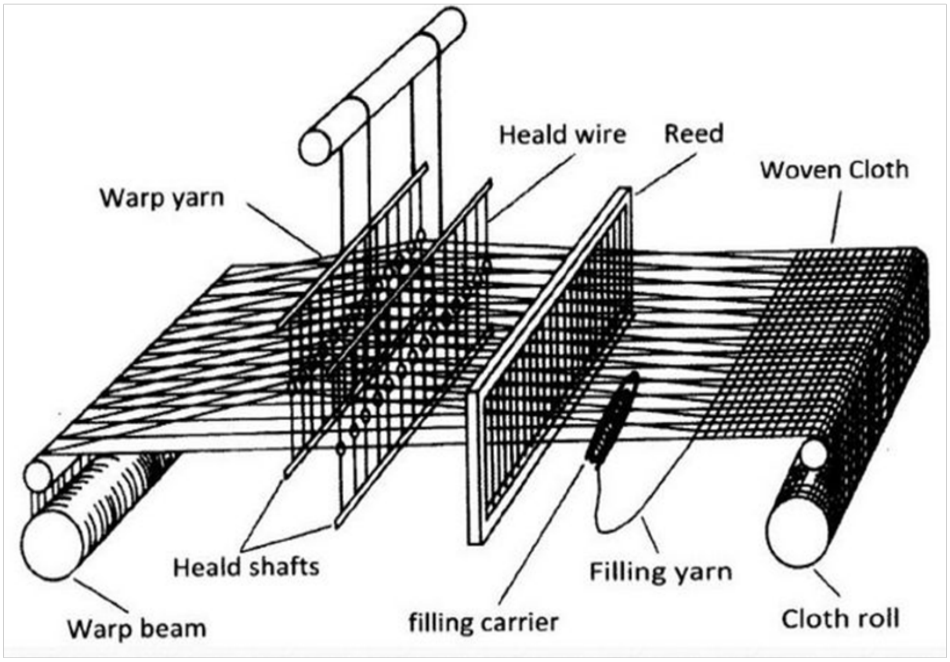

Fig: Basic structure of weaving loom machine

Different Parts of Weaving Machine in Textile

Weaving machines consist of the below parts:

1. Heald shaft,
2. Sley or lay,
3. Shuttle,
4. Shuttle ox,
5. Reed,
6. Picker,
7. Warp beam,
8. Back beam,
9. Breast beam,
10. Cloth beam.

Functions of the Parts of a Loom

Functions of all the above loom parts have described in the following:

1. **Heald Shaft:** This part is related to the shedding mechanism. In textile weaving industry, heald shaft is produced by using metal such as aluminium or wood. It carries a number of heald wires through which the ends of the warp sheet pass. The heald shafts are also termed as 'heald staves' or 'heald frames'. The total no. of heald shafts varies according to the warp repeat of the weave. It is decided by the drafting plan of a weave during weaving.

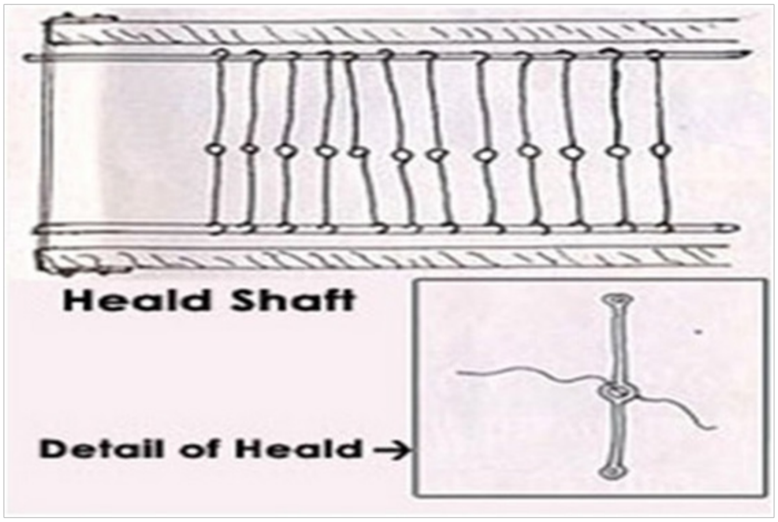

Fig: Heald shaft in weaving loom

Functions of Heald Shaft in Weaving:

- Heald shaft helps in weaving shed formation.
- It also maintains the sequence or order of the warp threads.
- Heald shaft determines the warp thread density in a fabric, i.e. the numbers of heald wires per inch determine the warp thread density per inch.
- It apprehends the order of lowering or lifting the necessary no. of healds for a pick. It helps in forming the design or pattern in a fabric.
- Heald shaft is useful in identifying broken warp threads in weaving.

2. **Sley of Lay:** It is made of wood and consists of the sley race board or sley race, reed cap and metal swords carried at either ends. The sley mechanism swings to and fro.

Functions of Sley of Lay:

- Sley is responsible for pushing the last pick of weft to the fell of the cloth by means of the beat up motion during.
- When moving towards the fell of the cloth the sley moves faster and moves slower when moving backwards. This unequal movement is termed as 'eccentricity of the sley'.
- In order to perform the beat up and also to give sufficient time for passage of shuttle to pass through the warp shed sley is needed in textile weaving.

3. **Shuttle:** In textile weaving, shuttle is a weft carrier and helps in interlacement

of the weft with the warp threads to form fabric.

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Fig: Shuttle in weaving loom

Functions of Shuttle:

- The shuttle is made of wood which passes from one end of the loom to the other.
- Shuttle travels along the wooden sley race and passes between the top and bottom layers of the warp sheet.
- After passing through the warp shed, shuttle enters a shuttle box fitted at either ends of the loom. It should be noted here that, a shuttle normally weighs about 0.45kgs.

4. **Functions of Shuttle Box:** Shuttle box is the housing for the shuttle and is made of wood. It has a picker and a spindle. It may also accommodate the picker without spindle. The top and side of the shuttle box unto the sley race are open. The shuttle dwells inside the box for the intermediate period between two successive picks.
5. **Reed:** Reed is a metallic comb which is fixed to the sley with a reed cap. In textile, shuttle is made of a no. of wires and the gap between wires is termed as dents. The count of the reed is decided by the no. of dents in two inches. There are different types of reed in textile weaving such as ordinary reed, expanding reed, gauze reed, V reed etc.

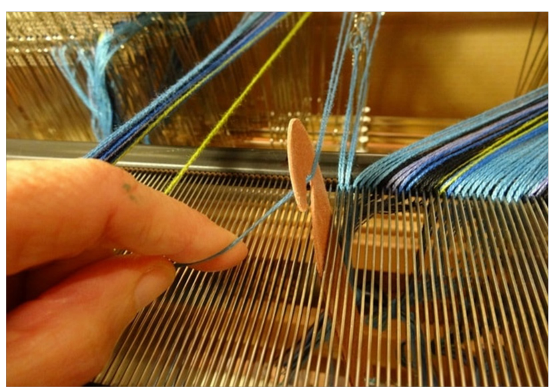

Fig: Reed in weaving loom

Functions of Reed:

- Reed pushes the lastly laid pick of weft to the cloth fell.

- It determines the fineness of the cloth in conjunction with the healds.
- Reed acts as a guide to the shuttle which passes from one end of the loom to the other.
- It helps to maintain the position of the warp threads.
- Reed determines the openness or closeness of the fabric.

6. **Functions of Picker:** Picker is a piece made either of synthetic material or leather. Picker may be placed on a grooves or spindle in the shuttle box. Picker is used to drive the shuttle from one box to another. While entering the box it also sustains the force of the shuttle.
7. **Functions of Warp Beam:** Warp beam is also known as the weaver's beam. It is fixed at the back of the loom. The warp sheet is wounded on to the warp beam. The length of warp in the beam may be more than a thousand meters.

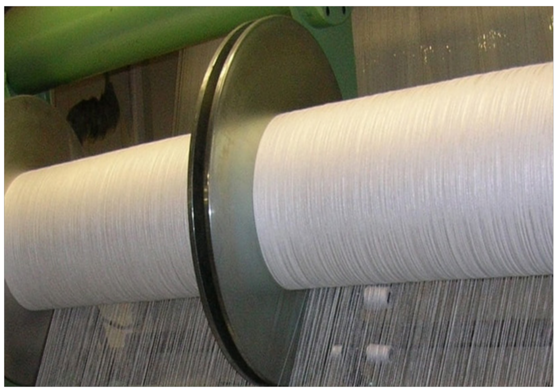

Fig: Warp beam in weaving loom

8. **Functions of Back Beam:** Back Beam is also known as the back rest. It is placed above the weaver's beam. Back Beam may be of the floating or fixed type. The back rest merely acts as a guide to the warp sheet coming from the weaver's beam in the first case. Back beam acts both as a sensor and as a guide for sensing the warp tension in the second case.
9. **Functions of Breast Beam:** Breast beam is also termed as the front rest. At the front of the loom, it is placed above the cloth roller and acts as a guide for the cloth being wound on to the cloth roller. It maintains proper tension to facilitate weaving.
10. **Functions of Cloth Beam:** Cloth beam is also called as the cloth roller. The woven fabric is wounded on to this roller. Cloth beam roller is placed below the front rest. It is also termed as the cloth roller. The woven fabric is wounded on to this roller. This roller is placed below the front rest.

Fig: Cloth beam in weaving loom

Different Parts of a Loom

Different Parts of a Loom

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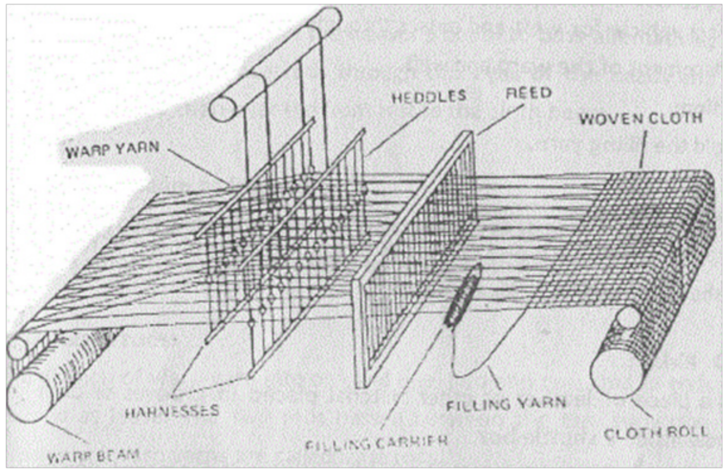

Fig. Different Parts of a Loom

Short Description of Loom is Given Below:

Heald/Heddle: Wire or cords with eyelets that hold warp yarns in a place.

Function:

1. It helps in shed formation.
2. It is useful in identifying broken ends.
3. It determines the order or sequence of the warp threads.
4. It determines the warp thread density in a fabric.

- **Heald shaft/Harness:** A wood or metal frame that holds the headl/heddles in position in the loom during weaving. It is usually more than one.
- **Shuttle:** This is a vehicle for weft & passes through the divided warp for the interlacement of the warp & weft.
- **Shuttle box:** Compartment of each end of the sley of a shuttle loom used to retain the shuttle between picking motion.
- **Picker:** It is a piece of leather or other metal placed in grooves or on a spindle inside a shuttle box.
- **Beams:** A cylindrical body with end flanges on which a multiple of warp ends is wound in such way to permit the removal of these yarns as a warp sheet.
- **Front rest:** It is a fixed roller placed in front of the loom above the cloth beam & act as a guide for the cloth to wind on to the cloth beam.
- **Lease rods:** The division of warp yarn into one & one, two & two, & so on is termed as lease. The two rods passed between the two successive divisions of warp yarns are called lease rods.
- **Slay:** It is the portion of loom that carries the reed and oscillates between the harness & the fell of the cloth.

- **Reed:** A comb like wire or device used to separate yarns on a loom & to beat up the filling during weaving.
- **Treadle:** The treadle is a paddle or lever under a loom with which a thread is connected by means of cords.
- **Temple:** Roller device on a loom that hold the cloth at a proper width to prevent it from being drawn in too much by the filling.

Description of the Basic Parts of a Loom

Clothes are second basic need of human being.people make clothes by using a method which interlacing the different types of yarns together. This process is popularly known as 'weaving'. Textile weaving is as old as our civilization. Weaving is practised all over the globe.looms are the most well known word to the people in terms of weaving. The main function of the loom is to weave clothes. For enhancing the working capabilities, the size and shape of the looms may vary but the basic structure of all types of looms are same. There are many types of looms are available in this era. Some of them are:

1. Back strap loom
2. Warp weighted loom
3. Draw loom
4. Handloom
5. Haute lisse loom
6. Power loom etc.

All these looms have the same basic structures.from this chapter we will know about the main parts of loom elaborately.

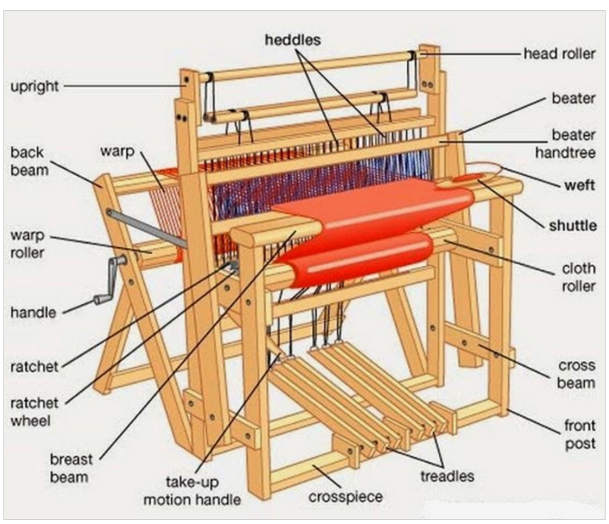

Fig. Basic Parts of a Loom

1. **Heald:** It is also called Heddle. It holds the warp yarns in a place.It also helps in shed formation. It is used for determining the warp thread density in a fabric.
2. **Heald shaft:** It is also known as harness.the wood or metal frame that holds the heddles in a certain position in the loom is called harness. Number of harness

available in loom usually more than one.

3.**Shuttle:** This is used for the interlacement of the warp & weft yarns.

4. **Shuttle box:** It is a box which is used to retain the shuttle in the picking motion.

5. **Picker:** It is placed in the shuttle box. It may be formed by leather or other metals.

6. **Beams:** It is a cylindrical body in which the multiple warp ends is used in such way that permits the removal of yarns as a warp sheet.

7. **Front rest:** It is a fixed roller placed in front of the loom.it is situated above the cloth beam & work as a guide for the cloth to wind.

8. **Lease rods:** The division of warp yarns into one & one, two & two etc is termed as lease. The two rods passed between the two divisions of warp yarns. Those are called lease rods.

9. **Slay:** Slay contains the reed.

10. **Reed:** It is generally comb which is used to separate yarns.it also beats up the yarns in weaving process.

11. **Treadle:** The treadle is a paddle or lever placed under a loom.here a thread is connected with the help of cords.

12. **Temple:** It is the roller device on a loom that hold the cloth at a proper width.

4.7 SUMMARY

Today the textile industry encompasses a significant number and variety of processes that are adding value in fiber. These processes may range over the yarn making through the garment stitching, fabric embossing, and composite production. However, considering the textile fiber as the basic building unit of any textile product, the textile manufacturing may clearly be identified as the conventional and technical textiles.

The conventional textile manufacturing process has a long history of converting the natural fiber into useful products including fabric, home textiles, and apparel and more recently into a technical textile through the utilization of special finishing effects.

The synthetic and semisynthetic fiber manufacturing is diversified with the utilization of monomer, chemical agent, precursor, catalyst, and a variety of auxiliary chemicals resulting in the formation of fiber or yarn. However, such man-made fibers are perceived as a separate specialized subject and beyond the scope of this book. Therefore, the man-made fiber manufacturing is not discussed.

The innovation in textile manufacturing introduced variety in raw materials and manufacturing processes. Therefore, process control to ensure product quality is desired. Monitoring and controlling of process parameters may introduce reduction in waste, costs, and environmental impact.

All the processing stages in textile manufacturing from fiber production to finished fabric are experiencing enhancement in process control and evaluation. It includes textile fiber production and processing through blow room, carding, drawing, and combing; and fabric production including knitted, woven, nonwoven, and subsequent coloration and finishing and apparel manufacturing.

The global textile industry, in yarn and fabric production, has strong presence and experiencing growth. In 2016, the yarn and fabric market was valued at USD 748.1 billion, where the fabric product was more in consumption and contributed 83.7% and the yarn product was at 16.3%. The market consumption is forecasted for growth at CAGR of 5.1% between 2016 and 2021, reaching to a market value of USD 961.0 billion in 2021.

Apparel production is another important area in textile manufacturing around the textile industry chain. Probably the apparel is what an individual wear for the purpose of body coverage, beautification, or comfort. Apparel and garment terms are used interchangeably. However, the two terms may be differentiated as apparel is an outerwear clothing and garment is any piece of clothing.

The study of apparel manufacturing market includes all the clothing articles except leather, footwear, knitted product, and technical, household, and made-up items. The worldwide apparel manufacturing market was valued at USD 785.0 billion in 2016 and estimated to reach the level of USD 992 billion in 2021. The market enhancement is forecasted to move from 2016 to 2021 at CAGR of 4.8%.

The Manufacturing Process of Fabric: There are three basic steps required for fabric production. The first step in creating fabric is yarn production. Here, the raw materials that have been harvested and processed are transformed from raw fibers into yarn and threads. This is done by spinning the fibers. Spinning can be done by hand, but this process is quite tedious and time consuming. These days, the vast majority of spinning is done by spinning wheel. The fibers are drawn across the wheel, and as it spins, the fibers are collected on a cylindrical object called a bobbin. The bobbin holds the spun fibers, which are now connected into a long strand of thread or yarn. In the next step, the bobbins will be transferred to another machine, where the yarn will continue on its journey into fabric.

After the raw materials have been converted into yarn, they're ready for the second step in the production process, which involves joining these individual threads together to form fabric. This process of joining the yarn together is called weaving. Weaving is done on a machine known as a loom and requires two sets of yarn. The first set, called the warp set, is strung tautly across a metal frame. The second, called the weft, is connected to metal rods, with one thread per rod. The loom is controlled by a computer, which lets the weft know how the fabric should be woven.

After the fabric has been woven, it's removed from the loom and is ready for the final step: processing. Fabric that's fresh off the loom is called greige, and it looks nothing like the crisp white sheets or clothing you're used to. It's discolored and full of impurities, seed particles and debris. Before it can be transformed into useful textiles, it must be cleaned. First, it's treated with bleach to purify the base color. Next, it's treated with a variety of chemicals and cleaners to remove oils, wax and other elements that are naturally occurring in most fibers. Finally, it's ready to be shipped out to clothing and textile manufacturers.

In addition to loom weaving, there are other methods for joining fabric, including knitting and crochet. While both are traditionally associated with wool materials, crochet is also common with lace production. Both are traditionally done by hand. Hand looms are also widely used throughout the world, and hand-woven textiles tend to be very popular with consumers.

4.8 GLOSSARY

Attenuator : Either fixed or variable components that are manufactured for testing electro-optical components or to incorporate a specific amount of loss into an operational optical network. Attenuators also provide a "safety margin" in planned networks to allow for electronics degradation over time, or physical changes to the optical component portion of the network. Available as fixed with specific amounts of attenuation or a variable optical attenuator (VOA) where the attenuation value can be changed for testing optical components or systems.

Attenuator, optical : Passive components that produce a controlled signal attenuation in an optical fiber transmission line.

Automatic test equipment (ATE) : Test equipment that is computer programmed to perform a number of test measurements on a device without the need for changing the test setup. Especially useful in testing components and assemblies.

Avalanche photodiode (APD) : A photodiode designed to take advantage of avalanche multiplication of photocurrent. It converts one photon to multiple electrons.

Back reflection : A percent of the transmitted signal reflected back towards the source from a fiber-optic interface. Referenced in dB.

Backscatter coefficient : The ratio of the optical pulse power (not energy) at the OTDR output to the backscatter power at the near end of the fiber (z=0). This ratio is inversely proportional to the pulsewidth, because the optical pulse power is independent. It is expressed in dB.

Backscattering : The scattering of light into a direction generally reverse to the original one.

Band : A range of optical spectrum allocated based on optical amplifiers. Six bands are specified: O (original), E (enhanced), S (short), C (conventional), L (long), and U (ultra). These cover the optical spectrum from 1260 nm to 1675 nm.

Fabric Construction : The details of structure of fabric. These include such information as style, width, type of weave, or knit, yarns per inch in warp and fill, and weight of goods.

Fabric Crimp : The angulation induced between a yarn and a woven fabric via the weaving or braiding process.

Fibers : A unit of matter, natural or manufactured, that forms the basic element of fabrics and other textile structures.

Fiber Number : The linear density of a fiber expressed in units such as denier or Tex.

Filament : A fiber of an indefinite or extreme length, such as one found in plant or animal structures. Manufactured fibers are extruded into filaments that are converted into filament yarn, staple, or tow.

Filament Count : The number of individual filaments that make up a thread or yarn.

Filament Yarn : A yarn composed of continuous filaments assembled with or without twist.

Filling : In woven fabric, the yarn running from selvage to selvage at right angles to the warp. Each crosswise length is called a pick. In the weaving process, a shuttle, rapier, or other type of yarn carrier carries the filling yarn.

Finished Fabric : Fabric that is ready for the market, having passed through the required

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finishing process.

Finishing : All the processes through which fabric is passed after bleaching, dyeing, or printing in preparation for the market or use.

Flame Resistant : A term used to describe a material that burns slowly, or is self-extinguishing after removal of an external source of ignition.

4.9 REVIEW QUESTIONS

1. Understanding the Weaving Process.
2. What is Knitting Process?
3. How to Textile Finishes for Flame Resistant Fabrics.
4. What is Plain weave?
5. Discuss the Jacquard weave.
6. What is Different types of weaves?
7. What kind of Honey Comb Weave?
8. What are the various functions a Textile Weaving Machine Parts?

UNIT

5

KNITTED

NOTES

STRUCTURE

5.1 LEARNING OBJECTIVE

After studying this unit you should be able to:

- Describe the technology for modify of Knits.
- Given the meaning and significance of Knitting Machine.
- Describe the Common materials used to make Different types of Knit Fabrics.
- The importance of Circular Knitting Machine in Textile.
- Give meaning and significance of Knitting Fabric.

5.2 INTRODUCTION

Knitted fabrics are constructed by interlocking a series of loops made from one or more yarns, with each row of loops caught into the preceding row. Loops running lengthwise are called wales, and those running crosswise are courses. Hand knitting probably originated among the nomads of the Arabian Desert about 1000 BCE and spread from Egypt to Spain, France, and Italy. Knitting guilds were established in Paris and Florence by the later Middle Ages. Austria and Germany produced heavily cabled and knotted fabrics, embroidered with brightly coloured patterns. In the Netherlands, naturalistic patterns were worked on fabric in reverse stocking stitch, and several Dutch knitters went to Denmark to teach Danish women the Dutch skills. The craft of hand knitting became less important with the invention of a frame knitting machine in 1589, although the production of yarns for hand knitting has remained an important branch of the textile industry to the present day.

The frame knitting machine allowed production of a complete row of loops at one time. The modern knitting industry, with its highly sophisticated machinery, has grown from this simple device.

Knitted fabrics were formerly described in terms of the number of courses and wales per unit length and the weight of the fabric per unit area. This system is limited, however, and there is a shift to use of the dimensions and configuration of the single loop, the repeating unit determining such fabric characteristics as area, knitting quality, and weight. The length of yarn knitted into a loop or stitch is termed the stitch length, and in a plain knitted structure this is related to the courses per inch, wales per inch, and stitch density. The two basic equilibrium states for knitted fabrics are the dry-relaxed state, attained by allowing the fabric to relax freely in the air, and the wet-relaxed state, reached after static relaxation of the fabric in water followed by drying.

Knitting machines: The needle is the basic element of all knitting machines. The two main needle types are the "bearded" spring needle, invented about 1589, and the more common latch needle, invented in 1847.

The bearded needle, made from thin wire, has one end bent, forming an operating handle; the other end is drawn out and bent over, forming a long flexible tipped hook resembling a beard. A smooth groove, or eye, is cut in the stem or shank of the needle just behind the tip. In use this needle requires two other units, a sinker to form a loop and a presser to close the needle beard, allowing the loop to pass over the beard when a new stitch is formed. Bearded needles can be made from very fine wire and are used to produce fine fabrics.

The latch needle is composed of a curved hook, a latch, or tumbler, that swings on a rivet just below the hook, and the stem, or butt. It is sometimes called the self-acting needle because no presser is needed; the hook is closed by the pressure of a completed loop on the latch as it rises on the shaft. Needles differ greatly in thickness, in gauge, and in length, and appropriate types must be selected for specific purposes. A 4-gauge needle, for example, is used for heavy sweaters, but an 80-gauge needle is required for fine hosiery.

Weft knitting: The type of stitch used in weft knitting affects both the appearance and properties of the knitted fabric. The basic stitches are plain, or jersey; rib; and purl. In the plain stitch, each loop is drawn through others to the same side of the fabric. In the rib stitch, loops of the same course are drawn to both sides of the fabric. The web is formed by two sets of needles, arranged opposite to each other and fed by the same thread, with each needle in one circle taking up a position between its counterparts in the other. In a 2:2 rib, two needles on one set alternate with two of the other. The interlock structure is a variant of the rib form in which two threads are alternately knitted by the opposite needles so that interlocking occurs. In the purl stitch, loops are drawn to opposite sides of the fabric, which, on both sides, has the appearance of the back of a plain stitch fabric. Jacquard mechanisms can be attached to knitting machines, so that individual needles can be controlled for each course or for every two, and complicated patterns can be knitted. To form a tuck stitch, a completed loop is not discharged from some of the needles in each course, and loops accumulating on these needles are later

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discharged together. The plaited stitch is made by feeding two threads into the same hook, so that one thread shows on the one side of the fabric and the other on the opposite side. A float stitch is produced by missing interlooping over a series of needles so that the thread floats over a few loops in each course.

Knitting machines can be flat or circular. Flat machines have their needles mounted in a flat plate or needle bed or in two beds at right angles to each other and each at a 45° angle to the horizontal. The knitted fabric passes downward through the space between the upper edges of the plates, called the throat. In the knitting process, the needles are pushed up and down by cams attached to a carriage with a yarn guide, which moves over the length of the machine. The width of the fabric can be altered by increasing or decreasing the number of active needles, allowing production of shaped fabrics, which when sewn together make fully fashioned garments. Although flatbed machines are suited for hand operation, they are power driven in commercial use, and, by selection of colour, type of stitch, cam design, and Jacquard device, almost unlimited variety is possible. The cotton frame, designed to knit fine, fully fashioned goods, shaped for improved fit of such items as hosiery and sweaters, is fitted with automatic narrowing and widening devices.

Circular machine needles are carried in grooves cut in the wall of a cylinder, which may be as small as 1 cm (0.4 inch) in diameter and as large as 1.5 metres (5 feet). Some circular machines have two sets of needles, carried in concentric cylinders, so that the needles interlock. During the knitting operation the butts of the needles move through cam tracks, the needles sliding up and down to pick up yarn, form a new loop, and cast off the previously formed loop. In the least complicated of these machines, yarn is supplied from one package, each needle picking up the yarn once per revolution of the cylinder. Modern machines may have as many as 100 feeders, allowing each needle to pick up 100 threads per revolution. Both latch and spring needles are used, with the former more common. Modern, large, circular, plain or jersey machines having 90–100 feeders are frequently used to produce medium-weight fabric. Small bladelike units, or sinkers, are inserted between every two needles to engage and hold the completed fabric, preventing it from riding up with the needles as they are lifted to form new stitches. Machines may be fitted with pattern wheels controlling needle action to produce tuck and float stitches, and a Jacquard mechanism may also be attached. Stop motions are essential to stop the machine when a thread breaks. Because yarn tension affects fabric uniformity, various tension controllers have been devised. An alternative method, positive feed, which feeds precisely measured amounts of yarn into the machine, is now considered more satisfactory.

Circular rib machines consist of a vertical cylinder, with needle slots on the outside, and a horizontal bed in the form of a circular plate or dial with needle slots cut radially, so that the two sets of needles are arranged at right angles to each other.

Seamless hosiery, knitted in tubular form, is produced by circular knitting machines. Modern hosiery machines, such as the Komet machine, employ double-hooked needles directly opposite each other in the same plane to knit the leg and foot portions, the heel and the toe. The toe is later closed in a separate operation.

In the Getaz toe, the seam is placed under the toes instead of on top of them.

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Underwear fabrics are usually knitted on circular machines, and—except for fully fashioned underwear, tights, and leotards, which are knitted to pattern and sewn together—underwear making is a cut, make, and trim operation. Tights or panty hose are a combination of hosiery and underwear and can be fully fashioned. Seamless panty hose are made on circular hose machines modified to make very long stockings with open tops, two of which are cut open at opposite sides and seamed together front and back. The wearing quality and fit of modern panty hose have been greatly improved with the development of stretch nylon and spandex, and greater variety has been introduced with the development of texturized yarn.

Much hosiery is finished by washing, drying, and a boarding process in which the hosiery is drawn over a thin metal or wooden form of appropriate shape and pressed between two heated surfaces. The introduction of nylon fibre led to the development of a preboarding process, setting the loops and the fabric in the required shape before dyeing and finishing. The article, fitted on a form of appropriate shape, is placed in an autoclave or passed through a high-temperature setting unit. Fabric treated in this way does not distort during dyeing.

Circular knitting machines can be adapted to make simulated furs. One type intermeshes plush loops with the plain-stitch base fabric then cuts the loops, producing a pile. A more common method forms the pile with a carded sliver. A plain-stitch fabric is used as the base and loose fibres from a sliver, fed from a brushing or carding device, are inserted by a V-shaped claw, forming the pile. Pile depth is determined by the length of the fibres in the sliver.

One of the most sophisticated knitting machines incorporates electronic selection of sinkers in a Jacquard circular knitting machine.

5.3 TYPES OF KNITS

Knitted fabric is a textile that results from knitting. Its properties are distinct from woven fabric in that it is more flexible and can be more readily constructed into smaller pieces, making it ideal for socks and hats.

Different types of Knit Fabrics

Jersey

Jersey is the most common type of knit fabric. To make this textile, both knit and purl stitching are put together using a single needle. Thus, this fabric is also called the single or plain knit. Among the types of knit fabrics, this one is easy to distinguish because of its unmistakable right and wrong side of fabric.

Jersey knit fabric is a common textile used for making basic T-shirts. It is also perfect for draped garments like dresses and tops. It can come in any fiber, we stock wool, hemp, bamboo, and cotton. We also stock tencel, modal, rayon and a little polyester.

Jersey Knit Fabric Features To Remember:

- lightweight

- not so stretchy unless the material has an amount of spandex in it
- distinct right and wrong side of the fabric
- edges curls up easily when pulled

Rib Knit

Rib knit or sometimes called ribbing has raised vertical textured lines. This textile is created using a double bed knitting machine that has two needles with vertical textured lines. This type of knit fabric is also easy to identify because of its vertical ribs. There are 2 basic types of rib knit fabric based on the sequence of knit and purl stitches. The 1×1 rib has a sequence of 1 knit and 1 purl stitch, while the 2×2 rib knit has 2 knit and 2 purl stitches sequence.

Since Rib knit fabric is more stretchy crosswise and lies flat on one side, this fabric is perfect for making turtleneck clothes, bottom edges of sweaters, cuffs, and necklines on clothes. It is also excellent in making mats including rugs and other home furnishings. It can come in any fiber, we stock wool, hemp, bamboo, and cotton. We also stock tencel, modal, rayon and a little polyester.

Rib Knit Fabric Features To Remember:

- heavier compared to Jersey
- generally very stretchy among the 3 basic types of knit fabrics, but the 1×1 rib is more stretchy than the 2×2 rib
- almost identical right and wrong side of the fabric
- not so smooth unlike Jersey knit
- edges don't curl up when pulled

Interlock Knit

Interlock knit is similar to rib knit. Some experts say it is a variation of ribbing because the fabric is created using 2 needles too. It also looks like 2 layers of single knit piled on top of each other. Thus, this type of knit fabric is also called double-faced rib.

When you want to sew pants, skirts, tanks, the best type of knit fabric to use is the interlock fabric. It can come in any fiber, we stock wool, hemp, bamboo, and cotton. We also stock tencel, modal, rayon and a little polyester.

Interlock Knit Fabric Features To Remember:

- heavier and thicker than jersey
- not too stretchy compared to Jersey
- reversible type of fabric, there's no right or wrong side of the fabric
- among the 3 basic types of knit fabrics, interlock is more stable.

French Terry knit

French Terry fabric is a knitted terry cloth fabric that features loops and soft piles of yarn on one side, (usually the inside of a garment), and a smooth, soft surface on the other side. The result is an absorbent, light-weight, moisture-wicking material that's super comfortable to wear any day of the year. It can come in any fiber, we stock wool, hemp, bamboo, and cotton. We also stock tencel, modal, rayon and a little polyester.

Fleece Knits

Fleece Knit Fabric is a durable, warm, and stretch fabric with a thick, deep pile. Fleece Fabric dries quickly, making it perfect for active wear. It can come in any fiber, we stock wool, hemp, bamboo, and cotton. We also stock tencel, modal, rayon and a little polyester.

This is just a beginning to the explanation of knit styles. There are so many, they can have spandex added and that changes the fabric behavior and uses.

Knitted fabrics and types – list of knitted fabrics

Knitting is the construction of an elastic, porous fabric, created by interlocking yarns by means of needles. A list of commonly used knitted fabrics and its construction are explained.

Knitting is the construction of the elastic, porous fabric, created by interlocking yarns by means of needles. Knitted fabrics can be made much more quickly and easily than woven fabrics at comparatively less cost.

Two yarns forming loops in each course of the fabric knit the fabric. Knitting machines form loops of yarn with many pointed needles or shafts. The vertical rows of loops are called ribs or wales, and horizontal rows of loops are called courses.

Knitted fabrics are generally light in weight, comfortable in wear even during travel, but yet require little care to keep their neat appearance. The tendency of knits to resist wrinkling is another factor to boost up their popularity.

Knitted fabrics are used for designing active clothing such as sports clothing. Their elastic nature permits for abundant physical activity.

Knit Schematics

Weft or filling knits are constructed from one yarn that is fed into knitting machine needles in a horizontal direction.

The circular knitting machine creates a spiral effect as it produces a fabric in tabular form. Because of this spiral characteristic, it is often difficult to have the wales and courses of the knit fabric form a perfect 90-degree angle match.

Knitted fabrics are produced by two general methods – warp knitting, and weft knitting, and each method produces a variety of types of knitted fabrics.

Knitted Fabric Knits

- Weft Knits
- Single Knits

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- Single Jersey
- Lacoste
- Double Knits
- Rib Knit
- Purl Knit
- Interlock Knit
- Cable Fabric
- Bird's Eye
- Cardigans
- Milano Ribs
- Pointelle
- Specialized Weft Knits
- Intarsia
- Jacquard Jerseys
- Knitted Terry
- Knitted Velour
- Sliver Knit
- Fleece
- French Terry
- Warp Knits
- Tricot
- Raschel

Either a circular or a flat-bed knitting machine can be used to make weft knits. Four basic stitches are used in the weft of filling knits.

1. Jersey stitch/plain knit
2. Purl stitch
3. Rib stitch
4. Interlock stitch (both for single and double knits)

Knitted Fabric Types

Flat or Jersey Knit Fabric

Flat or Jersey Knit fabrics have visible flat vertical lines on the front and dominant horizontal ribs on the back of the fabric. The flat or jersey knit stitch is used frequently, it is fast, inexpensive, and can be varied to produce fancy patterned fabrics. A major disadvantage of regular flat knits is their tendency to "run" if a yarn is broken. The flat or jersey stitch can be varied by using different yarns or double-looped stitches of different lengths to make terry, velour, and plush fabrics. This stitch is also used in making nylon hosiery, men's underwear, and t-shirts.

Purl Knit Fabric

Purl Knit Fabrics look the same on both sides of the fabric. Many attractive patterns and designs can be created with the purl stitch. It is often used in the manufacture of bulky sweaters and children's clothing. The production speed is generally slow with Purl knits.

Purl Knit is made by knitting yarn as alternate knit and purl stitch in one wale of the fabric. The fabric has alternate courses of knit stitch and purl stitch. The fabric is reversible and identical on both sides of the fabric. The fabric does not curl and lies flat. It is more stretchable in length direction.

Rib Stitch Knit Fabric

Rib Stitch Knits have stitches drawn to both sides of the fabric, which produces columns of wales on both the front and back of the fabric. Rib stitch produces fabrics that have excellent elasticity. Rib knits are used for the "ribbing" which is usually found at the lower edges of sweaters, on sleeve cuffs, and at necklines. The Rib-knit fabric is made by knitting yarn as alternate knit stitch and purl stitch in one course of the fabric. The fabric has alternate wales of knit and purl stitches. It is reversible fabric, as they look identical on both sides of the fabric. They may be made with both flat and circular knitting machines.

Cardigans

Cardigans are a variation of Rib Knit with half Cardigan and Full Cardigan varieties. The fabric has specific patterns of tuck stitches. These produce a raised effect and hence, cardigans are a thicker fabric.

Half Cardigan

The Half Cardigan is made of one course of all knit on both needle beds and second course of all knit on front needles and all tuck on back needles. The tuck loops present in the fabric reduce the stretch in width direction. It is not reversible fabric. They are generally coarsely knitted and used for making pullovers and sweaters.

Full Cardigan

The Full Cardigan is made of a repeat of one course of all knit on front needles and all tuck on back needles, the second course of all tuck on front needles and all knit on back needles. Full Cardigan looks identical on both sides. Excessive tuck loops make the fabric bulky and thick. It is usually knitted in coarser gauge and widely used in making sweaters and fashion garments. Cardigans are usually made of Wool or Acrylic.

Milano Ribs

Milano Ribs are a variant of Rib Knit with half Milano and full Milano variations. The fabric has specific patterns of knitting and misses.

Half Milano

Half Milano is made of a repeat of one course of all knit on both needle beds and second course of all knit on front needles only. It has an unbalanced structure. It is usually knitted coarse gauge and widely used for making sweaters.

Full Milano

Full Milano is made of a repeat of one course of all knit on both needle beds, the second course of all knit on front needles only and the third course of all knit on back needles only. Full Milano is finely knitted fabric and has better coverage. It has greater dimensional stability than half Milano rib. It is widely used as suiting fabrics.

Interlock Stitch Knit Fabric

Interlock stitch Knits are variations of rib stitch knits. The front and back of interlocks are the same. These fabrics are usually heavier and thicker than regular rib knit fabrics unless used with finer yarns. The interlocking of stitches prevents runs and produces apparel fabrics that do not ravel or curl at the edges.

Double Knit Fabric

Double Knits are made from the interlock stitches and its variations. The process involves the use of two pairs of needles set at an angle to each other. Fibers that the generally used to make double knits are polyester and wool. Double knits are weft knitted fabrics made with two sets of needle beds. The fabric structure is more stable and compact. The fabrics do not curl at the edges and do not ravel. They may be made with interesting designs and textures. One or two yarns are used to knit one course in the fabric.

Warp Knitted Fabric

Warp knitted fabrics are made in a special knitting machine with yarns from warp beam. Unlike weft knits, they are knitted from multiple yarns, with yarns forming loops in adjacent wales. The fabric may be identified with a pick glass. The face side of the fabric has slightly inclined vertical knitting loops whereas the backside of the fabric has inclined horizontal floats. They do not ravel. Warp knit fabrics are constructed with yarn loops formed in a vertical or warp direction. All the yarns used for a width of a warp knit are placed parallel to each other in a manner similar to the placement of yarns in weaving. The fabrics that are made of great quality with the technique are generally made with Tricot and Raschel knits.

Tricot Knit Fabric

Tricot knits are made almost exclusively from filament yarns because uniform diameter and high quality are essential yarn characteristics for use with the very high-speed tricot knitting machines. Fabrics constructed by the tricot knitting machine are usually plain or have a simple geometric design. The front surface of the fabric has clearly defined vertical wales, and the back surface has crosswise courses.

Raschel Knit Fabric

Raschel knits are produced from spun or filament yarns of different weights and types. Most raschel knits can be identified by their intricate designs, the open-space look of crochet or lace, and an almost three-dimensional surface effect design.

Cable Knit Fabric

Cable fabric is a double knit fabric made by the special loop transfer technique. The wales in the fabric have a rope-like an appearance, where plaits are based on the transfer of loops with adjacent wales. The fabric has an interesting surface texture like braids as the loops cross each other. It is widely used as sweater fabric.

Bird's Eye Knit Fabric

Bird's eye is a double knit fabric with a combination of tuck stitches along with knitting stitches. The tuck stitch creates interesting eyelet or hole effect on the fabric surface resembling a bird's eye. FabThe fabric usually made of multi-colored threads creating scrambling effect. The fabric may be made with designs having eyelets. They are a popular clothing fabric, especially women's wear.

Pointelle Knit Fabric

Pointelle is a type of double knit fabric. The fabric has patterned miss stitches. The fabric has looked like lace, with holes made by these transferred stitches. The feminine look of the fabric makes it ideal for women's tops and kids wear.

Intarsia Knit Fabric

Intarsia is patterned single knit fabric. It is made of knitting multi-colored yarns. The fabric has the same course knitted in different colors with different yarns. It has colored designs as blocks distributed in different color backgrounds. The patterns look identical on both the face and backside of the fabric. There are no floats found on the backside of the fabric. It is typically used to make shirts, blouses, and sweaters.

Jacquard Knit Fabric

Jacquard Jerseys are single jersey fabrics made of Circular Knitting machines using Jacquard mechanism. They are the simplest method of making patterned fabrics. They are produced with interesting patterns, which may have any of the following:

- Combinations of stitches, or
- Combinations of yarn types in terms of color textures etc.

Jacquard fabrics have different colored loops made of different threads in the same course. Floats are an inherent feature of single jersey jacquards. They are widely used in the sweater industry.

Knitted Terry Fabric

Knitted Terry is pile jersey fabric made with a special attachment in regular circular knitting machines similar to woven fabrics. The fabric has loops on the fabric surface. The fabric is made of two sets of yarns, in which one set of yarn makes the pile, while the other set of yarn makes the base fabric.

Knit terry is softer, more flexible and is more comfortable than woven terry fabrics. However, they are not firm and durable as woven terry. Owing to its softness and absorbency, it is widely used in beachwear, towels, bathrobes etc.

French Terry Fabric

French Terry It is a type of Weft Insertion Jersey. The piles on the fabric are not napped and the technical back of the fabric is used as face side. French Terry has loops or piles on one side only. The piles of the French Terry are much shorter when compared to usual Terry. The fabric has excellent stretch and gives fleece like a handle. These features make the fabric more comfortable hence, they are popularly used in clothing, especially infants and kids. French Terry is widely used in sportswear, jogging suits and workout suits owing to its absorbency and stretch.

Knitted Velour Fabric

Knitted Velour are Pile jersey fabrics having soft protruding fibers on the fabric surface. Like knit terry, they are also made of an additional set of yarns making pile loops on the fabric surface. However, in Velour, these pile loops are sheared evenly and brushed. It may be dyed and generally available with solid colors. They are used in luxurious apparels like jackets, blouses, dresses etc.

Sliver Knit Fabric

The Sliver Knit is Pile jersey fabric. Unlike Velour fabric, Sliver knit fabric is characterized by a longer pile on the fabric surface. It is made of special circular knitting machines in which the surface fibers imitating fur are attached to the fabric, by means of knitting sliver along with base yarn making the fabric. Sliver knit fabrics have longer and denser piles on the fabric surface than other pile jerseys. Animal printed sliver knit fabrics are popularly used as imitation fur fabrics. They are more popular than fur as they are light, more stretchable and do not require special care for storage. They are widely used in making jackets and coats.

Fleece Knit Fabric

Fleece is a type of weft insertion jersey. Weft insertion fabrics are weft knitted fabrics in which an additional yarn is inserted for each course. These additional yarns are not knit, rather they are held by the loops in each course of the fabric. The inserted yarn may be decorative or functional like stretch yarn. It provides stability, cover, and comfort. The insertion yarn is usually coarser than the base yarn. When the insertion yarn forming piles are sheared and napped, it is called Fleece. They are usually made of Cotton, Cotton/Polyester, Wool, and Acrylic. End

Uses include jackets, dresses, sportswear, and sweaters.

5.4 PARTS OF KNITTING MACHINE

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Different Parts and Function of Circular Knitting Machine

Circular Knitting Machine in Textile

In apparel manufacturing sector, knitted garment is one of the top demands from the buyer. Polo shirt, T-shirt, under garments all are produced from knitted fabrics. Knitted fabric is produced by using knitting machine. Among all the others knitting machine, circular knitting machine is widely used in knit fabric production. This chapter has shown the various parts of circular knitting machine and their functions.

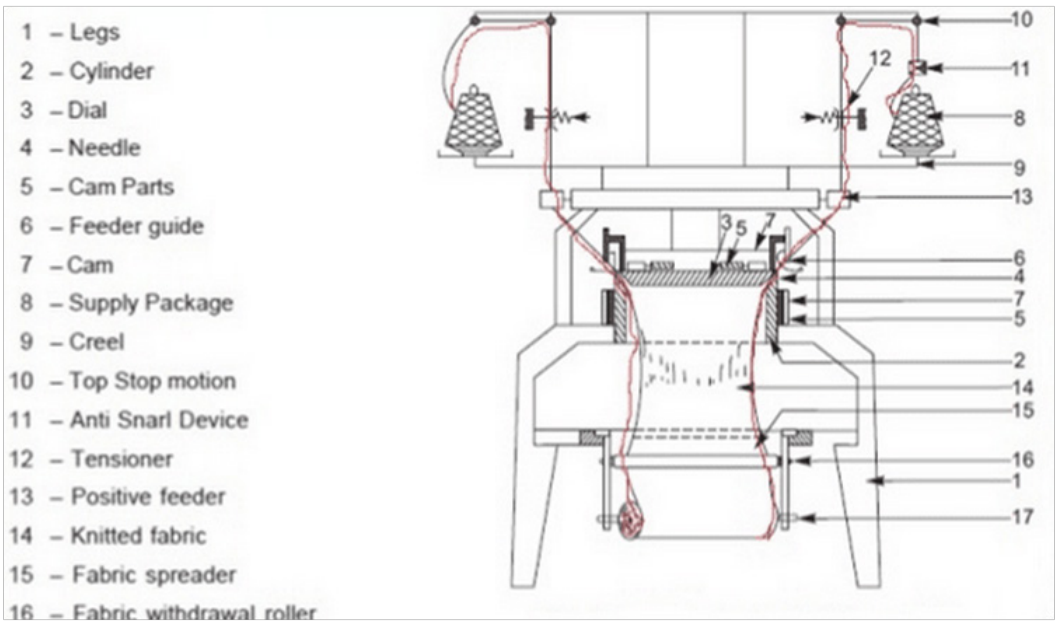

Fig: Parts of circular knitting machine

Parts of Circular Knitting Machine

Circular knitting machine contains the below parts:

- Yarn tensioner,
- Cam box,
- Creel,
- Feeder,
- Needle,
- Base plate,
- Take up roller,
- Yarn guide,
- Cylinder,

- Auto Stopper,
- VDQ pulley,
- Body,
- Sinker.

Functions of Circular knitting Machine Parts

Functions of all knitting machine parts have described in the following:

1. **Yarn tensioner:** It is used to perfect gripping of yarn by needle.
2. **Cam box:** It is used to hold the cam according to the fabric design. Knitting cams are arranged according to the design.
3. **Creel:** Creel is used to place the yarn cone. Yarn is supplied from here to the machine through the pipe.
4. **Feeder:** It is totally related with fabric production. If the number of feeder is higher then fabric production will be higher.
5. **Needle:** Needle is the main part of knitting machine. Needle is used to knit the fabric. There are different types of needle such as latch needle, bearded needle, compound needle etc. Among those latch needle is widely used in knitting technology.
6. **Base plate:** Cylinder is situated on the base plate.
7. **Take up roller:** It is used to take-up the fabric from the knitting machine. Take up roller also controls the proper tension on the fabric.
8. **Yarn guide:** Yarn guide is used to guide the yarn. During it is necessary for maintaining proper tension on yarn.
9. **Cylinder:** Cylinder is one of the important parts of knitting machine where all the needles are set.
10. **Auto Stopper:** If knitting machine is in the faulty situation then auto stopper will stops the knitting machine automatically.
11. **VDQ pulley:** VDQ means variable dia for quality pulley. It controls the quality of the fabric. VDQ pulley is very important in maintaining proper stitch length.
12. **Body:** Body of machine is the total area of knitting machine.
13. **Sinker:** During loop formation sinker is used to hold and support the thread.

Types of Circular Knitting Machine for Different Knitting Techniques

There are different types of circular knitting machines for different knitting techniques which are pointed out in the below:

- Open width knitting techniques machine,
- Double jersey circular knitting machine,
- Single jersey 4 track circular knitting machine,
- Body size rib knitting machine,
- Double jersey interlock knitting machine,

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- Double face terry circular knitting machine,
- Computerized knitting machine with auto stripper,
- Fleece machine interchangeable terry machine,
- Circular knitting techniques machine,
- Rib 4 track knitting techniques machine.

Parts of Circular Knitting Machine and Their Function

Circular Knitting Machine

Circular knitting machine is widely used through out the knitting industry to produce fabric. This machine can be built in almost any reasonable diameter and the small diameter of up to five, which are used for wear.

Machine for outerwear and under wear may vary from 12 inch to 60 inch in diameter according to manufactures requirement. This machine can be used either as fabric or for making garments completely with fancy stitch. Latch needles are commonly employed in all modern circular machines because of their simple action and also their ability to process more types of yarns.

Fig. Circular knitting machine

Important Parts of Circular Knitting Machine

- **Creel:** Creel is a part of a knitting machine. Hear yarn package are store and ready to feed in the machine.

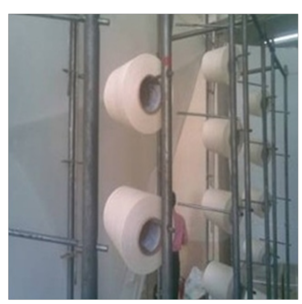

Photo: Creel.

- **VDQ Pulley:** It is a very important part of the machine. It controls the quality of the product. Altering the position of the tension pulley changes the G.S.M. of the fabric. If pulley moves towards the positive directive then the G.S.M. is decrease. And in the reverse direction G.S.M will increase.

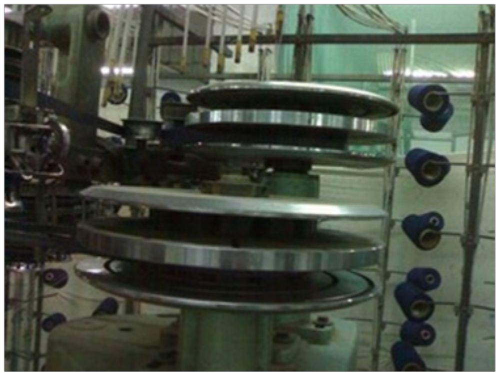

Photo: VDQ Pulley.

- **Pulley Belt:** It controls the rotation of the MPF wheel.

Photo: Pulley Belt.

- **Brush**: Its clean the pulley belt.

Photo: Brush.

- **Tension Disk:** It confronts the tension of the supply yarn.

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Photo: Tension Disk.

- **Inlet and Outlet Stop Motion:** It is an important part of the machine. It stops the machine instantly when a yarn is break.

Photo: Inlet and Outlet Stop Motion.

- **Yarn Guide:** Its help the yarn to feed in the feeder.

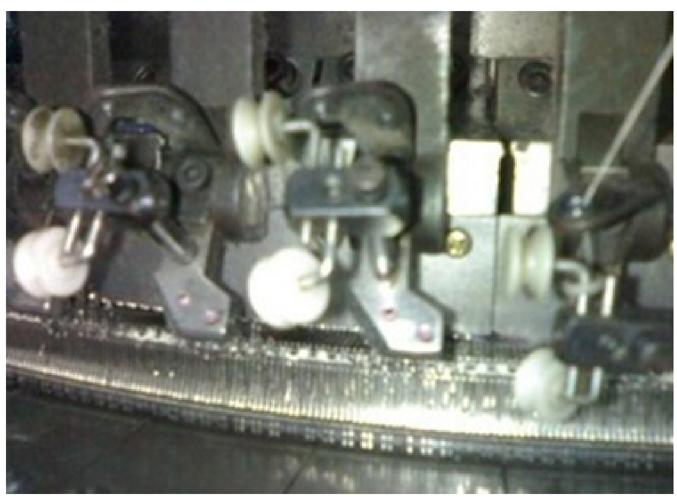

Photo: Yarn Guide.

- **MPF Wheel:** Its control the speed of the MPF. Pulley belt gives motion to the wheel.

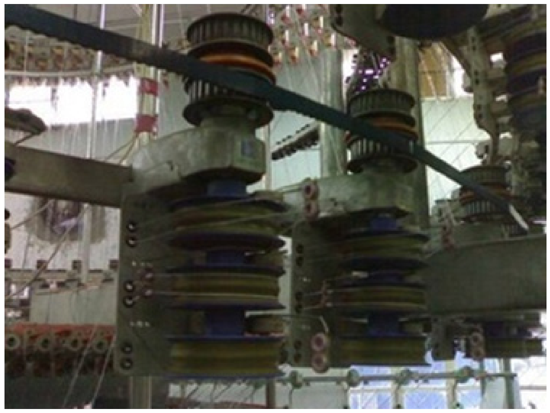

Photo: MPF Wheel.

- **MPF:** It is Mamenger positive feed. It is also an important part of the machine. It's give positive feed to the machine.

Photo: MPF.

- **Feeder Ring:** It is a ring. Where all feeders are pleased together.

Photo: Feeder Ring.

NOTES

- **Cam Box:** Where the cam are set horizontally.

Photo: Cam Box.

- **Cam:** Cam is device s which converts the rotary machine drive in to a suitable reciprocating action for the needles and other elements.

Photo: Cam.

- **Lycra Attachment Device:** Lycra is placed hear. And feeding to the machine.

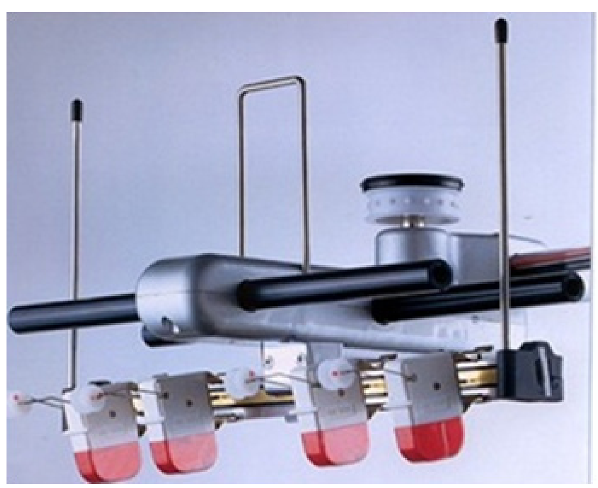

Photo: Lycra Attachment Device.

- **Lycra Stop Motion:** It is one kind of stop motion to stop the machine when the Lycra is break.

Photo: Lycra Stop Motion.

- **Cylinder:** Needle track are situated hear.

Photo: Cylinder.

- **Cylinder Balancer:** It helps the cylinder to set in a proper alignment.

Photo: Cylinder Balancer

NOTES

- **Uniwave Lubrication:** The Uniwave lubricator provides uniform lubrication to needles, cam tracks, lifters and other knitting machine components. The patented nozzle construction separates the air-oil mixture into air and droplets of oil.

Photo: Uniwave Lubrication System.

- **Adjustable Fan:** This part removes lint, hairy fibre from yarn and others. To clean the dust by air flow.

Photo: Adjustable Fan.

- **Expander:** To control the width of the knitted fabric. No distortion of the knitting courses. Even take down tension in the knitting machine. As a result, an even fabric structure is achieved over the entire fabric width. The deformation of the knitted fabric goods can be reduced.

Photo: Expander.

NOTES

- **Needle Detector:** This part detect the any type of faults of needles.

Photo: Needle Detector.

- **Air Gun Nozzle:** To feed the yarn; sometimes it is used for cleaning purpose.

Photo: Air Gun Nozzle.

- **Disk Drum:** Use in jacquard machine to produce various types of design.

Photo: Disk Drum.

- **Pattern Wheel:** Pattern Wheel use in Pai Lung and Auto Stripe machine because of that that help to produce various types of design and stripe.

NOTES

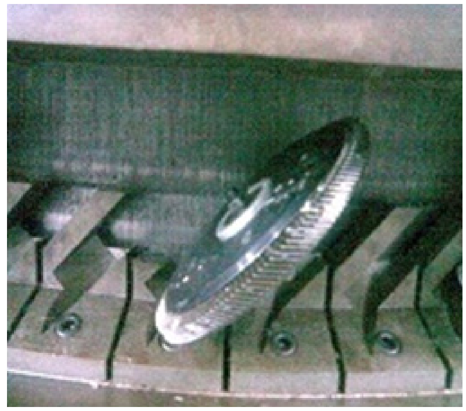

Photo: Pattern Wheel.

- **Feeder:** Feeder is help yarn to feed in to the machine.

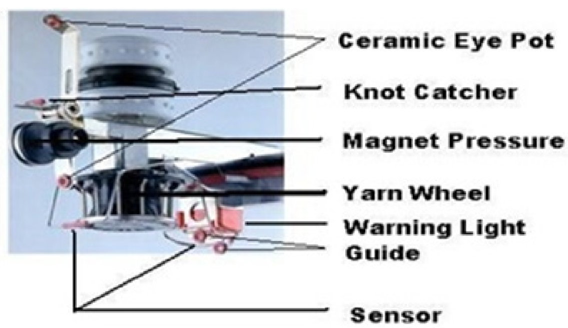

Photo: Feeder.

- **Needle Track:** Where all Needles is placed together in a decent design.

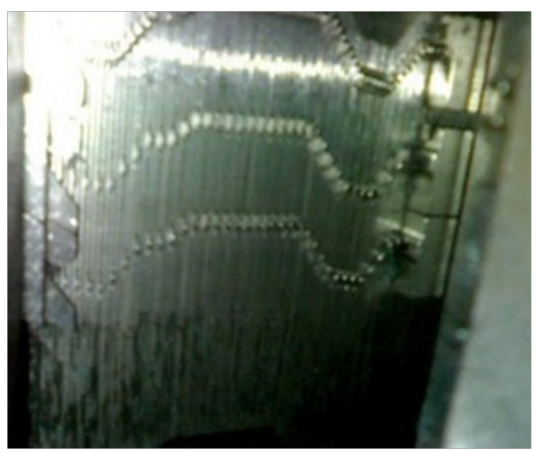

Photo: Needle Track.

- **Needle:** It is a principal element of the knitting machine. Its help the yarn to create a loop. And by this way fabric are produce. Prior to yarn feeding the needle is raised to clear the old loop from the hook, and received the new loop above it on needle stem. The new loop is then enclosed in the needle hook as the needle starts to descend.

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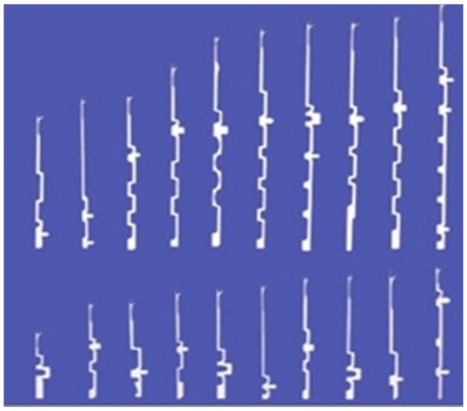

Photo: Different Types of Needle.

- **Sinker:** It is most important element of the machine. Its help to loop forming, knocking over and holding down the loop.

Photo: Sinker.

- **Sinker Ring:** Sinker ring is a ring. Where all sinkers are pleased together.

Photo: Sinker Ring.

NOTES

5.5 STUDENT ACTIVITY

1. What is Knits? Explain the Types of Knits?

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2. What is Knitting Machine? Explain the Parts of Knitting Machine?

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....

5.6 OTHERS- BONDED, FELT, BRAID, LACES AND NET

Bonding

Several methods for making nonwoven materials are now firmly established, and others are being developed.

In adhesive bonding, fabrics are made by forming a web of fibres, applying an adhesive, then drying and curing the adhesive. The web can be produced by a garnett machine or a conventional card, several layers being piled up to obtain the required thickness. Such webs are weak across the width, but this does not limit their use for certain end products. A more uniform product results from cross laying the web. Other machines, such as the Rando-Webber, lay down the fibres by an airstream.

The fibres in the web may be stuck together in various ways. The web may be sprayed with an emulsion of an adhesive—e.g., a latex based on synthetic rubber, acrylic derivatives, or natural rubber—or, alternatively, may be carried on a mesh screen through a bath of latex, the excess being squeezed out by a pair of rollers. Adhesives may also be applied as a foam or a fine powder. Thermoplastic fibres can be incorporated in the blend and on heating will bond together, giving strength to the mass of fibres.

Mechanically bonded nonwoven products (or fibre-bonded nonwovens) are webs strengthened by mechanical means. The web, sometimes reinforced by a thin cotton scrim in the middle or by texturized yarns distributed lengthwise through it, is punched by barbed needles mounted in a needle board. The fibres in the web are caught up by the needle barbs, and the resulting increased entanglement yields a compact product sufficiently strong for many purposes. Modern needle-felting or punching machines perform 900 punches per minute, and selection of appropriate needles is based on the fibre being processed and the desired product.

The Arachne machine, the best known unit for stitch bonding, operates much like a warp-knitting machine. Fibrous web is fed into the machine, and stitches are made by a series of needles placed about eight millimetres apart, giving the web longitudinal strength; lateral strength is provided by the fibre interactions.

The products are attractive for many purposes and can be improved by treatment with polyester resins to increase their wear resistance and with thermosetting precondensates to reduce their tendency to pill (e.g., to form small tangles). A new device attached to the Arachne machine permits introduction of weft ends at every single course, making colour effects possible. Araloop machines yield loop-pile fabric suitable for towels and floor coverings.

Three sewing-knitting machines were invented in East Germany in 1958. In the Malimo machine process, warp yarns are placed on top of filling yarns and stitched together by a third yarn. The Maliwatt machine interlaces a web of fibres with a sewing thread, giving the effect of parallel seams. The Malipol machine produces a one-sided pile fabric by stitching loop pile through a backing fabric. A new British process makes double-sided terry fabric, called Terrytuft, by inserting pile yarn into a backing and knotting it into position.

Webs made of yarns having a core of one polymer and an outer sheath of another material having a lower softening point may be lightly pressed and then heated to an appropriate temperature. The core yarn will “spot weld” together at the junction points, binding the mass of fibres together. Products made in this way find uses as industrial fabrics, coatings, and interlinings.

The pattern in the expanded stitch-bonding process

Diagramming the pattern with the needle shift technique by including the shift movement of the needle, new requirements to illustrate the pattern must be met. The shift must clearly and correctly emanate from the graphic and numeric illustration. In addition, the graphic illustration should provide a clear image as to the appearance of the finished product. All illustrations and specifications for warp-knitted materials with a needle shift are oriented on standard illustrations and pattern descriptions of conventional warp-knitted materials.

The lapping diagram has been based up to this point on the illustration for the movement of the yarn guide, which are clearly marked by position numbers for the needle spaces. This clear location marking is lost in the needle shift technique since the needle spaces no longer remain in their fixed positions. To compensate this, a relative and an absolute position number has been introduced. The absolute position numbers indicate the position of the needles when they are nearest to the pattern mechanism at "0" position (called absolute zero position). This is equivalent to the "0" position in conventional warp-knitting machines. When the pattern mechanism is mounted on the right side, the absolute "0" position is the outermost right position for the guide bar and the needle bar, and when mounted on the left side, it is the outermost left-hand position. The yarn guide on the furthest right is considered to be in the needle space "0". The absolute position numbers are the basis for controlling the movement of the guide bar, since they correspond to the standard needle space numeration and remain unchanged.

Because the numbering does not change, it is inevitable that with the shifting of the needle the actual needle space location and their numeration no longer correspond to one another. Therefore, the relative position numbers are used to mark the actual position of the needle spaces. The relative numbers are each assigned to only one needle space and therefore their position may be changed. The numerical description of the guide-bar movement is always relative to the absolute position numbers. These are also used to describe the shifting movement of the needle bar. With this modification, information is added to the lapping diagram. The lapping diagram for the needle bar is labeled with NB. Each knitting cycle is given two numbers. The first stands for the position of the needle bar before the swing-in movement of the yarn guide, the second for the position of the needle bar after the swing-out movement of the yarn guides. The second position of the previous knitting cycle is always identical to position one of the upcoming cycle. Since the pattern repeat for the needle-bar movement can begin in a position other than the absolute "0" position, it is necessary to assign a number to the first part of the knitting cycle. This is always the case when the first shift in the pattern repeat begins in the direction of the absolute "0" position. Just as in the lapping diagram for the 'guide bar, a backslash represents the end of a knitting cycle, a double backslash for the end of a pattern repeat. The last number in the pattern repeat is always identical to the first number; the guide bar always begins with the first step after the last shift. The length of a pattern repeat for the needle bar can differ from that of the guide bar.

When the pattern repeat lengths for the guide bar and the needle bar differ, the repeat of the resulting pattern is the least common multiple of the two-pattern repeats. For example pillar stitch, open (l-O/O-l/I) and the needle offset (1-2/2-0/0-1//), means the resulting pattern has a repeat of 2 x 3 = 6. The overlap and the shift are to be repeated until the calculated pattern repeat has been reached.

When using standard graphic diagrams, the actual position of the needle bar is not recognisable. When reading the diagram, the guide-bar course no longer depicts the actual thread line, nor does it relay information as to the actual appearance of the material. Because of this, the lapping diagram is expanded to include additional information. An arrow is added to mark the width and direction of the offset. Additionally, a needle in the first row is identified as a marker. This marking needle should be chosen so that the arrow does not interfere with this row or any subsequent rows in the lapping diagram. The same marking needle should be used in each row. The point of the arrow shows the direction and the length of the arrow depicts the span of the shift that takes place after the guide-bar movement. The length of the arrow corresponds to the second number in the lapping diagram.

If the actual position of the needle bar is to be identified at the time of loop formation, then the relative position number must be given for each row. Under the lapping diagram, the absolute position numbers are written and emphasised in a different font. It is to be noted that in this type of lapping diagram, the overlaps, according to the chain notation, are given with the absolute position numbers. The relative position numbers are only used to clarify the needle-bar position. They are placed underneath the row of the first loop, and in each subsequent row shifted according to the needle offset. The shift arrow in the row above depicts the offset. In order to clearly mark the relative position of the needle spaces to the absolute "0" position, an index number is introduced. The index number marks the needle space "0" in each row thereby clearly showing the number of needle spaces the guide bar has shifted from absolute zero. The relative position numbers always depict the position of the allocated needle row before the placement of the guide - before the shift - which follows at the end of the knitting cycle.

When defining the position of the needle bar relative to the absolute "0" position (the reference parameter for the guide-bar movement), it is clear that when shogging the needle bar from "0" to "1" and shifting the needle from "1" to "0" (absolute), the outermost yam guide on the right has no needle to feed. The number of needles affected by this is shown in the lapping diagram. Furthermore, by introducing relative position numbers it is obvious that the tricot pattern depicted combined with this particular offset cannot be that of a standard tricot pattern. This is made obvious by the thread guide, which continually places the thread on the same needle. This type of illustration does not accurately depict the material's final appearance.

In order to create an approximate depiction of the material, the needles are shown as if they were returned to the absolute zero position at the time the loops are formed. This can be done with the lapping diagram where the relative position numbers are shifted to the "0" position. However, to guarantee a correct drawing, or the overlaps, each needle space is labeled with the relative position number that it occupies at precisely that moment. This means that the needle space numeration in each row corresponds to the actual needle location at that given point. However, its position corresponds to that of the needle position in the absolute "0" position. The numbers on the lapping diagram always refer in this chain notation to the relative position numbers in each corresponding row and no longer to the absolute position numbers. Since the relative position numbers are no longer depicted in their offset position, they are determined in the following manner: they are calculated by adding (shift arrow points left) or subtracting (shift arrow points right) the position number of the previous row with the shift width (length of shift arrow). The relative position numbers always begin at "0". However, it is necessary to consider that all relative position numbers beginning to the right of the absolute "0" position are only virtual. At the time of Ioop formation, no needles are located here.

The lapping diagram with the shifted relative position numbers allow for an approximate illustration of the thread line in the material. However, the actual movement of the thread guides is not recognisable. It is the chain notation that is always decisive for guiding the machine.

Equivalent patterns

In general, an analogous pattern without a needle offset exists for all RL patterns with a needle offset. In other words, for every pattern with a needle offset there is an equivalent pattern with a similar structure produced without a needle offset. The equivalent pattern length is not necessarily evident from the chain notation for the guide bar and needle bar.

- The shift direction changes in each row whereby the shift width remains the same (basic offset),
- The shift direction changes in each row and the shift width is irregular

(irregular basic offset),

- The shift direction changes after n rows and the shift width remains the same, where n # 1 (diagonal offset),
- The shift direction changes after n rows and the shift width is irregular, where n # 1 (irregular diagonal offset).

All other offset variations are categorised as an irregular offset and include such 'shifts as:

- The shift that occurs multiple times in the same direction with a change after an irregular number of rows, or,
- An irregular shift with varying shift widths.

It is also necessary to differentiate in which, direction the needle bar shifts in relation to the guide bars. (relative direction):

- Same direction - the needle bar shift follows the same direction as the under lap of the guide bar.
- Opposite direction - the needle bar shift follows the opposite direction as the under lap of the guide bar.

When the guide bar under laps and the needle bar shifts change at regular intervals in each row or are otherwise constant relative to one another, then the allocation of the relative direction applies to the complete pattern. The relative direction of the needle-bar offset is always assigned in relation to the guide bar 1 (GB1). When multiple guide bars are present, the relative direction for the other guide bars is then obvious. For example, when in the pattern double tricot is in opposition, the needle bar moves parallel to GB1, then it follows that the movement in relation to GB2 is in the opposite direction. However, when the guide bar overlaps and the needle shifts are irregular in their relative direction, then the terms parallel and opposite can only be applied for each individual row and are not to be applied to the complete pattern. In such a case, the relative direction, when not noted otherwise, always refers to the first under lap in the pattern.

Another characteristic of the needle offset is the shift width in each row. In this paper, a maximum shift width of four has been considered. The shift width is given in the pattern description as a number with basic offset (ie basic offset 2). In patterns with a diagonal offset, the shift width is given after the marking for the number of rows n, after which, the direction changes (ie, diagonal offset 4-2; directional change after 4 rows, in each row a shift width of 2). The following examples are patterns where the guide bars and needle bar move in a regular pattern.

Pillar stitch

TQC combination of pillar stitch and needle-shift patterns always results in a fabric (as opposed to the conventional pillar stitch, which does not produce a fabric). The combination of an open-lap pillar stitch with base offset renders an equivalent pattern to that of the patterns tricot, cord, satin and velvet. When the needle shift runs in the same direction (in the absence of under laps relative to the overlaps) closed loops are produced and by all opposite needle shift open loops. The patterns with a needle shift in the same direction are mirror images to those with an opposite needle shift.

The combination of closed-lap pillar stitch and a basic off set results in patterns equivalent to tricot, cord, satin and velvet patterns, where each has an open loop and a closed loop since the relative direction changes in each row. In changing shift directions, a mirror image of the pattern is created where the sequence of open and closed loops is shifted up or down in a row.

Tricot, cord, satin and velvet

By combining the basic patterns tricot, cord, satin and velvet with a basic offset, equivalent patterns to the patterns pillar stitch and others ranging from tricot to velvet are created, as well as patterns with under laps covering more than four needle spaces.

In patterns with an offset in the same direction the equivalent patterns can be categorised as follows:

- When the needle-bar shift width is the same as the guide bar shift width, then the equivalent pattern open-lap pillar stitch is always created.
- When the needle-bar shift width is smaller than that of the guide bar, then the equivalent patterns, tricot (shift width is one space less), cord (shift width is two less) and satin (shift width is three less) are created. The loops remain the same.
- When the needle-bar shift width is greater than that of the guide bar, then the equivalent patterns, tricot (shift width is one space more), cord (shift width is two spaces more) and satin (shift width is three spaces more) are formed. Open loops become closed loops and the opposite is true for the closed loops.

When the needle-bar and guide bar shifts are in the opposite direction then the equivalent pattern is increased by the shift width of the needle bar. For example, from tricot the equivalent patterns are cord (shift width one), satin, (two) and velvet (three). The loops remain in an open pattern open and in a closed pattern closed.

Felt

Felts are a class of fabrics or fibrous structures obtained through the interlocking of wool, fur, or some hair fibres under conditions of heat, moisture, and pressure. Other fibres will not felt alone but can be mixed with wool, which acts as a carrier. Three separate industries manufacture goods through the use of these properties. The goods produced are wool felt, in rolls and sheets; hats, both fur and wool; and woven felts, ranging from thin billiard tablecloths to heavy industrial fabrics used for dewatering in the manufacture of paper. Felts of the nonwoven class are considered to be the first textile goods produced, and many references may be found to felts and their uses in the histories of ancient civilizations. The nomadic tribes of north central Asia still produce felts for clothing and shelter, utilizing the primitive methods handed down from antiquity.

NOTES

How to Felt

1. Begin with a knitted or crocheted piece that has been worked in natural animal fibers. You can't go wrong with 100-percent wool here (though superwash wools won't felt.)
2. Toss your piece into the washing machine with a couple of towels (for extra agitation) and wash it on the hottest cycle you have. Stop it every five minutes or so to check on how well your piece is felting, to reshape, and stretch. The time needed will depend on the wool and the size of the piece but in general, about 20 minutes should do it.

If you don't have a washing machine, no sweat. Fill a large basin with the hottest water you can, adding a little no-rinse wool wash. Wearing rubber gloves to protect your hands, plunge your piece into the basin, agitate that thing — rub it against itself, move it around, cause friction.

This way can take a little longer to felt but it gets the job done. I've heard that people who rely on this method often use toilet plungers, but of course, you'd want a brand-new one (otherwise, ick).

3. Once your piece is fully felted you will need to get all the water out. If you are using the washing machine, run it on a drain/spin cycle. If you're using the basin method, squeeze out as much water from the piece as you can, then wrap it in a towel and stomp all over it.
4. While your piece is still damp, it's time to reshape it. Knitters generally avoid tugging and pulling on your piece, but now's the time to be a rule breaker. If you're making felted slippers, a bag or another piece that needs stuffing to retain its shape, use plastic grocery bags.
5. Place your felted items in a place with a lot of ventilation. This is important! Because the fabric is so thick, it needs circulating air to help it dry. Otherwise this process can take forever and the piece can end up smelling musty.
6. Once the material is fully dry, you can trim any areas that need extra shaping with scissors. I also like to cut off any extra fuzzies from the wool. You've got a super sturdy fabric that's perfect for extra bling: try embellishing with embroidery or even fabric paint.

Braiding or plaiting

Braid is made by interlacing three or more yarns or fabric strips, forming a flat or tubular narrow fabric. It is used as trimming and for belts and is also sewn together to make hats and braided rugs. Plaiting, usually used synonymously with braiding, may be used in a more limited sense, applying only to a braid made from such materials as rope and straw.

Lace knitting

Lace knitting is a style of knitting characterized by stable "holes" in the fabric arranged with consideration of aesthetic value. Lace is sometimes considered the pinnacle of knitting, because of its complexity and because woven fabrics cannot easily be made to have holes. Famous examples include the Orenburg shawl

NOTES

and the wedding ring shawl of Shetland knitting, a shawl so fine that it could be drawn through a wedding ring. Shetland knitted lace became extremely popular in Victorian England when Queen Victoria became a Shetland lace enthusiast. Her enthusiasm resulted i.a. in her choosing knitted lacework for presents; e.g. when in ca. 1897 the Queen gave a lace shawl as a present to American abolitionist Harriet Tubman. From there, knitting patterns for the shawls were printed in English women's magazines where they were copied in Iceland with single ply wool.

Some consider that "true" knitted lace has pattern stitches on both the right and wrong sides, and that knitting with pattern stitches on only one side of the fabric, so that holes are separated by at least two threads, is technically not lace, but "lacy knitting", although this has no historical basis.

Eyelet patterns are those in which the holes make up only a small fraction of the fabric and are isolated into clusters (e.g., little rosettes of one hole surrounded by others in a hexagon). At the other extreme, some knitted lace is almost all holes, e.g., faggoting.

Knitted lace with no bound-off edges is extremely elastic, deforming easily to fit whatever it is draped on. As a consequence, knitted lace garments must be blocked or "dressed" before use, and tend to stretch over time.

Lace can be used for any kind of garment, but is commonly associated with scarves and shawls, or with household items such as curtains, table runners or trim for curtains and towels. Lace items from different regional knitting traditions are often distinguished by their patterns, shape and method, such as Faroese lace shawls which are knit bottom up with center back gusset shaping unlike a more common neck down, triangular shawl.

Technique

A hole can be introduced into a knitted fabric by pairing a yarn over stitch with a nearby (usually adjacent) decrease. If the decrease precedes the yarn over, it typically slants right as seen from the right side (e.g., k2tog, not k2tog tbl). If the decrease follows the yarn over, it typically slants left as seen from the right side (e.g., k2tog tbl or ssk, not k2tog). These slants pull the fabric away from the yarn over, opening up the hole.

Pairing a yarn over with a decrease keeps the stitch count constant. Many beautiful patterns separate the yarn over and decrease stitches, e.g., k2tog, k5, yo. Separating the yarn over from its decrease "tilts" all the intervening stitches towards the decrease. The tilt may form part of the design, e.g., mimicking the veins in a leaf.

There are few constraints on positioning the holes, so practically any picture or pattern can be outlined with holes; common motifs include leaves, rosettes, ferns and flowers. To design a simple lace motif, a knitter can draw its lines on a piece of knitting graph paper; right-slanting lines should be produced with "k2tog, yo" stitch-pairs (as seen on the right side) whereas left-slanting lines should be produced with "yo, k2tog tbl" (or, equivalently, "yo, ssk" or "yo, skp") stitch pairs (again, as seen on the right side). More sophisticated patterns will change the grain of the fabric to help the design, by separating the yarn overs and decreases.

It is common for lace knitters to insert a "lifeline", a strand of contrasting yarn threaded through stitches on the needle, at the end of every pattern repeat or after a certain number of rows. This allows the knitter to rip out a controlled number of rows if a mistake is discovered.

Simple examples

A horizontal row of holes can be produced by the pattern: *k3, k2tog, yo, k3*.

A pair of vertical columns can be produced by stacking the pattern: (k, k2tog, yo, k, yo, k2tog tbl, k) on the right side. Here the flanking decreases slant outwards away from the central stitch. For a thicker central column, one can move the decreases so that they slant inwards: (k, yo, dec 2 symmetrically, yo, k). For making the same pattern on the wrong side, the converse stitch patterns are: (p, p2tog, yo, p, yo, p2tog tbl, p) and (p, yo, dec 2 symmetrically, yo, p), respectively.

A diagonal row of holes can be made by shifting the (yo, dec) every row or every other row, e.g.,

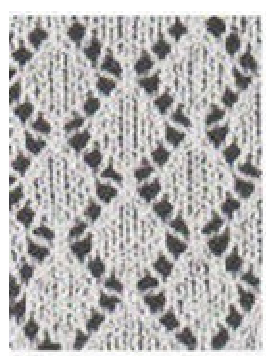
- Row 1: k, k2tog, yo, k5
- Row 3: k3, k2tog, yo, k3
- Row 5: k5, k2tog, yo, k1

History and comparison to other laces

Lace knitting is generally not as fine as other forms of lace, such as needle lace or bobbin lace. However, it is better suited for garments, being softer and much faster to produce.

Lace Knitting for Beginners

What are the defining characteristics of lace knitting/knitted lace? The essential building block of a knitted lace fabric is a 1 or 2 stitch decrease accompanied by a yarn over (an eyelet hole) to replace the stitch(es) lost in the decrease. The essential structure of hole and decrease can be arranged in various ways in pattern shapes, usually, but not always, geometrically based in order to create fabrics which are visually pleasing. Often, there is an attractive textural feature as well.



The most common and easiest to knit lace structure is stocking stitch-based, where the patterning takes place only on the knit (right side) row. The second and all even rows are purl-based. When the eyelets (holes) are arranged diagonally and are adjacent to a decrease which follows the same diagonal direction, the space between the holes is spanned by a herringbone cross link of 2 strands. This is known as "faggoting" and is one of the most open of pattern every alternate row (PEAR) fabrics.

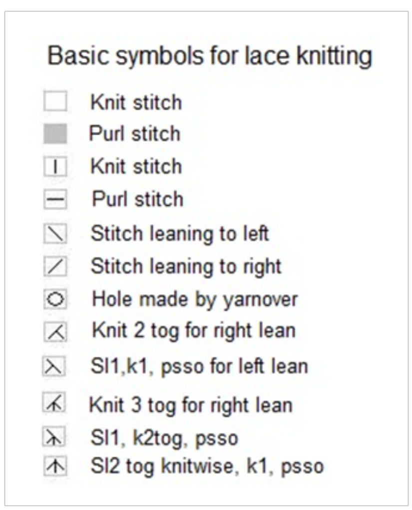
"Simple" and "Fashioned" Knitted Lace

These are terms borrowed from domestic machine knitted lace, since hand knitting does not have any terms to differentiate between a yarn over and adjacent decrease (or the other way round), which machine knitters call "simple", and "fashioned" whereby the decrease is delayed and is separated by several stitches, causing the stitches to lean in the direction of the decrease, the choice of which can accentuate the lean.

In more complex lace patterns, where curve and texture are considerations, these decreases can be delayed by several rows. On Japanese charts, the symbols // \\ show the direction of the lean in "fashioned" lace patterns. They do not represent an action to be taken. In other charting systems, those leaning symbols stand for decreases, and lean is not shown at all.

In the following exercises, only the symbols for the patterns offered for beginner lace knitters are given.

To find out more, please look up Paint for Charting Knitting Patterns and Key to Knitting Symbols on the Guild web site. The articles in 2013 issues of Slipknot on the Guild Collection's 1891 Victorian Sampler cover a wide selection of lace knitting techniques in a selection of lace patterns from that Sampler. The high quality and variety of the patterns, are evidence of a gifted and inventive lace knitter. Charts and written instructions accompany the majority of the patterns.



Lace Knitting Techniques

From the list of basic symbols you will see that knit and purl stitches may be shown in different ways in lace knitting patterns, perhaps depending on whether the pattern is of hand or machine knitting. In this section instructions are given for hand knitters starting on lace knitting.

NOTES

Yarn over on the knit side

- **Symbol:** O on the chart shown 7th in list. A blank mini grid is a knit stitch. Only the knit rows are represented on the chart. Read the repeat from right to left, as you would knit the row. To do a yarn over on the knit side, with the yarn at the back lift the yarn under the needle, then around. As you knit the next stitch, the yarn slopes over the right needle. That is a yarn over, the basis of the new stitch over the lace hole.

Single right-leaning decrease

Symbol is a right leaning stroke supported by a small one, shown 8th on the list. This is made by knitting the next 2 stitches together. This can be tough if you are a tight knitter, if your needles are too small, and if your needles have not got tapering ends. Abbreviation: k2tog.

Single left-leaning decrease

Symbol is a left leaning stroke supported by a small one, shown 9th on the list on the left. This can be accomplished in 2 ways:

1. Slip the next stitch, knit the next one and pass the slipped stitch over. Abbreviations: sl1,k1, psso OR skpo. NB: This is the older of the 2 forms and will be the one used in pre-1960s written patterns.
2. Slip the next 2 stitches, singly and knitwise, on to the right needle. Insert the left needle into the front of the stitches and knit off as one stitch. This is easier & quicker to accomplish than skpo. Abbreviation: ssk

Double left leaning decrease

This is the most common double decrease used in hand-knitting. The symbol is a mixture of the left leaning single decrease with the addition of a small vertical stroke, shown 11th on the list. To work it : slip the stitch, knit the next 2 stitches together and pass the slipped stitch over. Abbreviation: sl1,k2tog,psso

Other Abbreviations

rs = rows, sts = stitches. PEAR = pattern every alternate row, DDR = delayed decreases along the row. If you are helped by visual stage by stage, hands on illustrations, please visit the Japanese symbols website (English instructions) ssk however, is not illustrated, but look elsewhere for that on the Internet.

Simple Lace Patterns to Try

The patterns selected here as an introduction to lace knitting by hand, are graded and are chosen to give practice for the few techniques required. Suggestion: knit swatches appropriate for the size of the repeat+ 2 knit stitches at each selvage.

Then study the structure of the pattern and note how it has been achieved.

Broken Pairings

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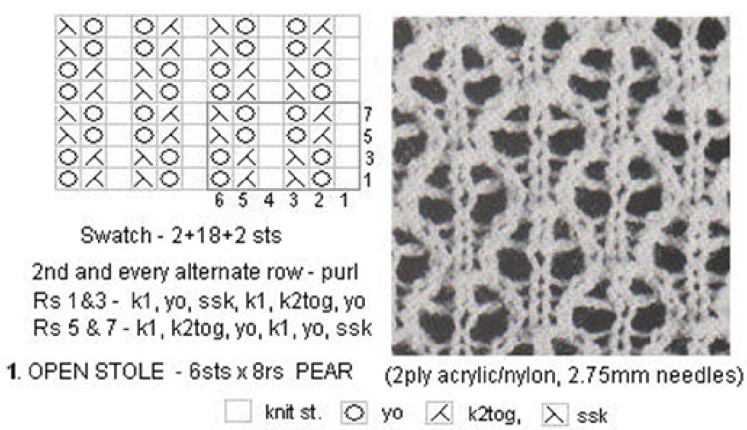
Usually, a yarn over must be paired with a decrease, to keep the complement of stitches correct in a row. (The places to check are the left and right selvages of the swatch, or in real terms, a garment or article). If one or the other is missing, you must take a step to remedy it. You can alter a yarn-over with no decrease, a single decrease with no yarn over to a knit stitch, and a double decrease to a single. Whatever you do, keep the right complement of stitches. NB. Only one pattern repeat is written. Work with the chart as well.

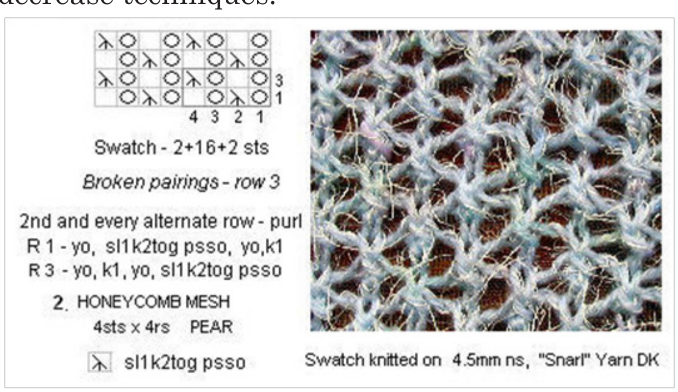
Needles and Yarn

Try first with the usual size needles you would choose for the yarn. Often a larger size works best, especially if you are a tight knitter. Fashioned lace patterns usually work better with finer yarns.



Open Stole

This is from the machine knitting tradition. It is about the easiest pattern to try and is a very attractive one too. Anyone hesitant about attempting lace knitting should be won over by this one. The pattern provides practice for yarn overs and for the 2 single decrease techniques.



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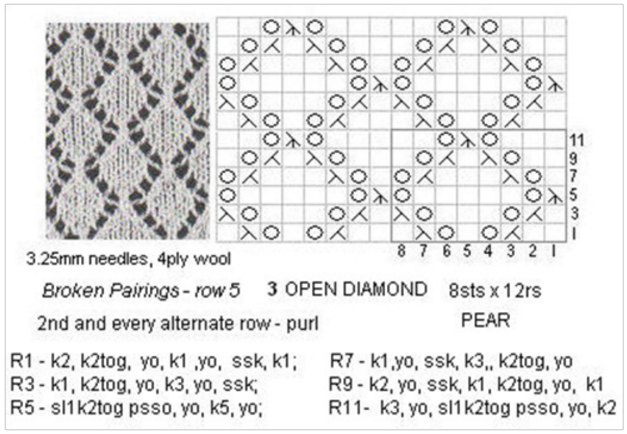
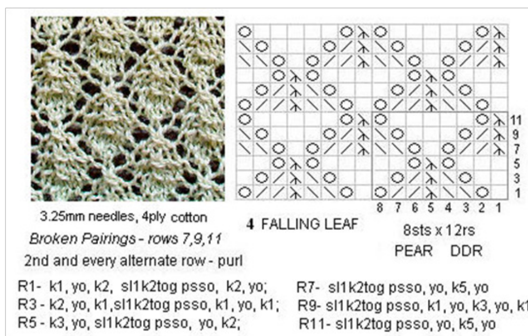
Honeycomb Mesh

This is an old pattern, popular in framework, hand knitting and machine knitting often as a background for solid stocking shapes or as a shawl centre (Shetland). It is good choice for DK, "interest" and hairy yarns. The pattern provides practice for double decreases only.



Open Diamond

This is probably the oldest and most well-known of any here. All 3 techniques are in use.



Falling Leaf

This is a Fashioned Lace Pattern to try. This pattern was a favourite with Victorian lace hand knitters. The placement of the holes is exactly the same as for Open Diamond, but look what happens when the decreases are delayed along the row. Note how the leaning strokes represent the direction of the stitches towards the decrease.

Making Nets, Knitting Fabric

A brief meditation on making nets and knitting fabric, two innovations that have had a tremendous long-term impact on human civilization.

Hearty thanks are due the prehistoric genius who first knotted together tough roots or lengths of vine and made a crafty web with which to share his dinner. In fact, it's pleasant to speculate that nature's master netmaker, the spider, inspired the first human attempt at making nets. We'll never know for sure ... but we do know that the early inventor's brainchild has served hundreds of purposes in almost every culture since the Stone Age.

Simple as it looks, the net is really an amazing conception. How can a fabric that's more empty space than anything else be strong enough to hold a ton of thrashing cod? Yet it does just that ... while a device made on exactly the same principle is still delicate enough to catch a butterfly unharmed.

A net is also a remarkable combination of firmness and flexibility. The fixed points created by the knots control the maximum size of the outstretched openings, yet allow the web to shift readily to take the stress of its load and—when not in use—to collapse into a lightweight bundle for easy storage and transport.

With nets all around us—as hammocks, sporting gear, shopping bags, storage space and restraints for our wandering hair—it's surprising that more of us haven't discovered the utilitarian craft of netting ... along with its decorative and satisfying cousin, knitting.

Knitting, like netting, is basically "holes tied together with string" ... only the loops aren't actually tied but just slipped one through another to form a mesh. The result is an elastic fabric that's perfect for close-fitting items like stockings. (Hand-knit footwear was made in Egypt very early in the present era, and the hosiery industry has been mechanized since the invention of the first knitting machine by an Elizabethan parson.)

5.7 SUMMARY

For the layman, a knit fabric is what the t-shirts are made of. For me, knit is a stretchy fabric that makes beautiful clothes, comes in a variety of vivid colors and prints and hides a multitude of faults in my body by virtue of its elasticity. For the expert, jersey knit, rib knit and all those different types of knit fabric names make sense- but for you and me the beauty and ease of the collective knit fabrics are usually enough.

- **Warp knitting:** The two types of warp knitting are raschel, made with latch needles, and tricot, using bearded needles.
- **Raschel:** Coarser yarns are generally used for raschel knitting, and there has recently been interest in knitting staple yarns on these machines. In the Raschel machine, the needles move in a ground steel plate, called the trick plate. The top of this plate, the verge, defines the level of the completed loops on the needle shank. The loops are prevented from moving upward when the needle rises by the downward pull of the fabric and the sinkers between the needles. Guide bars feed the yarn to the needles. In a knitting cycle, the needles start at the lowest point, when the preceding loop has just been cast off, and the new loop joins the needle hook to the fabric. The needles rise, while the new loop opens the latches and ends up on the shank below the latch. The guide bars then swing through the needles, and the front bar moves one needle space sideways. When the guide bar swings back to the front of the machine, the

front bar has laid the thread on the hooks. The needles fall, the earlier loops close the latch to trap the new loops, and the old loops are cast off. Raschels, made in a variety of forms, are usually more open in construction and coarser in texture than are other warp knits.

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- **Tricot:** Tricot, a warp knit made with two sets of threads, is characterized by fine ribs running vertically on the fabric face and horizontally on its back. The tricot knitting machine makes light fabrics, weighing less than four ounces per square yard. Its development was stimulated by the invention of the so-called FNF compound needle, a sturdy device that later fell into disuse but that made possible improved production speeds. Although approximately half of the tricot machines in current use make plain fabrics on two guide bars, there is increasing interest in pattern knitting. In this type of knitting, the warp-knitting cycle requires close control on the lateral bar motion, achieved by control chains made of chunky metal links.
- **Special effects in warp knits:** The scope of warp knitting has been extended by the development of procedures for laying in nonknitted threads for colour, density, and texture effects (or inlaying), although such threads may also be an essential part of the structure. For example, in the form called "zigzagging across several pillars," the ground of most raschel fabrics, the front bar makes crochet chains, or "pillars," which are connected by zigzag inlays.

An extension of conventional warp knitting is the Co-We-Nit warp-knitting machine, producing fabrics with the properties of both woven and knitted fabrics. The machines need have only two warp-forming warps and provision for up to eight interlooped warp threads between each chain of loops. These warp threads are interlaced with a quasiweft, forming a fabric resembling woven cloth on one side.

- **Basic methods and processes:** The term finishing includes all the mechanical and chemical processes employed commercially to improve the acceptability of the product, except those procedures directly concerned with colouring. The objective of the various finishing processes is to make fabric from the loom or knitting frame more acceptable to the consumer. Finishing processes include preparatory treatments used before additional treatment, such as bleaching prior to dyeing; treatments, such as glazing, to enhance appearance; sizing, affecting touch; and treatments adding properties to enhance performance, such as preshrinking. Newly formed cloth is generally dirty, harsh, and unattractive, requiring considerable skill for conversion into a desirable product. Before treatment, the unfinished fabrics are referred to as gray goods, or sometimes, in the case of silks, as greige goods.

Finishing formerly involved a limited number of comparatively simple operations evolved over the years from hand methods. The skill of English and Scottish finishers was widely recognized, and much British cloth owed its high reputation to the expertise of the finisher. More sophisticated modern finishing methods have been achieved through intense and imaginative research.

- **Preparatory treatments:** It is frequently necessary to carry out some preparatory treatment before the application of other finishing processes to the newly constructed fabric. Any remaining impurities must be removed, and additives used to facilitate the manufacturing process must also be removed. Bleaching may be required to increase whiteness or to prepare for colour application. Some of the most frequently used preparatory processes are discussed below.

- **Burling and mending:** Newly made goods, which frequently show imperfections, are carefully inspected, and defects are usually repaired by hand operations. The first inspection of woollen and worsted fabrics is called perching. Burling, mainly applied to woollen, worsted, spun rayon, and cotton fabrics, is the process of removing any remaining foreign matter, such as burrs and, also, any loose threads, knots, and undesired slubs. Mending, frequently necessary for woollens and worsteds, eliminates such defects as holes or tears, broken yarns, and missed warp or weft yarns.
- **Scouring:** When applied to gray goods, scouring removes substances that have adhered to the fibres during production of the yarn or fabric, such as dirt, oils, and any sizing or lint applied to warp yarns to facilitate weaving.
- **Bleaching:** Bleaching, a process of whitening fabric by removal of natural colour, such as the tan of linen, is usually carried out by means of chemicals selected according to the chemical composition of the fibre. Chemical bleaching is usually accomplished by oxidation, destroying colour by the application of oxygen, or by reduction, removing colour by hydrogenation. Cotton and other cellulosic fibres are usually treated with heated alkaline hydrogen peroxide; wool and other animal fibres are subjected to such acidic reducing agents as gaseous sulfur dioxide or to such mildly alkaline oxidizing agents as hydrogen peroxide. Synthetic fibres, when they require bleaching, may be treated with either oxidizing or reducing agents, depending upon their chemical composition. Cottons are frequently scoured and bleached by a continuous system.
- **Mercerization:** Mercerization is a process applied to cotton and sometimes to cotton blends to increase lustre (thus also enhancing appearance), to improve strength, and to improve their affinity for dyes. The process, which may be applied at the yarn or fabric stage, involves immersion under tension in a caustic soda (sodium hydroxide) solution, which is later neutralized in acid. The treatment produces permanent swelling of the fibre.
- **Drying:** Water, used in various phases of textile processing, accumulates in fabrics, and the excess moisture must eventually be removed. Because evaporative heating is costly, the first stage of drying uses mechanical methods to remove as much moisture as possible. Such methods include the use of centrifuges and a continuous method employing vacuum suction rolls. Any remaining moisture is then removed by evaporation in heated dryers. Various types of dryers operate by conveying the relaxed fabric through the chamber while festooned in loops, using a frame to hold the selvages taut while the fabric travels through the chamber, and passing the fabric over a series of hot cylinders. Because overdrying may produce a harsh hand, temperature, humidity, and drying time require careful control.

NOTES

- **Finishes enhancing appearance:** Treatments enhancing appearance include such processes as napping and shearing, brushing, singeing, beetling, decating, tentering, calendering or pressing, moiréing, embossing, creping, glazing, polishing, and optical brightening.
- **Napping and shearing:** Napping is a process that may be applied to woollens, cottons, spun silks, and spun rayons, including both woven and knitted types, to raise a velvety, soft surface. The process involves passing the fabric over revolving cylinders covered with fine wires that lift the short, loose fibres, usually from the weft yarns, to the surface, forming a nap. The process, which increases warmth, is frequently applied to woollens and worsteds and also to blankets.

Shearing cuts the raised nap to a uniform height and is used for the same purpose on pile fabrics. Shearing machines operate much like rotary lawn mowers, and the amount of shearing depends upon the desired height of the nap or pile, with such fabrics as gabardine receiving very close shearing. Shearing may also be applied to create stripes and other patterns by varying surface height.

5.8 GLOSSARY

Amplifier : A device, inserted within a transmission path that boosts the strength of an electronic or optical signal. Amplifiers may be placed just after the transmitter (power booster), at a distance between the transmitter and the receiver (in-line amplifier), or just before the receiver (preamplifier).

Analog : A continuously variable signal. Opposite of digital.

Angled physical contact (APC) : A polishing technique for fibers/ferrules that minimizes reflective light. A style of fiber-optic connector with a 5 -15 degree able on the connector tip for the minimum possible back reflection. Usually used in AM or DWDM single-mode transmission systems using laser light sources. Typically 65-70 dB.

Application-specific optical fiber (ASOF): Fibers built for specific applications such as erbium fibers used in EDFA optical amplifiers. Other types include high N.A. fibers used for manufacturing filters and gratings, etc.

Arrayed waveguide grating (AWG) : A device that allows multiple wavelengths to be combined and separated in a DWDM system. An array of planar waveguides diffracts light at angles that depend on the wavelength. The central element is an array of narrow, curved waveguides that run parallel to each other between a pair of mixing regions. The waveguides differ in length by an increment that is much larger than the wavelength. The input signal enters the first mixing region and is coupled into the waveguides to pass into the second mixing region.

Herringbone : A broken twill weave characterized by a balanced zig-zag effect produced by having the rib run first to the right and then to the left for an equal number of threads.

High Modulus : A term that refers to a material with a higher than normal resistance to deformation.

Hollow Filament Fibers : Manufactured, continuous filament fibers, having voids created by introduction of air, or other gas in the polymer solution, or melt spinning through specially designed spinnerets.

Homespun : Course plain-weave fabric of uneven yarns that have a handspun appearance.

Hopsacking : A course, open, basket-weave fabric that gets its name from the plain-weave fabric of jute or hemp used for sacking in which hops are gathered.

Impregnated Fabric : A fabric in which the interstices between the yarns are completely filled, as compared to sized or coated materials where the interstices are not completely filled.

5.9 REVIEW QUESTIONS

1. Understanding the Weft knitting.
2. What is Knitted fabrics and types?
3. Discuss the Knit Schematics.

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4. What is Double Knit Fabric?
5. What kind of Tricot Knit Fabric?
6. What are the various functions a Different Parts and Function of Circular Knitting Machine?
7. Uses of Lycra Attachment Device.
8. What is Lace knitting?