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SCHOOL OF BUILDING & ENVIRONMENT

DEPARTMENT OF FASHION DESIGN

UNIT – I - Elements of Textiles – SFDA1103

What is a Textile Fibre?

The use of textiles for clothing and furnishing depends upon a unique combination of properties. Textiles are warm; they are soft to the touch; they are completely flexible and thus take up any desired shape without resistance; and they are usually hard-wearing.

The reason for these properties is to be found in the structure of textile materials. Textiles are derived from threads or yarns which have been interlaced in one way or another. The threads them- selves are flexible, and in their loose interweaving they remain flexible, conferring this property on the-cloth itself.

In their turn, the threads or yarns are built up by twisting together the long, thin, flexible but strong things we call fibres. Ultimately, therefore, the properties of any material must depend very largely on the properties of the fibres from which it is made. The spinning and weaving processes obviously have their effect on the final textile. A worsted suit, for example, bears little superficial resemblance to a baby's cardigan, though both are made from wool. But the basic natures of the two garments are similar, and are a consequence of the fact that each is made from wool. For a fibre to be suitable for textile purposes, certain qualities are desirable; others are essential. First, to be a fibre at all, the length must be several hundred times the width. It is this that enables fibres to be twisted together to form a yarn or thread. In addition, the fibre must be strong and yet extremely flexible. Strength is needed to enable it to withstand the spinning and weaving processes, and to provide strength in the final cloth. Flexibility permits the fibres to be spun and woven, and gives to a textile its unique draping characteristics.

The actual length of the fibre is important. It can be infinitely long, but should not be shorter than 6 - 12mm *(V** - *Vi* in), or it may not hold together after spinning. The width of the fibre can vary between considerable limits, and it is upon this that the fineness of the material eventually depends. Silk, for example, is a fine fibre and yields a delicate cloth; jute is a coarse fibre that is largely used for making sacks. In addition to having strength and flexibility, a textile fibre should be elastic. Brittleness leads to poor wear in the garment; elasticity allows the material to 'give' when subjected to a stretching force.

Waviness, or crimp, is a natural feature of certain fibres such as wool. It affects the 'holding together' power of the fibres in the spun yarn and controls the porosity and warmth of the fabric.

The ability of a fibre to absorb moisture influences the hygienic qualities of the cloth. Fibres that cannot absorb moisture may help to make the cloth feel clammy when it is worn.

The weight of a fibre affects the draping qualities when it is made into a cloth. If the fabric is too light, it may not drape well; yet if it is too weighty, the material will be heavy and dull.

With all the variability possible in these important properties, it is not surprising that we find such diverse characteristics in the natural fibres. Nor is it reasonable to expect that anything that looks fibrous will be suitable for making into textiles.

When we add to these requirements the essentials of abundance and cheapness, we find that the number of fibres suitable for large- scale textile use has narrowed down to relatively few.

Some of them, like cotton and flax, are vegetable fibres which nature uses for some essential purpose in the growing plant; others, like wool or silk, are produced by the animal world.

Classification*

The fibres used in modern textile manufacture can be classified into two main groups (a) natural and (b) man-made fibres. The natural fibres are those, such as cotton, wool, silk and flax, which are provided by nature in a ready-made fibrous form. The man- made fibres, on the other hand, are those in which man has generated a fibre for himself from something which was not previously in a suitable fibrous form.

NATURAL FIBRES can be subdivided into three main classes, accord- ing to the nature of their source.

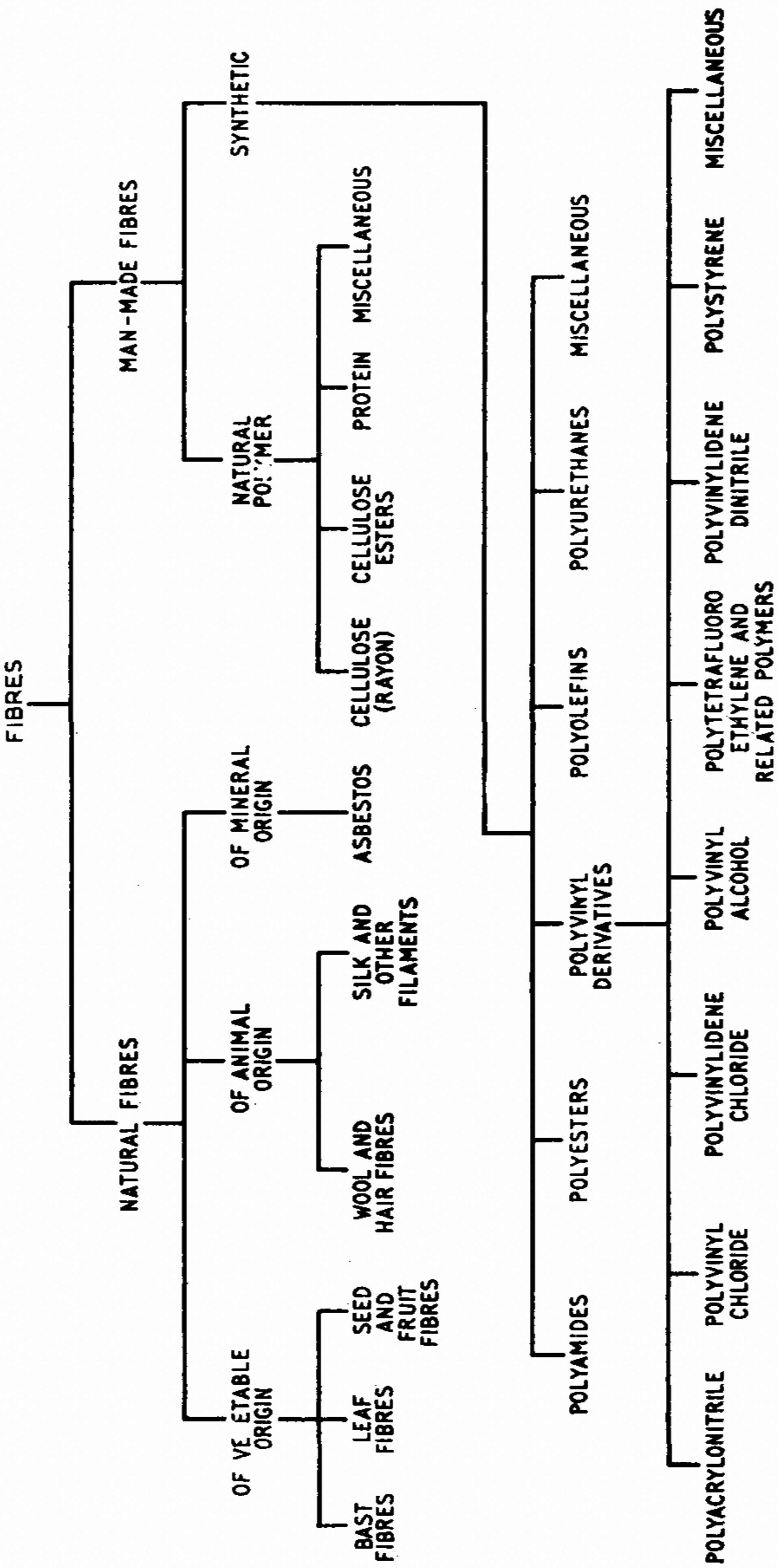
(a) Vegetable fibres (b) Animal fibres (c) Mineral fibres

Vegetable fibres include the most important of all textile fibres - cotton - together with flax, hemp, jute and other fibres which have been produced by plants. They are based on cellulose, the material used by nature as a structural material in the plant world.

Animal fibres include wool and other hair-like fibres, and fibres, such as silk, produced as filaments by cocoon-spinning creatures. These animal fibres are based on proteins, the complex substances from which much of the animal body is made.

Mineral fibres are of limited importance in the textile trade. Asbestos is the most useful fibre of this class; it is made into special fire-proof and industrial fabrics.

FIBRE CLASSIFICATION CHART



MAN-MADE FIBRES can be sub-divided into two distinct classes, according to the source of the fibre-forming substance from which they are made.

(a) Natural polymer fibres

(b) Synthetic fibres

Natural polymer fibres are those in which the fibre-forming sub- stance has been made by nature. Vast quantities of cellulose, for example, are available to us in the plant world. Only a small fraction of this cellulose is used by nature for making fine fibres such as cotton. Most of it is used as a structural material, for example in the trunks of trees and the skeleton framework of stems and leaves. This cellulose is largely useless to us as a direct source of textile fibres; it is in fibrous form, but is contaminated with other substances.

In the last half-century or so, we have learned how to manipulate this natural cellulose into a form suitable for use as textile fibres. It is the source of the fibres which became known as artificial silks.

In these natural polymer fibres nature has done the work of creating a substance (cellulose) capable of taking on a fibrous form. Man has merely taken a further step by using this cellulose as raw material for a fibre.

In a similar way, it has been possible to use materials made by animals as a source of man-made fibres. The proteins used for so many structural purposes in the animal world are often capable of forming fibres. Nature has produced the proteins without necessarily using them for fibres. Man has then taken these proteins and manipulated them into a fibrous form. So we have natural polymer fibres made from the proteins of peanuts and milk, maize and soya beans.

Synthetic fibres, on the other hand, are those in which man has performed the entire operation of fibre-production without allowing nature to manufacture the fibre-forming substance. Nylon, 'Terylene' and 'Orion' are fibres made by man from simple chemicals such as those derived from coal or oil. These chemicals have been made into materials capable of forming fibres, and these materials have then been manipulated into a fibrous form. Man has carried out the entire operation. Nature has had no hand in the production at all. They are truly synthetic fibres.

NATURAL FIBRES OF VEGETABLE ORIGIN

Introduction

In the complex designs and structures of the higher plants, nature has used fibres as the basis of the strength-providing skeleton. Bundles of fibres, bound together by natural gums and resins, run through the roots and stems and leaves of plants. Some of these fibrous structures act as pillars and girders, for example in the woody cores of the trunks and branches of a tree. Others function as hawsers, like the fibrous bundles that take the strain in the stalks and stems of less robust plants, or in the roots that grip the ground and hold the plant firm against the buffeting of the weather.

Flimsy fibres, delicate and yet supremely flexible and strong, are used by many plants as streamers to catch the wind and carry their seeds for immense distances through the air.

These vegetable fibres are all based upon cellulose,* the substance related to the starch and sugars which the plant builds up from water and from carbon dioxide gas absorbed through its leaves. The re- sources of cellulose fibre available to us in the plant world are virtually inexhaustible. But only a comparatively small proportion of these resources can be made use of directly as textile fibres. The strands of cellulose fibre in plants are associated with varying amounts of other natural substances such as lignin, pectins, hemicelluloses, waxes and gums. The amount of these associated substances and the ease with which the cellulose fibre can be separated from them determine how useful any vegetable fibre can be as a textile material.

The cellulosic fibres at present in use as textile raw materials can be classified most conveniently by referring to the part of the plant from which they come. There are three ma

STRUCTURE AND PROPERTIES

This section summarizes the important characteristics of a fibre under a series of sub-headings.

(1) FINE STRUCTURE AND APPEARANCE. The surface structure of a fibre is most important in that it controls the behaviour of the fibre in the yarn or fabric. The rough scaly surface of wool, for example, influences the felting and shrinkage properties of wool fabrics, and helps to give wool its characteristic handle. The scales enable in- dividual fibres to grip one another when twisted together as a yarn. The convolutions of the cotton fibre, similarly, enable fibres to grip one another when spun.

The smooth, glassy surface of a fibre such as nylon, on the other hand, affects the lustrous appearance of the fabric. Smooth surfaces may not cling to dust and dirt so readily as rough surfaces do.

The cross-sectional shape of a fibre has an important influence on its behaviour in a textile fabric. Fibres of circular or near- circular cross-section often have an attractive handle. Wool, for example, is a fibre of near-circular cross-section; it has a more 'comfortable' feel than cotton which has a flatter, ribbon-like cross-section. 'Orion', on the other hand, which has a dog-bone cross-section, has a very good handle.

Circular fibres often have a poorer covering-power than the flatter fibres.

Diagrams showing the microscopic appearance (cross-sectional and longitudinal) are provided for many fibres.

(2) TENSILE STRENGTH. This is the breaking strength of any material, which is commonly expressed as force per unit cross- sectional area, e.g. as dynes per square cm. In these terms, we may describe the ability of a bundle of fibres, or a yarn, to resist breakage under tension.

When a single fibre is being considered, the strength of the fibre is commonly described as *tenacity,* which is a measure of *specific stress* at break,

Tenacity is expressed in terms of grams per decitex or centinewtons pertex(cN/tex).

Two fibres with identical tenacities may have different tensile strengths; if their densities are different, the cross-sectional areas will be different too.

(3) ELONGATION. When afibreis subjected to a force, it will stretch to a certain degree. This stretching is described as elongation or extension, in terms of a percentage of the fibre's original length. It can be measured either as an elongation under a certain load, or as the elongation reached when the fibre breaks. Unless specified to the contrary, the figure given represents the elongation at break.

(4) ELASTIC PROPERTIES. *Elastic Recovery.* When afibreis stretched by a small amount, it may exhibit almost perfect elasticity. That is to say, it will return to its original length when it is released. The *elastic recovery* in this case is 100 per cent. If, however, thefibreis subjected to a greater degree of stretch, it may react in a much more complex way. Some permanent deformation may take place, so that when it is released the fibre will return to an elongated form. It recovers from some of its elongation, but not all.

This behaviour of a fibre can be denoted by describing its elastic recovery at certain elongations (specified as percentage of original length). Thus, in the case of a fibre which returns completely to its original length after, say, a 2 per cent elongation, we can say that the elastic recovery is 100 per cent at 2 per cent elongation. In the case of a fibre which retains half its extra length after release from an 8 per cent elongation, we say that it has a 50 per cent elastic recovery at 8 per cent elongation.

The elastic properties of a fibre are normally defined only with limited usefulness in this way. The recovery of a fibre, for example, depends upon the length of time it is held in the stretched position. Also, the degree to which it recovers depends on the time between its release from tension and the taking of the measurement.

Stress-Strain Diagram

The tensile and elastic properties of a fibre are usually summarized in a *stress-strain diagram.* In this diagram, the strain (i.e. the dis- tortion in the fibre) is plotted against the stress (i.e. force) exerted on the fibre. A stress-strain diagram gives a much more complete record of the behaviour of a fibre under tension than isolated figures can.

Typical stress-strain diagrams are provided for many fibres.

A straight line on the stress-strain diagram may indicate that the fibre is truly elastic. The extension of the fibre is proportional to the applied load. This is, however, rarely achieved in practice. As the load on a fibre increases beyond that needed to cause a few per cent extension, the deformation of the fibre is greater than that due to true elasticity. Superimposed upon the 'elastic' stretch there is some more or less permanent deformation of the fibre, or plastic flow.

As the tension increases, the stress-strain curve indicates how the fibre continues to deform up to the point at which it eventually breaks.

The stress-strain diagram therefore provides a much more com- plete picture of the deformation caused in a fibre as tension is applied to it. The diagram includes tenacity and elongation at break. Elastic recovery and the slow recoverable deformation de- scribed as 'creep' are determined from a number of stress-strain diagrams where repeated stresses are given, and the return paths measured.

The stress-strain behaviour of a fibre is of great importance in practice, and influences to a large degree the behaviour of the fibre in textile manufacture. During processing of the fibre into a yarn and weaving of the yarn to fabric thefibresare under varying degrees of tension. They should be able to withstand these tensions without stretching permanently to any great degree.

Wool is unusual in that it can stretch by 35 per cent and will return to its original length when relaxed. Cotton, on the other hand, has an extension at break of only about 5-10 per cent.

The general reaction of a fibre to longitudinal tensions and to flexing backwards and forwards has an immense influence on the properties of the cloth made from the fibre. A resilient fibre such as wool will tend to return to its original shape after a fabric has been crushed or creased. The crease-resistance of a fabric is usually a consequence of the resilience of the fibre itself.

Work of Rupture. The area below the stress-strain curve provides a measure of the energy needed to break the fibre. It indicates the ability of the fibre to withstand sudden shocks, and is measured in grams per decitex or centinewtons per tex.

Initial Modulus. This is a measure of a fibre's resistance to small ex- tensions. A high modulus means that the fibre has a good resistance

to stretching, and a low modulus means that it requires little force to stretch it. Flexibility and modulus are closely linked, a low-modulus fibre tending to be flexible, and a high-modulus fibre tending to be brittle.

Average Stiffness. This is the ability of afibreto carry a load without deformation. It is based on the modulus of elasticity, and is expressed as grams per dtex or cN per tex.

Average Toughness. This is the ability of a fibre to endure large permanent deformations without rupture. It is expressed as grams per dtex or cN per tex.

(5) SPECIFIC GRAVITY. This is a measure of the density of a fibre; it is the ratio of the mass of a material to the mass of an equal volume of water at 4°C. This is an important characteristic of any fibre; it affects the way in which a fabric will drape.

(6) EFFECT OF MOISTURE. Allfibrestend to absorb moisture when in contact with the atmosphere. The amount absorbed depends upon the relative humidity of the air.

In practice, the moisture-absorbing properties of a fibre are de- scribed by afigureknown as the 'regain'. This is the weight of moisture present in a textile material expressed as a percentage of its oven-dry weight (i.e. the constant weight obtained by drying at a temperature of 105 to 110°C).

The 'percentage moisture content' of a fibre is the weight of moisture it contains, expressed as a percentage of the total weight. This is a measure of the amount of water held under any particular set of circumstances.

Fibres vary greatly in the amount of moisture they will absorb. Wool, for example, has a regain of 16 per cent, acetate of 6 per cent and 'DyneF 0-4 per cent. A fibre which absorbs water readily is often most suitable for use in certain types of clothing fabrics. These fabrics will absorb perspiration from the body and will hold con- siderable amounts of water without feeling clammy. The ability of a fibre to absorb moisture will also affect the processing and finishing of yarns and fabrics. Dyestuffs are generally able to penetrate a moisture-absorbing fibre much more easily than they will penetrate a fibre that does not absorb much moisture.

The new synthetic fibres, which often have a very low moisture regain, are easily washed and dried by comparison with fibres which

absorb a lot of moisture. On the other hand, they tend to accumu- late charges of static electricity much more readily than the moisture-absorbing fibres.

The tensile properties of a fibre are affected significantly by the water it absorbs. A fibre which absorbs water freely will usually suffer a loss in tensile strength when wet. (Cotton is an exception.) Elonga- tion at break is also increased.

As fibres absorb moisture they may swell to a considerable degree.

(7) THERMAL PROPERTIES. All fibres are affected in one way or an- other as they are heated. Some, like wool, will begin to decompose without melting; others, like polyethylene or acetate will soften and melt before decomposition sets in. The behaviour of fibres on heating is of real importance, particularly within the range of temperatures that are met in practical use. Fabrics should, for example, withstand the temperatures used in laundering and ironing without undue deterioration.

Many of the new synthetic fibres are thermoplastic substances; that is to say, they will soften as they are heated. The temperature at which they soften largely determines their practical usefulness, in the textile field.

In the presence of air, most fibres will burn. The readiness with which they catch fire and support combustion is of immense im- portance. Many accidents are caused every year by clothing catching fire, and there is an increasing realization of the need for reducing the flammability of textile fibres and fabrics.

(8) EFFECT OF SUNLIGHT. Almost every fibre is affected by the powerful radiations of sunlight. Some will decompose and deteriorate fairly rapidly, losing tensile strength and changing colour. Others will resist deterioration for years, and are particularly useful for fabrics such as curtains, awnings and furnishings which are con- stantly exposed to light.

(9) CHEMICAL PROPERTIES. Modern techniques of processing fibres, yarns and fabrics often involve the use of chemicals in great variety. Bleaching agents, detergents, alkaline scouring agents, dyeing assis- tants and other chemicals are used in preparing the finished textile. The fibre itself must be able to withstand these substances without suffering harmful effects.

(10) EFFECT OF ACIDS. Textiles are commonly subjected to acid

solutions of one sort or another, and the effects of different acids under varying conditions are important.

(11) EFFECT OF ALKALIS. From the very earliest times, alkaline agents have been used for washing and scouring textiles. Soap itself forms an alkaline solution in water.

(12) EFFECT OF ORGANIC SOLVENTS. The introduction of dry-clean- ing has made solvent-resistance of great importance in a textile. Solvents such as carbon tetrachloride and trichloroethylene are com- monly used for cleaning fabrics, and the effect of these solvents on the fibre itself is obviously important.

(13) RESISTANCE TO INSECTS. The cellulose of plant fibres and the protein of wool and other animal fibres are substances produced by living things. They are, as might be anticipated, enjoyed by other living things as food.

Wool suffers more than other fibres from the fact that it is eaten by certain types of moth grub and beetle. Many fibres, particularly the synthetics, are not attacked in this way.

(14) RESISTANCE TO MICRO-ORGANISMS. Cellulose is attacked by certain moulds and bacteria, which decompose it and make use of the degradation products as food. Textiles stored in damp ware- houses are often affected by mildews, which may discolour and weaken the fibres to the point at which they become useless.

(15) ELECTRICAL PROPERTIES. The dielectric strength of a fabric is important if the material is to be used for insulation purposes in the electrical industry. It also influences the degree to which static electricity will accumulate on a yarn or fabric during processing or wear. Static electricity may be produced by friction between the yarns or fabrics and the surfaces they meet on processing machinery. The electricity often causes serious difficulties by entangling or misaligning yarns on machinery and attracting dust and fluff to the finished fabric.

The electrical resistance of a fibre may be described in terms of the mass specific resistance, i.e. the resistance of a 1 gram specimen 1 cm. long.

The production of static electricity is affected greatly by the moisture-absorbing characteristics of the fibre. A damp fibre will conduct electricity away as it is formed, so that pools of static do not collect on the fibre.

These properties can be regarded as fundamental characteristics of a fibre, and they are discussed in the 'Structure and Properties' section of each important fibre.

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THE BAST FIBRES

The bast fibres form bundles or strands that act as hawsers in the fibrous layer lying beneath the bark of dicotyledenous plants. They help to hold the plant erect.

These fibres are constructed of long thick-walled cells which overlap one another; they are cemented together by non-cellulosic materials to form continuous strands that may run the entire length of the plant stem.

The strands of bast fibres are normally released from the cel- lular and woody tissue of the stem by a process of natural de- composition called retting (controlled rotting). Often, the strands are used commercially without separating the individual fibres one from another.

On a tonnage basis jute is the most important of all the bast fibres; the world output (about 4 million tonnes in 1979) is greater than that of all the other bast fibres combined. But most of the world's jute is made into sacking and baggage cloths.

The production of flax is roughly one seventh that of jute (606,000 tonnes in 1979). But flax is the fibre from which we make linen; it is on this basis the most important of the bast textile fibres.

FLAX

Flax was probably the first plant fibre to be used by man for making textiles, at least in the Western hemisphere. Specimens of flax have been found in the prehistoric lake dwellings of Switzerland, and in the tombs of Ancient Egypt. The evidence of biblical writings

shows that the spinning and weaving of flax were well advanced thousands of years ago. Linen mummy-cloths have been identified as more than 4,500 years old.

Flax fibre comes from the stem of an annual plant *Linum usitatis- simum,* which grows in many temperate and sub-tropical regions of the world. In the inner bark of this plant there are long, slender, thick-walled cells of which the fibre strands are composed.

From the Mediterranean region,flax-growingspread over Europe. Centuries before the beginning of the Christian era, Phoenician traders were bringing Egyptian linen to Britain. Roman legions carried the Mediterranean textile skills, including the crafts of spin- ning and weavingflax,to every corner of their empire.

During the seventeenth century, linen manufacture became estab- lished as a domestic industry in many countries of Western Europe. Flax from Germany was the raw material for a flourishing linen industry that grew in the Low Countries. Linen manufacture spread from Western Europe into England, Scotland and Ireland, stimu- lated by the flow of French and Flemish weavers who were driven from their homes by religious persecution.

Until the seventeenth century only small amounts of flax were grown in England. Competition from wool had stifled the linen industry. The arrival of linen workers from France and the Low Countries created a demand for flax that was met by importation of the fibre, largely from Russia.

PRODUCTION AND PROCESSING

Grown for fibre, the flax plant is an annual that reaches 90 - 120cm (3 - 4 ft). It has a single slender stem that is devoid of side branches other than those which bear the flowers. When the plants have flowered and the seeds are beginning to ripen, the crop is pulled up by the roots (by hand or by mechanical pullers). About one-quarter of the stem consists of fibre.

Retting

The flax fibres are held together in the stems by woody matter and cellular tissue, and 'retting' is a fermentation process that frees the fibres from these materials.

Retting may be carried out in one of several ways:

(1) DAM-RETTING. The flax plants after pulling are tied up in sheaves or 'beets' and immersed for about ten days in water in special dams or ponds dug in the ground. An obsolete method no longer practised except in Egypt.

(2) DEW RETTING. The crop is spread on the ground after pulling and left for several weeks. Wetting by dew and rain encourages fermentation by moulds to take place.

Dew-retting tends to yield a dark-colouredfibre.It may be used in regions where water is in short supply; it is commonly practised in the U.S.S.R. and France. This is the method by which some 85% of the West European crop is retted. It is far less labour intensive than water-retting and therefore less expensive.

(3) TANK-RETTING. After harvesting, the seed bolls are stripped from the stems by reciprocating metal combs. The de-seeded straw, tied in bundles, is packed into concrete tanks which arefilledwith water and artificially heated to about 30°C. Retting is completed in about three days. Some of the best and most uniform fibre is produced by this process. Almost all of the flax from the Courtrai district of Belgium is tank-retted. The highest quality of straw may be double- retted, i.e. the partly retted straw is removed from the tank, dried, and then given a further period of retting.

Flax is brought in from a large area to be retted centrally in this way. The advantage of this form of retting lies in the fact that con- ditions can be controlled and the process can be carried out at any time of the year. In the Belgian method the straw is usually given a preliminary steeping treatment.

Flax used to be retted in the River Lys in Courtrai by immersing the straw in wooden crates, but retting in the Lys is no longer permitted in Belgium.

(4) CHEMICAL RETTING. Retting can also be carried out by treating the flax straw with chemical solutions. Such reagents as caustic soda. sodium carbonate, soaps and dilute mineral acids have been employed with some success. In general, chemical retting of the straw proved to be a more costly process than biological retting and the fibre produced was no better. More recently, attention has been turned towards the chemical treatment of fibre extracted in the green state from unretted straw. With developments in chemical plant for the processing of fibre, this method becomes an economic possibility. A third alternative is to prepare the unretted fibre into rove, and boil or bleach the rove before spinning. During the last war, many thousands of tonnes of green fibre were spun from boiled rove in this way.

'Cottonization' of flax is a form of chemical retting which is carried to the point where the flax is separated into very fine strands. The flax can then be spun on cotton-spinning machinery. This was carried out in Germany and other Continental countries during the war.

Breaking and Scutching

The next stage in fibre-production is 'breaking'. The straw is passed between fluted rollers in a breaking machine, so that the woody core is broken into fragments without damaging the fibres running through the stems. The broken straw is then subjected to the process known as 'scutching', which separates the unwanted woody matter from the fibre. This is done by beating the straw with blunt wooden or metal blades on a scutching machine. The woody matter is removed as *shive,* which is usually burnt as fuel, leaving the flax in the form of long strands formed of bundles of individual fibres adhering to one another.

Hackling

After scutching the fibres are usually combed or 'hackled' by draw- ing them through sets of pins, each successive set being finer than the previous one. The coarse bundles of fibre are, in this way, separated into finer bundles, and the fibres are also arranged parallel to one another. The long fine fibres are known as *line:* the shorter fibres or *tow* are spun into yarns of lower quality.

The tow is subjected to further combing or 'carding', which aligns the fibres more accurately alongside one another. They are then collected into the loosely-held rope of fibre called a *sliver* or *rove.*

STRUCTURE AND PROPERTIES

Flax fibre strands in the scutched state vary in length from a few centimetres (tow fibre) to as much as 1 metre (line). A good fibre averages 45 - 60cm (8 - 24 in). By the time the fibre reaches the spinning stage is has been broken down in length. Even thefibresin line yarn may be shorter than 30 - 38cm (12 -15 in).

Commercial flax is in the form of bundles of individual fibre cells held together by a natural binding material. Scutching and hackling tend to break up the coarse bundles of fibre as they exist in the bast, but do not separate the fibre strands into their individual fibre cells.

Flax is usually coloured yellowish-white, but the shade of the raw fibre varies considerably depending upon the.conditions under which it has been retted. Dew-retted fibre is generally grey.

Flax is usually soft and has a lustrous appearance. The lustre im- proves as theflaxis cleaned, wax and other materials being removed. The highest quality flaxes come from Belgium, Northern France and the Netherlands. Russian flaxes are generally weaker but are

remarkable for theirfinenessof fibre.

Fine Structure and Appearance
Strands of commercialflaxmay consist of many individual fibre cells;

they vary in length from 6 - 65mm *(V* - 2Vi* in) with a mean diameter of about 0.02mm (l/1200th in). Seen under the microscope, the fibre cells show up as long transparent, cylindrical tubes which may be smooth or striated lengthwise. They do not have the convolutions which are characteristic of cotton. The width of the fibre may vary several times along its length. There are swellings or 'nodes' at many points, and thefibresshow characteristic cross-markings.

The fibre cell has a lumen or canal running through the centre; the lumen is narrow but clearly defined and regular in width. It disappears towards the end of the fibre, which tapers to a point. The cell walls of the flax fibre are thick and polygonal in cross- section. Immature flax fibres are more oval in cross-section, and the cell walls are thinner. The lumen is relatively much larger than in the mature fibre.

Tensile Strength
Flax is a stronger fibre than cotton. It has an average tenacity of

about 57.4 cN/tex (5.8g/dtex).

Elongation

Flax is a particularly inextensible fibre. It stretches only slightly as tension increases. The elongation at break is approximately 1-8 per cent dry, and 2-2 per cent wet.

Elastic Properties

Within its small degree of stretch, flax is an elastic fibre. It will tend to return to its original length when the tension is relaxed. It has a high degree of rigidity and resists bending.

Linen fabrics tend to crease, but this can be significantly reduced by modern crease-resisting treatments.

Specific Gravity. 1-54.

Effects of Moisture

Flax has a regain figure of about 12 per cent.
Linen is about 20 per cent stronger when wet than dry, which

helps it to withstand mechanical treatment in laundering.

Effect of Heat

Highly resistant to decomposition up to about 120°C, when the fibre begins to discolour.

Effect of Sunlight

Gradual loss of strength on exposure.

Chemical Properties

Linen is more difficult to bleach than cotton, but modern methods of bleaching achieve whiteness with the minimum of chemical degrada- tion.

Effect of Acids

Flax will withstand dilute, weak acids, but is attacked by hot dilute acids or cold concentrated acids.

Effect of Alkalis

Flax has a good resistance to alkaline solutions; linen fabrics can be washed repeatedly without deterioration.

Effect of Organic Solvents

Flax is not adversely affected by dry-cleaning solvents in common use.

Insects

Flax is not attacked by moth grubs or other insects.

Micro-organisms

When boiled and bleached, flax is virtually pure cellulose. Like other pure cellulose fibres, flax in this state has a high resistance to rotting. Under severe conditions of warmth, damp and contamina- tion, however, mildews may attack the cellulose offlax,but resistance is generally high, particularly if the yam or fabric is dry.

Other Properties

Flax is a good conductor of heat; this is one of the reasons why linen sheets feel so cool.

Flax IN USE

In the past flax was in demand where extra strength and resistance to moisture were important. However, such flax products as sail and tent canvas, fishing lines and bookbinders' threads have now been replaced largely by synthetic substitutes. Leather-working thread, sewing thread and suture thread are still produced fromflax.The fine household linen trade has declined greatly, but developments in blending with synthetics to give linen 'easy care' properties has ensured a long-term future for flax products. The use of union cloth (cotton andflaxblended at the weaving stage) for furnishing fabrics is also established.

Waste flax fibre is made into high-grade banknote, writing and cigarette papers.

The ability of flax to absorb water rapidly is particularly useful in the towel trade. Linen glass-cloths will remove all traces of moisture from a glass without leaving any particles of fluff behind.

The molecular structure of the flax fibre makes linen an excellent conductor of heat; linen sheets are cool and linen garments are comfortable in hot weather.

Linen is often calendered or pounded in the roll by wooden ham- mers ('beetling') for as long as thirty-six hours. These treatments close up the fabric and bring out the beautiful finish that is charac- teristic of good linen.

Linen becomes stronger when it is wet, and will withstand repeated washings without deterioration. It is ideal for anything that has to put up with really hard wear.

The long life of linen fabrics was exemplified when Tut-ankh- amen's tomb was opened in 1922. Linen curtains, which had been there since about 1250 B.C., were still intact.

JUTE

In common with other bast fibres, jute has been used by man since prehistoric times. It comes from the inner bark of plants of the genus *Corchorus,* which probably originated in the Mediterranean area and was subsequently taken to India where it now grows pro- fusely. Jute fabrics formed the 'sackcloth' of Biblical times.

The jute plant flourishes in hot, damp regions of Asia, and jute has for centuries been grown in enormous quantities for textile purposes. It is now produced in greater quantity than any textile fibre other than cotton. In 1976 - 77 some 3,468,000 tonnes of jute were produced, mainly in India (1,276,000 tonnes), Bangladesh (851,000 tonnes) and Thailand (183,000 tonnes).

During the latter half of the eighteenth century, the first shipments of jute reached Western Europe from India. In 1820, jute was spun experimentally at Abingdon near Oxford. The new fibre was of immediate interest to the flax and hemp spinners located at Dundee in Scotland. The Napoleonic Wars had cut off supplies of hemp and flax from Russia, and the Dundee mills began spinning jute in 1822. After ten years of experiment, the Dundee manufacturers were able to spin jute satisfactorily, and by 1850 the jute industry was well established. It was given further encouragement by the Crimean War which cut off hemp and flax supplies in 1853, and by the American Civil War of 1861-65 which interrupted the flow of cheap cotton.

Although other European countries took up the spinning and weaving of jute, Dundee has remained a centre of the industry. Meanwhile, India and Bangladesh have been steadily increasing the number of jute spinning and weaving mills, and both countries are now processing much of their own fibre.

PRODUCTION AND PROCESSING

The jute plant, *Corchorus,* is a herbaceous annual. It may grow to 5m (15 ft), with a stalk diameter of 20mm (^{3}A in). In India and Bangladesh, the plants are commonly harvested with a hand sickle.

Retting is carried out in a manner similar to that used forflax,the stalks being steeped in a sluggish stream of water. They are examined daily until the stage is reached at which the fibre can be separated easily from the stem. The strands offibre,often as much as 2m (7 ft) long, are washed and hung up in the sun to dry. They are compressed into bales and sent off to the mills for spinning.

It is necessary to incorporate small amounts of mineral spindle oils into the fibre during conversion into yarn. Normal jute goods may contain up to 5 per cent oil, but so-called 'stainless' yarns containing 1 per cent of oil or less are commonly available when the jute-is to be used for special purposes, e.g. cables, fuses, carpet backings, wall- coverings, etc.

Bleaching and Dyeing

Jute is used very largely for cheap commodities such as sacks, bags and wrappings. Where necessary, and the extra cost is warranted, it is possible to bleach jute goods through various shades of pale cream up to pure white, and also to incorporate 'optical bleaches' (i.e. colourless dyestuffs which fluoresce a vivid white in daylight).

Dyestuffs of various types, as used for cotton, may also be applied to jute. The fibre has a special affinity for basic dyes, which provide brilliant effects even on unbleached base. Unfortunately, these effects are not very fast either to light or to water. Acid, direct and sulphur dyes are increasingly fast in this order, but also give increasing dullness of shade - all at reasonable cost. The increased demand for rugs, mats and carpets (especially cheaper tufted carpetings) has stimulated a corresponding demand for dyed jute yarns and fabrics suitable for these applications. Very bright and fast results are obtained with azoic and vat dyes, but their high cost limits their use with jute. The tendency for jute to turn brown in sunlight is a permanent disadvantage in better quality applications.

STRUCTURE AND PROPERTIES

Fine Structure and Appearance

Commercial jute varies from yellow to brown to dirty grey in colour, and it has a natural silky lustre. It consists of bundles of individual fibres held together by gummy materials, including the natural plastic lignin which plays an important role in the structure of all woody plants.

Jute usually feels coarse and rough to the touch, although the best qualities are smooth and soft. Retting destroys the cellular tissue that holds the bast bundles together, but does not normally separate the individual cells one from another. Some of thefibre-endsbecome detached from the strands, giving the jute its hairy, rough feel.

The individual cells of jute are about 2 -6mm (l/10th in) long, on average. The cell-surface is smooth, but disfigured here and there

by nodes and cross-markings. The fibres are coated with a layer of woody material.

Seen in cross-section, the cell is polygonal, usually with five or six sides. It has thick walls and a broad lumen of oval cross-section. By contrast with the regular lumen of flax, that of jute is irregular; it becomes narrow in places quite suddenly. Towards the ends of the cell, which are tapered, the lumen widens; the cell walls become correspondingly thin.

Jute contains about 20 per cent of lignin.

Tensile Strength

Jute is not so strong as flax or hemp, nor is it so durable. Individual fibres vary greatly in strength, owing to the irregularities in the thickness of cell walls.

Elongation

Jute fibres do not stretch to any appreciable extent. Jute has an elongation at break of about 1 -7 per cent.

Elastic Properties

Jute tends to be a stiff fibre, owing to the part played by the material which cements the cells together.

Specific Gravity. 1-5. Effects of Moisture

Jute is an unusually hygroscopic fibre. Its regain figure is 13-75 per cent. It can absorb as much as 23 per cent of water under humid conditions.

Effect of Age

If kept dry, jute will last indefinitely although the high content of non-cellulosic matter tends to make it sensitive to chemical and photochemical attack. Moisture encourages deterioration of jute, which loses strength with age.

Micro-organisms

Jute is more resistant to rot than either grey cotton or flax (i.e. uncleaned or unscoured). If lightly scoured it can have an excellent resistance owing to the protective effect of the lignin.

JUTE IN USE

Jute is cheap and reasonably strong, and is available in large quan- tities. These characteristics have enabled it to become an important fibre for sacks and packing cloths. These are used extensively for the storage and transport of agricultural products.

The resistance of jute fibres to stretching forces has proved a valuable property when jute is used for storage and transport purposes. Sacks and bales remain firmly in place after stacking; they do not distort and shift position as they would if made from a fibre more elastic than jute.

The hairiness of jute can be a disadvantage when jute sacks are used for food storage. The fibre-ends may break away and con- taminate the food.

The finer qualities of jute are made into curtains and furnishing fabrics; mixed with wool, after treatment with caustic soda, jute is spun and woven into cheap clothing fabrics.

Familiar uses for jute include the following: Sacks, bags, baling and bundle cloths, wrappings (e.g. for bacon), bedding foundations, bonded fabrics, boot and shoe linings, mine brattice cloths and vent tubings, starched and glued buckrams and tailor's black packings, camp beds, cargo and other separation cloths (e.g. in rubber tech- nology), cattle beddings, concrete cleavage fabrics, tarpaulins, damp courses, cables, plastics reinforcement, filter cloths, fire curtains, fuse yarns, furnishings, handbag and all types of stiff bag and case linings, hop pockets, horse covers, aprons of all heavy types, iron and steel tube and rod wrappings, canal linings (heavily bituminized), mail bags, motor car body linings, need lefel ts, oakum, oven cloths, plasterers' scrim, prefabricated road and runways, roofing felt, rope soled sandals, trunk covering fabrics, tyre wrappings, upholstery foundations, strings for all purposes, certain ropings, wall coverings, wool packs, etc.

THE LEAF FIBRES

The leaves of monocotyledenous plants are held in shape and strengthened by fibres which run in hawser-like strands through the length of the leaf. These leaf fibres are often of great commercial value, and are used in large quantities for making ropes and cordage, and for the production of textile fabrics.

In general, leaf fibres are coarser than the fibres which come from the bast of dicotyledenous plants. Bast fibre sare commonly described as ‘soft fibres and the leaf fibres as ‘hard 'fibres.This classification is not, however, a rigid one; some leaf fibres are softer than some bast fibres.

SISAL

The ancient Mexicans and Aztecs clothed themselves in fabric woven from the fibre known as sisal. This is a leaf-fibre that comes from the plant *Agave sisalana,* which is indigenous to Central America. It derives its name from the Yucatan port of Sisal on the Gulf of Mexico.

The sisal plant is now cultivated widely in East Africa, Mexico, Haiti, Brazil and in other regions of South America. The world output (1978) is in the region of 550,000 tonnes.

PRODUCTION AND PROCESSING

Sisal plants send up huge leaves almost from ground level. The leaves are firm and fleshy ,and form a rosette on a short trunk.

After six or seven years of growth, the sisal plant sends out a flower stalk that rises to some 6m (20 ft). When it has flowered ,the plant produces tiny buds which develop into small plants. These fall to the ground and take root, and the parent plant dies.

Leaves are harvested when the plants are 2Vi to 4 years old and at intervals until the plant eventually dies. A good plant may yield 400 leaves during its lifetimes, and each leaf may contain upto1,000 fibres. The outer mature leaves are cut away and treated in machines which scrape the pulpy material from the fibres. After washing, the fibre is dried and bleached in the sun, or oven-dried.

Dyeing

Sisal has a good affinity for direct cotton and acid dyestuffs, which provide attractive shades of good light fastness.

Direct dyestuffs are used in the same way as in the dyeing of cotton. Acid dyes are applied from a neutral or acid dye bath.

Basic dyes are commonly used for dyeing sisal which is used in ropes. They have poor light fastness and are less satisfactory than direct or acid dyes when the sisal is used for matting.

STRUCTURE AND PROPERTIES

Strands of commercial sisal are 60 - 120cm (2 - 4 ft) in length. They are strong and consist of many individual fibres held together by natural gums. If processing has been carried out carefully, the sisal is creamy-white in colour.

Sisal fibre tends to be stiff and rather inflexible. It absorbs moisture readily and is weakened by being steeped for long periods in salt water.

There are a number of different types of cell in a typical specimen of sisal. The 'normal' fibre cells are straight and stiff; they are cylindrical and often striated. The average length is about 2.5mm (l/10th in). These fibres sometimes appear saw-edged and have tapering ends. The lumen varies in thickness and definition; the cell walls are thick where the lumen is thin and vice versa. The lumen is often packed with tiny granules.

Sisal also contains broader fibres with a characteristic lattice pattern and with small pore-markings. Some cells are cushion- shaped and others are short and rectangular. Here and there, small spiral-shaped bodies can be seen, like little springs.

Sisal contains about 6 per cent of lignin (based on dry material).

SISAL IN USE

Sisal is one of the most valuable of all cordage fibres. It is too stiff to be used satisfactorily for certain purposes, such as power transmission, in which it has to run through pulleys or over wheels. Prior

to World War II, sisal ropes were also regarded as being of limited use in marine cordage; it was believed that sisal deteriorated too rapidly in salt water. Experience during the war showed, however, that this is not the case, and sisal is now widely used for marine ropes and hawsers particularly in under-developed areas.

Sisal is used extensively for making baler and binder twine, and for sacks, paper filters and other industrial uses.

The high strength, lustre and good colour of sisal have made it into an attractive fibre for certain textile uses. It is made into matting and rugs. Its ability to take up direct cotton and acid dye- stuffs has made it a popular fibre for ladies' hats.

ABACA (MANILA)

The *Musaceae* family of plants is one of the most useful in the world. It provides us with all manner of foods and industrial raw materials. *Musa sapientum,* for example, gives us the banana; *Musa textilis* is a source of the paper-making and cordage fibre abaca, or Manila hemp.

The abaca plant is indigenous to the Philippine Islands; native islanders were making textiles from its fibres when Magellan visited the islands in 1521 during his circumnavigation of the globe. During the early nineteenth century, supplies of abaca began to reach the Western world, and its value as a cordage fibre was quickly appreciated. It was better than hemp for many purposes, particularly in marine ropes and hawsers. Despite the many attempts that have been made to establish abaca production in other parts of the world, the Philippine Islands remain the chief source of the fibre. Total production in 1977 was 75,000 tonnes, of whch some 85 per cent came from the Philippines. The remainder came from Ecuador.

PRODUCTION AND PROCESSING

M. textilis grows easily in the Philippines and needs little cultivation. The plant comprises a cluster of sheath-like leaf stalks. The stalk is composed of a fibre less pulpy centre core surrounded by overlapping leaf-sheaths. Each sheath contains a thin layer of fibre.

These stalks often reach a height of 7.5m (25 ft). After one and a half to two and a half years' growth the blossom appears on some of these stalks, normally on two to four. This is the most satisfactory stage for fibre production, and these stalks are then cut down near the ground level. By this time the plant consists of from ten to thirty stalks in various stages of growth, and two to four of these reach maturity in four to six months after the previous cutting. The diameter of mature stalks is usually 13 - 30cm (5 - 12 in). The average useful life of the plant is about fifteen years, although some varieties continue producing for up to thirty years.

Fibre Extraction

The fibre is extracted by separating the ribbons of fibre from the layers of pulp. These ribbons, which are known as tuxies, are then drawn under a knife, usually made of metal, and the residual pulp is removed from thefibre,which is then hung up to dry.

Grades

The leaf sheaths vary in colour and texture according to then- position on the stalk. The sheaths comprising the stalk normally fall into four groups. The outside sheaths (baba) are of dark brown or light purple and green strips. (This discoloration is due to exposure to the sun.) The sheaths next to the outside (segunda baba) are striped very light green and purple. The middle sheaths are a very light green or light yellow. The inner sheaths (ubud) are almost white. The outer sheaths produce the strongest and the inner sheaths the weakest fibre.

The tuxies from these four groups of sheaths produce basically four qualities of fibre. In practice many qualities are produced by varying the type and pressure of the knife used for removing the residual pulp.

Other factois affecting the quality of the fibre are the condition of the stalks; immature or over-mature stalks reduce the quality as also does delay in removing the tuxies from a stalk after it has been cut, and delay in drying the fibre after extraction.

STRUCTURE AND PROPERTIES

Commercial abaca fibre is in the form of strands containing many individual fibres held together by natural gums. The strand-length varies greatly depending on the precise source and treatment of the fibre during processing. Good quality abaca is often in the form of strands up to 4.5m (IS ft) long.

Abaca has good natural lustre. Its colour depends upon the con- ditions under which it has been processed; good quality abaca is off-white, whereas some poor qualityfibreis nearly black.

Abaca is strong and sufficiently flexible to provide a degree of 'give' when used in rope. The fibre is not readily affected by salt water. It has a slight natural acidity which can cause corrosion when abaca is used as a core in wire ropes.

Individual fibre cells are cylindrical and smooth-surfaced. They are as much as 6mm *(V** in) long, are are regular in width. The ends taper gradually to a point.

In cross-section, the fibres are polygonal and the cell walls thin. The lumen is large and distinct; it is round and uniform in diameter although both fibre and lumen show occasional constrictions. In places, the lumen contains granular bodies.

Abaca fibres are largely cellulose (about 77 per cent of moisture- free fibre), but are coated with considerable amounts of lignin (about 9 per cent). The individual fibres can be freed by boiling the strands in alkali.

Abaca which has been treated in this way contains epidermal cells which are almost rectangular. They cling together forming little rafts among the fibrous cells.

ABACA IN USE

Most of the abaca produced today is used in the manufacture of strong high-grade paper, such as tea-bags, stencil tissue, meat casing and disposables. Some is still used for ropes and cordage. The fibre's resistance to the effects of sea-water, and its natural buoyancy, have created a ready market for it in the manufacture of hawsers and ships' cables.

Abaca fibre is also used for making hoisting and power-trans- mission ropes, well-drilling cables, fishing nets and lines, and other types of cordage where strength, durability and flexibility are essential.

Some of the fine inner fibres from the abaca leaf-stalk are used directly, without spinning, for making delicate, lightweight, yet strong fabrics. These fabrics are used in the Philippines for clothing, and For hats and shoes. Some abaca is used for carpets, table mats, etc

THE SEED AND FRUIT FIBRES

The seeds and fruits of plants are often attached to hairs or fibres which, like other plant fibres, are constructed in the main from cellulose. Many of thesefibresare used in the textile industry; one of them - cotton - has become the most important textilefibrein the world.

COTTON

Though the bast and leaffibresare of very great value to the world, they cannot begin to compare in importance as textilefibreswith the seedfibre,cotton. Cotton is the backbone of the world's textile trade. Many of our everyday textile fabrics are made from cotton; fabrics that are hard- wearing and capable of infinite variety of weave and colouring. Like the other plant fibres, cotton is essentially cellulose. But it is not produced by the plant as part of its skeleton structure, as are the bast and leaffibres.Cotton is attached to the seeds of plants of the *Mallow* family; the fibre serves probably to accumulate moisture for germination of the seed.

Early History

The idea of using these fine seed-hairs as textilefibrescame at an early stage in textile manufacture. Cotton fabrics were made by the Ancient Egyptians and by the earliest of Chinese civilizations. Samples of cotton materials have been found in Indian tombs dating back to the year 3000 B.C. There is some evidence that cotton may have been in use in Egypt in 12,000 B.C., before the use offlaxwas known. Specimens of woven cotton fabric have been found in the desert tombs discovered in Peru. These pre-Inca textiles were designed and woven with immense skill. They include brocades and tapestries, crocheting and lace. No matter where the spinning and weaving of cotton may have been developedfirst,there is no doubt that India was the true cradle of the cotton industry. Cotton fabrics of remarkable quality were being produced as early as 1500 B.C., using only the most primitive of spinning and weaving techniques.

As textile skills developed in India, many different types of fabric were produced. Brocades and heavy fabrics, embroidered materials and muslins were made in great variety and of incredibly high quality. By the seventeenth century, Indian textile craftsmen were spinning and weaving cotton into the fabulous Dacca muslin; this beautiful fabric was so light that 66m (73 yd), 90cm (1 yd) wide, weighed only 454g (1 lb) - less than one-quarter of the weight of a modern fine- quality muslin. These Dacca muslins were used for royal and ceremonial occasions. They were woven from yarn spun entirely by hand, using only a simple spinning stick. At the time of the Roman Empire, cotton growing and manu- facture became established around the shores of the Mediterranean. Trade with India developed, and lasted until the Roman Empire collapsed, bringing with it a breakdown in trading activities between the Mediterranean and the East.

During the seventh century A.D.the Saracens built up their Mediterranean empire and reached to the borders of India itself. Once again trade grew between India and the Levant. New caravan routes were established and commerce thrived as it had never done before. The foundation of much of this intercontinental trade was cotton. Cotton was being grown on the Greek mainland from the eighth century A.D., and its cultivation became established in other European countries. As the Moors penetrated into Spain, they carried their technical and artistic knowledge with them. Some of the finest fabrics were made in Spain during the tenth century; Cordova, Seville and Granada were centres of the cotton weaving and dyeing trades, and their products compared favourably with those of Eastern cities.

Europe, however, was too involved in religious struggles to allow of any volume of trade with Spain. When the Moors were eventually driven out their skills in cotton cultivation and manufacture went with them. During the twelfth and thirteenth centuries, the Crusades brought Europe into contact with the arts and crafts of Eastern countries. Once again, cotton became one of the most important of the articles that flowed through these great trade routes, and the textile industries of southern France and northern Italy began to flourish. The trading centres of Genoa and Venice became the gateways of the European continent.

PRODUCTION AND PROCESSING

Formation of the Fibre

Cotton grows inside the seed pods of a wide variety of plant species included in the *Gossypium* family. The early primitive cottons grew naturally as perennials, and for many years cultivated cotton was also grown as a perennial. In the tropics, perennial cotton plants may grow 6m (20 ft) high. Nowadays, with only one or two major exceptions, the world's cotton is grown by raising annual crops, the plants reaching a height of between 1.2 and 1.8m (4 - 6 ft).

Cotton seed is usually sown in the spring and the young plants are thinned out later into rows. In due course, many creamy-white flowers appear, which turn pink towards the end of the first day. On the third day, the flower withers and dies to leave a small green seed pod, or 'boll'. The cotton fibres form en the plant as long hairs attached to the seeds inside the boll. As the plant grows, the fibres are packed tightly into the boll. When it reaches maturity, the boll bursts and the cotton appears as a soft wad offinefibres. The individual cotton fibre is a seed-hair consisting of a single cell. It grows from the epidermis or outer skin of the cotton seed. Each cotton seed may produce as many as 20,000 fibres on its surface, and a single boll will contain 150,000 fibres or more. The boll itself is a fruit which forms when the flowers drop from the cotton plant. The young fruit that remains increases in size for per- haps seven weeks, forming the ripe boll; this then opens to expose the mass of cotton fibres which expand and dry into a light fluffy mass.

The growth of these cotton fibres takes place throughout the boll- ripening period. In some varieties of cotton, tiny fibres can be detected on the embryo seed one or two days before flowering. Other varieties begin their fibre-production a day or two after flowering.

Fibre Growth

During the first week after the cotton plant has flowered, hundreds of fibres appear from the seed coat. For several days, more and more young fibres continue to thrust their way out of the seed until each seed is carrying a 'crop' of thousands of individual fibres.

For six days, the growth of the young cotton fibre is comparatively slow. Then for the next fifteen days it is much more rapid; the fibre may reach a length equal to 2,000 times its diameter during this three- week growing period. Then for three days it grows more slowly again until the lengthwise growth comes to a sudden stop.*

During its period of rapid elongation, the cotton fibre is in the

* The time-scale given in this section represents that of a typical cotton plant; it varies considerably according to variety and conditions of growth.form of a thin-walled tube of cellulose with one end closed and the other attached to the seed. It is filled with protoplasm and liquid nutrients which have been drawn from the main supply vessels of the plant. It resembles a long thin balloon distended with water from a tap. Magnified to the thickness of a finger a typical fibre would be about 15m (50 ft) long.

(1) STAPLE LENGTH 1-2V2 IN. (26-65mm). Includes the fine, lustrous fibres which form the top quality cottons. The fibres are generallly of 10-15 microns diameter 1.1-1.8 dtex (0.99-1.62 den).

Sea Island, Egyptian and American Pima (American-Egyptian) cottons are in this category. These high quality cottons are often the most difficult to grow, and are in comparatively short supply.

(2) STAPLE LENGTH Vz—l5/ie IN. (12-33mm). Includes the medium strength, medium lustre cottons which form the bulk of the world crop. The fibres are generally of 12-17 microns diameter, and are of 1.4 — 2.2 dtex (1.26-1.98 den).

(3) STAPLE LENGTH 3/s-l IN. (9-26mm). Includes the coarse, low- grade fibres which are' often low in strength and have little or no lustre. The fibres are generally of 13-22 microns diameter, and are of 1.5-2.9 dtex (1.35-2.61 den).

Many of the Asiatic, Indian and some Peruvian cottons come into this category.

Ginning the Seed Cotton

After picking, the cotton fibre has to be separated from the seeds, a process carried out mechanically by the cotton gin. There are two forms of this machine in general use, the saw gin and the roller gin. The saw gin is used mainly for short and medium length cotton, and the roller gin is often preferred for longer fibres, although the short Asiatic types of India and Pakistan are roller ginned. Roller ginning is a slower and more costly process.

The Saw Gin

This consists of a steel grating in which are narrow slits. Through these come toothed saws that revolve, catching the fibres in their teeth and pulling them through the slits. The seeds are too big to go through, and remain behind. The ginned cotton is called 'lint'.

Ginning does not remove all the cotton; short fibres are left adhering to the seeds. These fibres are removed by passing the seed through another gin, and the mass of short fibre produced ('linters') is used for stuffing upholstery and as a source of pure cellulose for industry.
The Roller Gin

This consists of leather discs attached to a wooden roller. The leather surface of the revolving roller passes close to a 'doctor' knife leaving a space through whichfibrescan pass but seeds cannot. As the roller revolves, the fibres cling to the leather surface and are carried through the gap between the leather and the knife. The seeds are caught by the knife and removed.

Ginned cotton is pressed and packed into bales weighing 200 - 720 lb (91 - 327kg) and sent off for spinning into yarns. 1 oz (28.4g) of cotton contains about 100 million fibres, so that a 500 lb (227kg) bale will contain some 800,000 million fibres. Placed end to end, these fibres would reach 20 million km (12V2 million miles).

Grading

Hundreds of varieties of cotton are grown in different climatic conditions and in all manner of soils and environments. The grading and classification of all these cottons, with special reference to the yarns and fabrics they will produce, is obviously no simple task.The assessment of cotton is carried out traditionally by the cotton 'classer', who depends upon personal skill and long experience in judging cotton quality by inspection and feel. In arriving at his assessment, the classer takes note of

(1) the staple length, (2) the colour and. (3) the amount of impurity in the cotton, and the quality of its preparation.

- ***Cotton pods***
- **Ginning (Removal of Seeds)**
- **Lap Formation**
- **Carding Doubling**
- **Combing**
- **Drawing**
- **Roving**
- **Spinning**

Preparation: The fibres are first removed from seeds in a gin. This process is called ginning. Every bit of the cotton fibre is used in the manufacture . The fibre mass is then compressed into bales and shipped into spinning mills.

The short ends left on the seeds after the longer fabric. Fibres have been removed are used in the production of rayon, plastics, dynamite and many other by products, which are then used in the production of seed oil, hydrogenated fats, soaps and cosmetics.

Forming the laps: In the step dirt from cotton fibre is removed and fibres are made in to a soft roll or lap. Then several laps are combined into one.

Carding: These fibres are drawn together to form a loose rope called sliver.

Doubling: Slivers are combined here for uniformity.

Combing: This process is continuation and refinement of carding process. All cotton yarns for fabrics are carded but not all are combed. Yarns that are combed are finer even and free from all woody stalk of the plant. They are used for finer quality fabrics such as voile and organdie. Fabrics made from these fabrics are expensive too. The slivers are called carded slivers.

Drawing: The slivers is then combined, smoothened and stretched. The slivers may be drawn reduced further in size and given a slight twist by a process

called roving in which the slivers is passed through rollers and wound on to bobbins set into spindles. It is done in a speed frame.

Roving: The bobbins are placed on the roving frame where further drawing and twisting takes place until the cotton stock is about a pencil lead in diameter.

Spinning: Done on the spinning frame where the stock passes through sets of high speed rollers and gives the yarn of desired thickness.

Weaving and dying: The yarn is then knitted or woven in any one of the variety of weaves and structures. Warp yarns are usually more strongly twisted than filling yarns since they must withstand greater strain in weaving and finishing. Dye stuffs may be applied to raw cotton, yarn or piece goods.

Finishing:It includes starching,calendaring,sanforizing,mercerizing orother finishes as it is necessary for the particulars use for which the cloth is intended. These finishes may be applied to yarns but are usually applied to fabric. The fabrics may be given these special finishes before or after dyeing.

NATURAL FIBRES OF ANIMAL ORIGIN

Animal fibres make up less than 7 per cent of the total weight of textile fibres produced annually. In quantity, therefore, they repre- sent a minor part of the world's fibre resources. But animalfibresplay a much more important role in the textile trade than their limited production indicates. They are all fibres of character; each one has unique properties which ensure it a position of special significance as a textile fibre.

Wool and Hair Fibres

Whenever fur-bearing animals form part of the domestic economy of a country, the fibrous materials of their coat are put to good use in one way or another. Wool, the fibrous covering of the sheep, is by far the most important of these fibres, and sheep-farming is now an extremely important activity in many parts of the world. Wool forms more than 90 per cent of the total world production of animal fibres.

Although wool plays such a dominant role in the animal fibre industry, a number of other animal fibres are of considerable com- mercial importance. In the textile industry, it is usual to describe all animal-covering fibres other than wool as hair fibres. The term wool is restricted to the covering of the sheep. This terminology can lead to some confusion, as the two terms 'hair' and 'wool' are often used to differentiate between the two types of fibre commonly forming the covering of animals. The long, coarse fibres forming the outer coat are called hair, and the short, fine fibres of the undercoat are called wool. It is preferable, therefore, to qualify the term wool by the name of the animal when it refers to anything other than sheep's wool.

Hair fibres are all related to wool in their chemical structure; they are all keratin. But they all differ from wool, and from each other, in their physical characteristics; they are of different length and fine- ness, and have different shapes and internal structures.

Many hair fibres are used in high-quality applications in the textile trade. Others have specialized non-textile uses; horse-hair,

for example, is a padding or filling material; camel hair and pig's bristles are made into brushes; rabbit fur is used for producing felts.

Silk

This fibre, spun by the silkworm as it makes its cocoon, is the only natural fibre of importance which is in the form of a continuous filament. The quantity of silk produced is so small as to amount to only about 0-25 per cent of the total fibre production. But silk has always held a special position as a quality fibre, and sustains a high price by comparison with other fibres.

WOOL

Though vegetable fibres were probably the first to be used for spinning and weaving into cloth, animal fibres in the form of skins and furs were undoubtedly the earliest form of clothing used by primitive man. But at what stage did he discover that the hairs on a sheepskin could be cut off, twisted into yarn and then woven into cloth?

A fabric or garment labelled as 'all wool' is not necessarily made from new fleece wool; it may contain a proportion of recovered wool. As such fabrics are inferior to those from new wools, it is customary to refer to new-wool materials as 'virgin wool'. The 'Woolmark', which designates such virgin wools, guarantees that a fabric is made from new wools.

PRODUCTION AND PROCESSING

When primitive man selected the sheep for domestication, he was guided in his choice by his clothing needs. He wanted an animal that would provide a skin of a size suitable for use as a human garment; and he wanted, at the same time, a creature that grew a soft and comfortable fleece. The sheep was an obvious choice.

The ancestors of our modern sheep grew coats of fibres that

served in two essential ways. On the outside of their fleece was a layer of long, coarse hairs which acted as a protective overcoat; these hairs were shed every spring. Under the layer of coarse hair fibres, the sheep grew an undercoat of finer hair, much more delicate and downy; this inner layer acted as a blanket to keep the animal warm. This insulating layer has given us the textile fibre that we now know as wool.

Modern sheep have been bred to provide as large a proportion of wool as possible. Sheep that are used primarily as a source of wool may carry only a trace of the outer covering in their fleece. Certain mountain breeds retain a relatively high proportion of coarse hair fibres. Thesefibresare sometimes unusually white in colour, and are opaque; in the finer woolled breeds they are generally regarded as a sign of poor breeding.

The merino, most important of all the sheep used as a source of wool, has almost entirely dispensed with its outer coat. Moulting no longer takes place, and the wool will go on growing year after year if it is not cut off.

Quality of Wool

Merino Wool

The raising of sheep for wool is now an important industry in many countries, and the quality of different wools is correspondingly diverse. The merino sheep, which produces fine, soft wool forms the basis of wool production in Australia, South Africa and South America. Immense flocks of merinos are raised in these countries.

Crossbred Wool.

The merino sheep imported into Britain by George IV did not find conditions to their liking. In some other countries, however, crossing of the merino with other breeds of sheep was highly successful, and breeds originating from such crosses are now of great importance as wool and meat producers. Sections of the New Zealand sheep industry, for example, are based on cross-bred sheep which provide both wool and mutton. Australia and South Africa also export a great deal of wool produced by cross-bred sheep.

British Wool

British-grown wool can be graded into four main types described as lustre, demi-lustre, down and mountain wools.

LUSTRE WOOL comes from Lincoln, Romney Marsh, Cotswold and Leicester sheep. It is up to 30.5cm (12 in) long and is made into lustrous dress fabrics, buntings and linings.

DEMI-LUSTRE WOOL is shorter and has less pronounced lustre. It is made into serges, dress fabrics and curtains.

DOWN WOOLS are medium length 75- 100mm (3-4 in) staple; fibre is curly and has a crisp handle. Sussex or Southdown sheep provide some of the finest of English wool; it is made into hosiery, cheviot suitings and flannels.

MOUNTAIN WOOLS from breeds such as the Scottish Blackface vary greatly in quality and length. Blackface wool is long and coarse and contains a high proportion of kemp fibres. * It is made into tweeds and carpets; the famous Harris tweed is commonly made from Blackface wool.

Cheviot, a medium length wool, is made into knitwear, tweeds, worsteds and cheviot suitings. It is strong and of bright colour, and has good felting properties. Welsh wool is used largely for making flannels.

Irish wool is too thick to be spun into fine yarn, and is used for homespun tweeds and woollens and for carpets.

In the Shetlands, wool is combed from the sheep instead of being removed by clipping. It has a very soft handle although it may contain a high proportion of hair, and is knitted into the shawls, cardigans and other garments that are known the world over.

Asian Wool

In China and other parts of Asia, in Turkey and Siberia, the pro- duction of wool is of growing importance. The wool is often long and coarse compared withfibreproduced in Australia, South Africa and the other great wool-producing countries.

As in the case of cotton and other plantfibres,the quality of wool depends greatly upon the conditions.under which it is grown. Wool derives from a living creature, and it is affected not only by the hereditary characteristics of the sheep but by the environment in which the sheep has lived.

Wool Production

Wool fibres grow from small sacs or follicles in the skin of the sheep. The woolfibresgrow in groups of 5-80 hairs and there are 1550-3410 per sq cm (10,000-22,000 per sq in).

A typical Hampshire sheep will have some 16—40 millionfibresin its fleece; a Rambouillet between 29 and 97 million, and an Australian merino may carry as many as 120 million individual wool fibres. Thesefibresgrow on the average at the rate of 2.5cm (1 in) in two months; altogether they represent a considerable drain on the resources of the animal.

Shearing

Sheep are normally shorn of their fleece every year (in some countries, e.g. South Africa, up to twice a year). On large stations,

* 'Kemps' are a short wavy type of hairy fibre which are shed periodicallythe fleece is removed in one piece by power-operated clippers. In efficient hands, the sheep is parted from its wool in two and a half minutes. A first-class shearer will get through two hundred sheep a day, from which he will clip a tonne or more of wool. This type of wool is known as 'fleece or clip wool'.

Immediately after it has been removed, thefleeceis 'skirted'. This involves pulling away the soiled wool around the edges. Then the whole fleeces are graded by experts who judge the fineness, length, colour and other characteristics. Finally, the various grades are packed into large sacks and then sewn up into the bales which are a familiar sight in any Yorkshire town. Each bale contains about 136kg (300 lb) or more of wool.

Slipe Wool; Mazamet

Wool is also removed from the pelts of slaughtered sheep. The pelts are treated with lime and sodium sulphide or some other depilatory. This loosens the wool, which can be pulled away without damaging the hide. This wool is called 'slipe wool'. Hides can also be subjected to bacterial action to loosen the wool; the product is called fellmongered or 'Mazamet' wool, from the French town of Mazamet where it is produced in quantity. Wool removed from the skin in these ways is usually inferior in quality to clip wool; it is often used mixed with fleece wool.

Wool Sales

In the U.S.A. and in some South American and other countries, wool is sold direct by the shearer by private treaty, often with a minimum of preparation. In Australia, New Zealand and South Africa, fleeces are skirted and classed carefully into recognised categories before being sold at public auction. In Great Britain wool is sold by farmers to the British Wool Marketing Board who bulk- class the fleeces before selling the wool at public auction.

British Wool Industry

Raw wool reaching Britain is sent off to the great manufacturing centres. Most important of all is the West Riding of Yorkshire, where woollen fabrics of almost every type are made. Heavy and medium classwoollenscomefromthemillsofLeeds,Dewsbury,Morley and Batley. Carpets are made in south west England, Ireland and elsewhere The finest saxony woollens are made in the West of England, near Trowbridge. Tweeds and cheviots come from Galashiels, Hawick and other border towns, where Scottish cheviot wool is spun and woven into the famous 'Scotch Tweeds'. From Aberdeen come the world- renowned Crombie materials. Witney makes blankets, and Rochdale makes flannels. In the Leicester and Nottingham districts, woollen yarn is made into knitted materials.

The worsted industry is less scattered, and is centred in Yorkshire. Bradford - 'Worstedopolis' - makes all manner of dress goods and linings. Huddersfield has a reputation for the finest quality worsted suiting materials. Wakefield, Keighley and Halifax make worsteds **in** a **great** variety of forms.

Preparation of Wool for Spinning

Grading and Sorting

The quality of wool varies greatly with the breed of sheep and the conditions under which it has lived. Quality depends also upon the characteristics of the individual sheep, and upon the region of the sheep's body in which the wool has grown.

As the fineness and length, the softness and colour of wool deter- mine the uses to which the fibre is put, grading and sorting of wool are essential preliminaries to spinning.

Counts

The first grading of wool takes place asit is being prepared for sale. The price of raw wool depends upon the buyer's assessment of its fineness and length. Quality is defined by numbers which atone time described the limiting fineness or 'count' of yarn into which it could be spunonthe English worsted count system. An 80s wool, for example, was at that time considered capable of being spun into a yarn of 80s count. This meant that 1 lb (454g) of wool would yield 80 hanks each containing a fixed length of yarn. In the worsted industry, the standard length of a hank is 560 yd (504m). 1 lb (454g) of 80s wool would thus be capable of spinning into 80 hanks each of 560 yards if it was spun to the finest limit. Under modern conditions these spinning limits are no longer valid, but the traditional numbers continue to be used to describe wool quality or fineness. (In woollen manufacture, the unit of skein-length is shorter and varies from place to place. In Yorkshire, the standard is 256 yd (230.4m), whereas in the West of England it is 320 yd (288m).

Thus, although wool quality numbers no longer relate directly to 91

the worsted yarn count system, they form an arbitrary scale whereby the higher the quality number, the finer is the wool. A merino wool usually lies between 60s and 100s; wool from cross-breds is 36s - 60s, and coarse wool such as that used in carpets is less than 44s.

Fibre Length

The average length of wool fibres is described by special terms such as 'combing' or 'clothing'. When the fibres are long enough to undergo combing and be made into worsteds -65mm (2Vi in) or more - they are combing wools; 176mm (7 in) they are long wools. Fine fibres, 38-65mm (IV2-2 in), can be combed in the French comb and are 'French combings'. Short wools of less than about 32mm (1Y4 in) are described as 'carding or clothing wools'.

Classifying

When the bales of wool are opened in the mill, the fleeces are skirted if this has not already been done. Thefleecemay be classified as a whole or, if variable in quality, separated into sections such as shoulders, sides, back, thighs and britch and belly. In general, the shoulders provide the best wool, and the flanks a slightly lower quality wool. The belly, tail and legs yield the poorest quality of wool. In medium and long wool breeds of sheep, the head, legs and britch usually produce the highest proportion of hair and kemps. Some breeds, such as the Scotch blackface, produce hair and kemp fibres in all parts of their fleece.

Lamb's Wool

The finest wool is obtained from young sheep. Lamb's wool clipped at eight months is very fine and of excellent quality.

Hog Wool

Six months later, when the sheep is fourteen months old, the wool ('hog') is stronger and thicker. As the animal grows older, the quality of the wool decreases slightly.

Altogether, a sheep, on the average, will provide between 0.9 and 4.54kg (2-10 lb) of wool per year, according to breed.

Scouring

Raw wool is dirty and contaminated with natural substances that must be removed before processing can be carried out. Often, as much as 50 per cent of the weight of raw wool consists of impurities

Wool. Woollen and Worsted Yarns. In a woollen yarn (A), the random

arrangement of the fibres results in a bulky yarn with a fuzzy surface.
In a worsted yarn (B), thefibresare lying more parallel, and are more

tightly twisted, producing a thinner yarn with a smoother surface.

of one sort or another. In addition to dust and dirt, the wool is mixed with natural grease (yolk) and with dried perspiration (suint). In general, the finer wools such as merino contain a higher propor- tion of natural impurities than the coarser wools.

Raw wool is washed or scoured by being agitated gently in tanks filled with warm water containing detergent. The raw wool is propelled gently through a tank, then squeezed between rollers and carried into another tank. It may pass through four or more tanks in this way, until eventually it is rinsed in clean water. It is then dried until about 20 per cent of water remains in it.

Other methods are now being used for cleaning raw wool. It can be washed, for example, in a grease solvent fluid.

Although these processes clean raw wool by removing unwanted substances from it, they do not necessarily produce a white fibre. The wool may contain natural colouring matters.

Processing and Spinning

Wool is spun into two types of yarn, woollen and worsted, and the treatment of the fibre after scouring varies accordingly.

oollen yarns are thick and full; the fibres are held loosely and subjected to only a limited twist during spinning. These yarns, made usually from short-staple wool, are woven into thick, full-bodied materials such as tweeds or blankets and used for knitting.

Worsted yarns, on the other hand, are finer, smoother and firmer. The fibres in worsted yarns are aligned so that they lie closely alongside each other in the direction of the yarn; for woven fabrics they are twisted tightly together to form a fine strong yarn. Worsteds are spun commonly from fibres 5-38cm (2-15 in) long. These yarns are woven into fine dress materials and suitings. Worsted spun yarns with less twist are used for knitting yarns and knitted fabrics.

Woollen Yarns

Although scouring will wash most of the grease and suint from the raw wool, it does not necessarily remove any burrs, twigs and other vegetable material from thefibres.These impurities can be destroyed by steeping the wool in dilute sulphuric acid and then heating at high temperature. The cellulosic material is charred and can then be broken up and beaten out of the wool. This process is called **CARBONIZING.**

Burrs and other vegetable impurities can also be removed mechanically by passing the wool through heavy crushing rollers before the intermediate stage of carding, so that the vegetable impurities are removed as a powder in subsequent carding.

Often, woollen yarns are spun from a mixture of new wool with reclaimed wool, or with rayon, cotton or other fibres. After scouring and cleaning, the wool is blended to mix various grades together and to incorporate any other fibres.

Carding

The wool is now ready for carding in machines equipped with rollers covered with sharp steel wires which disentangle the matted fibres. There are usually three parts to the machine used in woollen carding, called the scribbler, intermediate and carder. They all perform in much the same way, separating the fibres and mixing them thoroughly. The wool emerges from the carding machine as a thin blanket of fibres about 1.5m (5 ft) wide, holding together as a fluffy mass.

SILK

Like wool, silk is an animal fibre. But instead of being grown in the form of hair, it is produced by insects as a handy material with which to build their webs, cocoons and climbing ropes.

Almost the entire commercial silk industry is based on one insect - the silkworm. In spite of its name, this is really a caterpillar; the silk is made by it when it wants to change into a chrysalis and then a moth. It spins the silk and wraps the fibre round itself in the form of a cocoon inside which it can settle down in comfort.

According to Chinese legend, silk culture dates back to the year 2640 B.C., when the Empress Si-Ling-Chi learned how to rear the caterpillars and unwind the cocoons that they made. The Empress devoted herself personally to rearing the worm, and it was largely through her encouragement that the silk industry became estab- lished in China.

For three thousand years China held a monopoly in the silk industry. Then sericulture - as silk production is called - spread to Japan via Korea. An ancient Japanese book - *Nihongi* - describes how in A.D. 300 a number of Koreans were sent from Japan to China to engage people experienced in the weaving and finishing of silk cloth. Four Chinese girls were brought back, and they instructed the court in the art of plain and figured weaving. The Japanese erected a temple to their honour in the province of Settsu.

Gradually, silk production spread westwards over Asia. Many tales are told of the ways in which the eggs of the silkworm and the seeds of the mulberry tree on which it fed were smuggled from one country to another. According to legend, they were carried to India by a princess who concealed them in her head-dress.

Between the Ganges and the Brahmaputra the Indian silk industry soon became established. From India, sericulture moved west again to Persia and the countries of the Mediterranean. Aristotle gives us our first description of the silkworm as 'a great worm which has horns and so differs from others. At its first metamorphosis it pro- duces a caterpillar, then a bombylius and lastly a chrysalis - all these are changes taking place within six months. Then, from this animal, women separate and reel off the cocoons and afterwards spin them. It is said that this was first spun on the island of Cos by Pamphile, daughter of Plates.'

PRODUCTION AND PROCESSING

The silkworm is the caterpillar of a small off-white moth belonging to the species *Bombyx mori.* It lives on one thing only - the leaves of the mulberry tree. First essential for a silk industry, therefore, is an adequate supply of mulberry leaves - and the quantities needed are prodigious, for the silkworm spends its life doing little else but eat.

In Europe, silkworms are fed largely on the white-fruited mulberry, though other species are suitable. Much depends on the conditions under which the mulberries are grown, for this determines whether the leaves will be suitable for the worms.

Rearing of the silkworms starts as soon as leaves begin to appear on the mulberry trees. Eggs that have been laid by the moth and stored in a cool place during the winter are warmed up to encourage them to begin hatching. In large, scientifically-run farms, warming is done artificially; but where silk production is a part of peasant economy, as in many regions of China, the eggs are warmed by contact with the human body.

Hatching

After a few days the eggs hatch out to tiny caterpillars less than 3mm (7sin) long. 28g (1 oz) of eggs yields as many as 36,000 silkworms.

Every effort is made to get the eggs to hatch out in batches at the same time, as the economy of silk production depends largely

on this; the worms will sleep and eat and spin at roughly the same time. Hatching is normally done by spreading the eggs over trays in the hatching shed. When the worms appear, perforated paper is placed over them and a supply of chopped mulberry leaves is spread on the paper. The worms climb through the holes and set to work on the leaves; dirt and egg-residues are left behind.

Moulting

During this stage the silkworms do nothing but eat, except for four periods of sleep lasting a day at a time, during which they shed their skins and grow new ones. Mulberry leaves are the sole diet. And they must be just right or the silkworm will refuse to eat them. They must be fresh and slightly wilted - but not faded.

After its fourth moult, the silkworm settles down to a final feed lasting approximately ten days, during which it eats twenty times its own weight of leaves. About thirty-five days have passed since it was hatched, and the worm is ten thousand times as heavy as when it was born. It is over 76mm (3 in) long and weighs about 7g *(V** oz). It has become a huge bloated greenish-white caterpillar filled with liquid silk, and is ready to start spinning. Rearing up on its hind legs, the silkworm weaves about looking for somewhere to settle down and build its cocoon. Bundles of straw are put on to the trays where the worms have been feeding, and those that are ready to spin climb ponderously up into the straw and begin to make their cocoons.

Spinning the Cocoon

The liquid silk is contained in two glands inside the silkworm. From these glands it flows in two channels to a common exit tube, called the spinneret, in the silkworm's head. As it emerges, the liquid silk hardens into very fine filaments and these are coated and stuck together by a gummy substance called sericin which comes from two other glands nearby.

The silk used by the worm, therefore, is really a twinfilamentheld together as a single strand by the sericin cement. As the silk exudes, the silk worm moves its head backwards and forwards in a figure 8 movement. Gradually, it surrounds itself with a strongly built cocoon made from a continuous silk strand that may be up to 1.6km (1 mile) in length.

Spinning usually takes two or three days, during which time the silkworm has shrunk to a mere vestige of its original silk-bloated

self. Inside its cocoon it begins to change into a chrysalis or pupa and then into a moth. On the silk-farm, the crysalis must be killed before this happens. For the moth escapes from the cocoon by secreting a fluid that dissolves away a section of the cocoon to make a hole through which it can crawl out. The continuous silk filament is thus broken up into thousands of short pieces which are useless for reeling. So within a few days of making its cocoon, the crysalis is killed by heating or stifling. It is baked in the sun or in an oven, or stifled in hot air or steam. The cocoon can then be kept indefinitely without damage until it is wanted for reeling.

Egg Production

From 28g (1 oz) of eggs, the rearer gets up to 63kg (140 lb) of cocoons. These yield some 5.5kg (12 lb) of raw silk. To produce it, the worms consume a ton of mulberry leaves. In many countries it is forbidden for silkworm rearers to provide themselves with eggs from their own moths. This is essential to control the many serious diseases to which the worm is prone. Egg production is thus an entirely separate branch of the industry and is carried out under rigorously controlled conditions.

The moths emerge from their cocoons as small greyish-white insects with rudimentary wings. They cannotfly;they have no mouths and cannot eat. The sole job in life of the silkworm moth is to mate and lay its batch of 350-400 eggs.

In order to check and control the health and vitality of the worms for spinning, each moth, after mating, is put into a linen bag 50mm (2 in) square. This has previously been cleaned and disinfected. After its eggs have been laid, the moth dies. Its body is examined micro-scopically, and if germs are present the bag and its contents are burned. In addition, some of the eggs - or 'seeds' as they are called by the rearers - are crushed and examined. It they are germ-free the eggs are passed for hatching.

Wild Silk

Although the domesticated silkworm *Bombyx mori* **is the mainstay of the silk industry, there is a considerable trade in some countries in silk produced by silkworms living 'wild'. Most important of these wild silks is that which is known as Tussah ('Tussur', tussore).**

Tussah Silk

Tussah silk is the product of several species of silkworm of the genus *Antheraea* - **particularly** *A. mylitta,* **indigenous to India and** *A. pernyi* **which is native to China. These worms feed almost exclu- sively on the oak** *Quercus serrata.*

Despite the fact that different species of worm produce Tussah silk, the cocoons are sufficiently alike for the silk to be regarded as a reasonably homogeneous material. The silk is affected more by the climatic conditions and the environment in which it has been produced than by the species of silkworm that produced it.

The tussah silkworm differs considerably in appearance and habits from *Bombyx mori.* **It is usually larger, and may be 15cm (6 in) or more. It is a greener colour and is covered with tufts of gingerish hair.**

The tussah silkworm lives an outdoor life, feeding on the leaves of dwarf oak trees. Crops of cocoons are produced twice a year, in the spring and autumn. The latter is the most important as a source of silk; the spring crop provides the worms that make the autumn cocoons.

Tussah silk production is an important peasant industry in northern China and Manchuria, and in parts of India. Manchurian cocoons are generally heavier than thosefromthe Shantung region of China, and Manchurian silk is darker in colour. It has been estimated that 4 x $10^3 m^2$ (1 acre) of oak trees can support 60,000 cocoons; this is equivalent to about 360kg (800 lb) of raw silk.

The tussah silkworm leaves one end of its cocoon open, sealing the hole with a layer of sericin gum before settling down to its metamorphosis. When the moth wishes to emerge from the cocoon, it breaks through the sericin wall without damaging the continuous silk filament from which the cocoon has been made. Tussah silk cocoons are not necessarily treated, therefore, to kill the chrysalis before the silk is reeled.

Other Wild Silks

Although tussah silk is the most important wild silk in commercial use, there are other types of wild silk produced by caterpillars of different species in many parts of the world. In Japan, *Antheraea yama-mai* produces a silk that was at one time reserved for royal use. It feeds on oak leaves.

Attacus ricini provides a high-quality white silk; it is found in both the American and Asian continents. It feeds on the castor oil plant. In Africa there is a silkworm of the Anaphe family which feeds on fig leaves. Groups of these caterpillars will build large nests inside which they make their individual cocoons. The nests and cocoons are made entirely from silk. This type of wild silk is collected in considerable quantities in Uganda and Nigeria, and used for making

native fabrics.
In India, *Antheraea mylitta* and *Antheraea assama* are important

silk-producing caterpillars. They make cocoons often more than 5cm (2 in) long. *A. mylitta* feeds on the bher tree, *Zizyphus jujuba.*

Reeling and Throwing

Vegetable fibres such as cotton, and hair fibres such as wool have one thing in common; they are produced in relatively short lengths. Cotton and wool fibres are usually a few centimetres long; even flax, which is one of the longest of the vegetable textile fibres, is only about 60cm (2 ft). In order to convert these short fibres into long threads or yarns, we have to align the fibres and then 'spin' them by twisting the fibres together. In this way, innumerable short fibres are made to grip one another to form a thread or yarn that is long enough to be used for weaving purposes.

Silk, however, is quite different from these other natural fibres; the silkworm makes its cocoon from a twin filament that is extnidedfrom its spinneret in a continuous strand. This filament may be as much as 1.6km (1 mile) in length.

The production of a 'thread' or 'yarn' of silk suitable for weaving therefore a process different from that which is used in the case of shorter fibres. All that is necessary, in principle, is to unwind the long continuous filaments from the cocoons and then twist a number of these together to form a thread of useful thickness.

The unwinding of the fine silk filaments from the cocoons is called reeling, and the process is carried out in a building called a filature. The cocoons are soaked in hot water to soften the sericin gum that is cementing thefilamentin place. A revolving brush is then used to find the end of the filament- a difficult job with something so fine that it is almost invisible.

When the end of the filament has been picked up, it is drawn through a guide along with thefilamentsfrom several other cocoons. The filaments may be given a slight twist to hold them together and are reeled steadily off the cocoons which are left floating in hot water to keep the gum softened.

Tussah cocoons are gummed more firmly than those of cultivated silk, and contain more calcium salts. They are usually soaked in sodium carbonate before reeling.

Reeling requires great skill, as the operator must produce a uniform thread by combining the silk filaments in suitable fashion. Each filament is narrower towards the beginning and the end than it is in the middle, and the reeler must join the filaments in such a way as to allow for this variation in width. The actual size of the threads produced is denoted by weighing a certain length in half decigrams. This is called the denier of the silk.

Silk is wound up by the reeler in the form of skeins. These are made up into bundles of about 2.7kg (6 lb), called 'books'. These are then packed into bales for shipment.

When the raw silk arrives at the manufacturing centre, it is in the form of continuous strands in which the individual filaments are cemented together by the sericin. Silk may, for some purposes, be woven without further preparation. Usually, however, two or three of these multi-filament strands are twisted together to form heavier threads; this process is called 'throwing' from the Anglo-Saxon word 'thrawan' meaning to whirl or spin.

Degumming

The natural gum, sericin, is normally left on the silk during reeling, throwing and weaving. It acts as a size which protects the fibres from mechanical injury. The gum is removed from the finished yarns or fabrics, usually by boiling with soap and water. Silk fabrics woven with the sericin still on the yarn have a characteristic stiffness of handle; they are also dull in appearance. After degumming, the silk acquires its beautiful lustre.

As much as one-third of the weight of the fabric may be lost when the gum is removed in this way.

Raw silk with the gum still on the filaments is called 'hard silk'. Degummed silk is 'soft silk'.

Foulard fabric, georgette, chiffon and crepe de chine are woven from hard silk which is afterwards degummed.

Spider Silk

The silken filaments spun by spiders are so fine that they can often be seen only with difficulty. The golden garden spider spins a filament only 0;00001 in (0.00025mm) in diameter.

Many attempts have been made to use spider silk as a textile fibre. More than 200 years ago, a Monsieur Bon of Languedoc in France collected enough silk from spider cocoons to spin into a yarn. He made silk stockings and gloves from the fine grey silk and exhibited these at the Academy of Science in Paris in 1710.

Great excitement was aroused in France and M. Bon was loaded with honours. Rene Reaumur, the famous physicist, was commissioned to examine the feasibility of setting up a spider silk industry. But in spite of his initial enthusiasm, Reaumur concluded that the difficulties would be too great. The spiders were tempera- mental and unco-operative; they became excited and resented the food they received so much that they ate each other instead. Such silk as they produced was delicate and extremely difficult to spin.

In 1864, Dr. Wilder, an American army surgeon stationed in South Carolina revived the idea of using spider silk for textiles. He found that instead of waiting for the spiders to spin their cocoons he could 'milk' the silk artificially from the spider. A pair of stockings made from this spider silk cost over 100 dollars. They represented the life's work of nearly 500 spiders, and the stockings were so sheer that they were of little practical value.

Since then, attempts have been made in other parts of the world to domesticate the spider and relieve it of its silk. A *2Vi* in (6.35cm) spider living in Madagascar has been used. 'Milked' of its silk by native girlsfiveor six times a month, it yields about 3.2km (2 miles) of filament and then dies.

A fabric of spider silk, 18 yd (16m) long and 18 in (45cm) wide was shown at the Paris Exposition in 1900. It contained 100,000 yd (90km) of thread containing 24 strands - the work of more than 25,000 spiders.

Today, we have virtually given up the attempt to use spider silk

in textiles. It still finds an important outlet for making 'crosswires' in optical instruments. The silk is uniform and strong, and withstands changes in humidity and temperature. Spider silks used in this way have often outlasted the life of the optical instrument, remaining unchanged after half a century or more.

STRUCTURE AND PROPERTIES

Fine Structure and Appearance

The raw silk strand from which a cocoon is built consists of two fine filaments cemented together by sericin gum. Seen under the microscope, raw silk has a rough and irregular surface, and it is marked by lumps, folds and cracks in the sericin layer. Often, the twin filaments of silk are separated for considerable distances, each with its own coating of sericin.

Seen in cross-section, the strand of cocoon silk is of irregular shape. It is roughly oval with average diam. of 0.178mm (0.007 in). The individual filaments (brins) can be distinguished inside the sericin coating. They are triangular in cross-section, with rounded angles. Usually, thefilamentslie with one flat side of each facing the other.

The degummed filaments are smooth-surfaced and semi- transparent. The diameter fluctuates from place to place, averaging 0.0127mm (0.0005 in). The filaments become thinner towards the inside of the cocoon.

In the raw state, silk varies in colour from cream to yellow. Most of this colour lies in the sericin gum, and is lost when the filaments are degummed. The silky sheen develops after degumming.

Mid Silk

There is naturally much more variation in the physical properties of wild silk than there is in cultivated silk. Colour, for example, may be yellow, grey, brown or green.

Seen under the microscope, wild silk may be distinguished from cultivated silk by its irregular width. It is also marked by longi- tudinal striations and tends to have flattened areas on which are transverse markings. These flattened areas are caused by filaments pressing against one another in the cocoon before the material of the silk has hardened.

Treatment of the wild silk filament with chromic acid will dis- integrate it into a bunch of finer filaments, fibrils or micelles about 1 0/i in diameter.

The same effect can be obtained by severe mechanical or chemical treatment of cultivated silk, in which the fibrils are more closely compacted.

Seen in cross-section, the twin filaments in wild silks are wedge- shaped, with the short bases facing one another. The cut section of the filament is dotted with markings corresponding to the striations running lengthwise through thefilament.These mark the boundaries between the fibrils, which are less closely held together than in cultivated silk.

Tensile Strength

Silk is a strong fibre. It has a tenacity usually of 30.9-44.1 cN/tex (3.5-5.0 g/den). Wet strength is 75-85 per cent of the dry strength.

Elongation

Silk filaments have an elongation at break of 20-25 per cent under normal conditions. At 100 per cent R.H. the extension at break is 33 per cent.

Elastic Properties

The elastic recovery of silk after spinning is not so good as that of wool, but is superior to that of cotton or rayon. Once it has stretched by about 2 per cent of its original length, silk tends to remain permanently stretched. There is a slow elastic recovery or creep after extension, but the silk does not regain its original length.

Elastic recovery from
50 per cent breaking load:
50 per cent breaking extension: Work of rupture (cN/tex): Initial modulus (cN/tex):

Specific Gravity

Japanese Tussah

0.56 0.40 0.38 0.41 5.98 7.46 735.8 490.5

Degummed silk is less dense than cotton, flax, rayon or wool. It has a specific gravity of 1-25. Silk fabrics are often weighted by allowing the filaments to absorb heavy metallic salts; this increases the density of the material and affects its draping properties.

Effects of Moisture

Like wool, silk absorbs moisture readily. It can take up a third of its weight of water without feeling wet to the touch. Silk has a regain of 11 0 per cent.

If there are salts or impurities in the water, silk tends to absorb them too. Hard water, therefore, will contaminate silk. Degummed silk will swell as it takes up moisture; the extent of the swelling depends upon the relative humidity of the atmosphere. At 100 per cent R. H., silk absorbs 35 per cent of its weight of water and increases in cross-sectional area by 46 per cent (from 65 per cent **R.H.).**

Effect of Heat

Silk will withstand higher temperatures than wool without de- composing. Heated at 140°C. it will remain unaffected for prolonged periods. It decomposes quickly at 175°C.

Silk burns, emitting a characteristic smell like that of burning hair or horn.

Effect of Age

Silk is attacked by atmospheric oxygen, and may suffer a gradual loss of strength if not carefully stored.

Effect of Sunlight

Sunlight tends to encourage the decomposition of silk by atmo- spheric oxygen.

Chemical Properties

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 per cent of the strand is silk and 23 per cent is sericin; the remaining material consists of fat and wax (1 -5 per cent) and mineral salts (0-5 per cent).

As would be expected in a fibre of animal origin, silk is a protein. The filament itself is the protein fibroin; it is similar in composition to the sericin protein, despite the differences in physical behaviour between the two materials.

Silk fibroin differs fundamentally from the keratin from which animal hair fibres are made. The fibroin molecule contains only carbon, hydrogen, nitrogen and oxygen; there is no sulphur in it.

Silk does not dissolve in water, and it withstands the effects of boiling water better than wool. Prolonged boiling tends to cause a loss of strength.

Silk will readily absorb certain salts from their solutions in water; aluminium, iron and tin salts, for example, are used for 'weighting' silk fabrics in this way.

Silk dissolves in solutions of zinc chloride, calcium chloride, alkali thiocyanates and ammoniacal solutions of copper or nickel. Silk fibroin is attacked by oxidizing agents; bleaches such as hydrogen peroxide must be used with care. Hypochlorite bleaches must never be used, as they rapidly tender silk.

Effect of Acids

Like wool keratin, the fibroin of silk can be decomposed by strong acids into its constituent amino acids. In moderate concentration, acids cause a contraction in silk; this shrinkage is used to bring about crepe effects in silk fabrics.

Dilute acids do not attack silk under mild conditions. Organic acids are used for producing the scroop of silk, which may be due to the surface-hardening of the filaments. Acids are readily absorbed into silk filaments, and are not easily removed.

Effect of Alkalis

Silk is less readily damaged by alkali than is wool. Tussah silk is particularly resistant. Weak alkalis such as soap, borax and ammonia cause little appreciable damage. More concentrated solutions of caustic alkalis will destroy the lustre and cause loss of strength.

Silk dissolves in solutions of concentrated caustic alkali.

Effect of Organic Solvents
Silk is insoluble in the dry-cleaning solvents in common use.

Electrical Properties

Silk is a poor conductor of electricity, and tends to acquire a static charge when it is handled. This causes difficulties during manufacture, particularly in a dry atmosphere, but is of value for in- sulating materials in the electrical trade.

Other Properties

Raw silk has a rough handle; it acquires its smooth 'silky' feel only when the gum has been removed.

The peculiar noise or 'scroop' made by silk when it is crushed is not an inherent property of the fibre. It is given to the silk by treat- ment with dilute acids, possibly through a surface-hardening effect. Scroop is not a sign of quality, as is commonly supposed.

SILK IN USE

For thousands of years, silk has reigned as the queen of fibres. It is expensive, tedious to produce and subject to all the hazards inevitable in an industry whose assembly line is a living thing. Yet until a few years ago, silk has been unchallenged in its position as the most desirable of all textile fibres.

NATURAL FIBRES OF MINERAL ORIGIN

ASBESTOS

Asbestos is one of the strangest of all the naturally occurring fibres. It is a rock which has been subjected to unusual treatment during its formation. Instead of crystallizing in the normal way, it has done so in the form of fibres. These are all packed tightly together along-side each other, giving a grainy structure to the rock, resembling wood. Asbestos is non-inflammable and heat resisting.

Asbestos has been known and used as a textile since the earliest times. The lamps of the vestal virgins are supposed to have had wicks made from asbestos, and a lamp made for Minerva 'had a wick made of Carpasian linen, the only linen which is not consumed by fire'. This linen was made from asbestos mined in Cyprus.

The Chinese used asbestos to make false sleeves which could be cleaned by putting them in the fire. All the dirt was burnt off, leaving the asbestos clean. The Emperor Charlemagne is alleged to have owned a tablecloth of asbestos which he threw on to the fire after a meal, to the consternation and amazement of his guests. When Charlemagne was being threatened by Harun-al-Raschid and his hordes, he put his tablecloth to excellent use by performing his trick before the ambassadors of thefierceEmperor of the East. They were convinced that Charlemagne was a wizard, and recommended to Harun-al-Raschid that the impending war should be called off. So asbestos had an early influence on the history of the world.

In 1684, we hear of an asbestos handkerchief being demonstrated before the Royal Society of London. And after the discovery of asbestos in Russia between 1710 and 1720, a factory was established for the manufacture of asbestos textiles, socks and gloves. This industry continued for half a century.

Benjamin Franklin brought back a purse from Canada in 1724, made from asbestos spun and woven by the Indians. The deposits of asbestos in Canada were discovered in 1860; since then Canada has become a most important source of the fibre.

Today, asbestos is the raw material of an impressive industry, with the fibre serving in many invaluable ways.

PRODUCTION AND PROCESSING

Asbestos is the name given to several natural minerals which occur in a fibrous crystalline form. There are three important minerals of this type:

(a) Anthophyllite (b) Amphibole (c) Serpentine

A. *Anthophyllite*

This is a magnesium-iron silicate which occurs in some districts in the form of thin plates or fibres. It is not of great importance as a source of commercial asbestos.

B. *Amphibole*
There are several important varieties of this mineral:

(1) *Tremolite* is a calcium magnesium silicate which occurs as greyish masses of brittle, fibrous crystals.

(2) *Actinolite* is an iron calcium magnesium silicate which occurs as greenish masses of fibrous crystals.

(3) *Crocidolite* (Blue Asbestos; Amosite) is a iron sodium silicate which occurs as long flexible fibres of bluish colour, and with a characteristic silky lustre. The fibres are 7.5-10cm (3-4 in). Croci- dolite has a higher tensile strength than other asbestos fibres, but is not so resistant to high temperatures as crysotile.

(4) *Mountain Leather* (Mountain Cork) is found in the form of leathery sheets or masses of matted fibres.

(5) *Amphibole Asbestos* (Horneblende Asbestos) is found as fine fibrous crystals, usually of greenish colour.

C. *Serpentine*
This is a hydrated silicate of magnesium which occurs in two fibrous

forms:

(1) *Chrysotile* is found as narrow veins in serpentine rock. It is of green to brown colour, and is separated easily into fine silky fibres. This material provides the major part of the world's supply of asbestos.

(2) *Picrolite* is found as fibrous masses in serpentine rock. The fibrous crystals may be 33-36cm (13-14 in). They are inflexible and difficult to separate without breaking.

The bulk of the asbestos used today comes from Canada, South Africa, Rhodesia and Russia. Canada produces more than two- thirds of the total supply.

Opening

The compressed mass of fibrous crystals forming raw asbestos is given a preliminary crushing as the first stage of the opening process. A rotating wheel and pan crusher may be used, great care being taken to avoid undue breakage of the brittle fibres.

From the crusher, the asbestos passes through further opening machines, generally of the toothed roller type. Dirt and powdered rock are removed by means of grids. When the fibrous mass has been opened thoroughly, it may be blended with cotton or other fibres before passing to the carding machine.

Carding

Asbestos fibre is carded by combing with rotating brushes covered with steel bristles. Short fibres and impurities are removed, and the longer asbestos fibres are delivered as a loose web or sheet of fibre. As it leaves the carding machine, the sheet is split into narrow ribbons or rovings, which are wound onto spools.

Spinning

Asbestos rovings are spun on conventional spinning frames (ring or flyer). Doubling is commonly used to increase the uniformity of the yarn.

Asbestos may be mixed with other fibres before spinning, and yarns may also be spun round cores of cotton, glass, nylon, metal wire and other materials.

Short asbestos fibres may be spun by first beating them with water, and then feeding the pulp into a paper machine. A thin sheet of asbestos paper is formed, which is dried and cut into strips which are twisted into yarn.

STRUCTURE AND PROPERTIES Fine Structure and Appearance

The fibrous crystals of commercial asbestos are 12-300mm (V2-I2 in) or more in length. They have a smooth, regular surface resembling that of a glass fibre. They are usually near-circular or polygonal in cross-section.

There is virtually no limit to the fineness of asbestos fibres; the crystals may be subdivided until they are so fine that they cannot be seen through the optical microscope. The molecules of asbestos minerals are arranged in the form of curved sheets which build up into cylindrical structures or tubes. The fibrous crystal of asbestos is made up of many of these tubular structures held together by a mass of crystalline material. The tubes will separate easily one from another, enabling the fibrous crystals to be split into finer and finer fibres.

Other Properties

The outstanding property of all commercial asbestos fibres is their resistance to heat and burning. They are also highly resistant to acids, alkalies and most common chemicals.

Asbestos does not deteriorate in normal use, and it is not attacked by micro-organisms or insects.

ASBESTOS IN USE

Asbestos yarn is durable but has little strength. It is woven into tapes, cloth, brake linings, gaskets and twine. The main applications are those in which its resistance to heat and burning are all-important, such as conveyor belting for hot materials, industrial packings and gaskets, fireproof clothing, theatre curtains and scenery, electrical windings and installation.

CELLULOSE FIBRES; RAYONS

The generic term *rayon* was adopted by the U.S. Federal Trade Commission for fibres of the regenerated cellulose type, the official definition being as follows:

Rayon. A manufactured fibre composed of regenerated cellu lose, as well as manufactured fibres composed of regenerated cellulose in which substituents have replaced not more than 15 per cent of the hydrogens of the hydroxyl groups.

This definition includes three types of regenerated cellulose fibre in production today, i.e. *Viscose Rayon, Cuprammonium Rayon* (Cupro), and *Saponified Cellulose Acetate.*

VISCOSE RAYON

INTRODUCTION

The large-scale development of rayon was made possible by C. F. Cross, E. J. Bevan, and C. Beadle in England in 1892, who found that they could dissolve cellulose without first making it into nitrocellulose. The cellulose was treated with caustic soda, then with carbon disulphide, and the product dissolved in dilute caustic soda. This viscous liquid they called 'viscose'.

A method of producing textile filaments from the viscose was discovered by C. **H.** Stearn and C. F. Topham, the latter of whom invented the 'ageing' of viscose (to its correct condition for spinning), the multiple hole spinning jet and the famous Topham spinning box.

In 1904, the British rights of the viscose process were purchased by Courtaulds Ltd., who developed it into the most successful method of rayon manufacture in the world.

The viscose process is comparatively lengthy and some 300 accurately controlled steps are involved. The raw materials, how ever, are cheap. Viscose rayon can generally be produced cheaper than other rayons, and viscose is now manufactured in greater quantity than either cuprammonium rayon or acetate. Water is needed in great quantity and many chemicals are used in viscose rayon manufacture. A kilogram of rayon fibre entails the use of more than 1,600 kg of water, nearly 2 kg of sulphuric acid, P/ikg of caustic soda, \l*A* kg of wood pulp or cotton linters,

i kg of carbon disulphide and smaller amounts of other chemicals.

Continuous Filament and Staple

Until 1914, viscose rayon was produced almost entirely in the form of continuous filament yarn. During World War I, German and Italian firms began producing staple rayon fibre by chop ping the filaments after extrusion.

The production of rayon staple made rapid progress during the 1930s, and by 1940 there was as much staple being used as continuous filament. After World War II, filament production exceeded that of staple until 1954, when staple once again took the lead. In 1961, some 60 per cent of the world production consisted of staple fibre.

In the 1960s and 1970s production of continuous filament diminished but staple production increased.

TYPES OF VISCOSE RA YON

As control and understanding of the viscose process has increased, it has become possible to modify the properties of the fibre in a variety of ways. A range of viscose rayons is now available which includes fibres of widely differing characteristics.

Physical modifications of the viscose fibre range from changes in the form of the filament, e.g. hollow, shaped and surface- modified filament (see page 20) to changes in the fine structure as in the high tenacity rayons (see page 39) and high wet modulus (including polynosic) rayons (see page 47).

Chemical modification, likewise, has resulted in many types of modified viscose fibre, such as cross-linked, basified and grafted rayons (see page 38).

PRODUCTION Raw Materials

The raw materials for making viscose rayon are either cotton linters (the short, useless fibres in the cotton boll) or wood pulp

derived from such timber as northern spruce, western hemlock, eucalyptus or southern slash pine. These pulps contain about 94 per cent cellulose, and are most suitable for fibre manufacture.

Wood pulp is purified by boiling with caustic soda or sodium bisulphite solution. It is bleached and washed, and reaches the rayon factory in the form of sheets like thick blotting paper. The cellulose pulp is stored under controlled conditions of humidity and temperature until the moisture is distributed uniformly; this 'conditioning' may take several weeks.

Formation of Alkali Cellulose (Soda Cellulose)

The first step in viscose rayon manufacture is the production of alkali cellulose. The cellulose pulp sheets are steeped in warm caustic soda for an hour, and then pressed to remove excess solution. The treated cellulose is broken up in a shredder to form powdery crumbs.

The crumbs are aged for up to a day, during which time the caustic soda reacts with cellulose to form alkali cellulose (soda cellulose) (see page 12). During the ageing process, the long cellulose molecules are attacked by oxygen from the air and broken up to some extent into shorter molecules.

Sodium Cellulose Xanthate Production

The aged crumbs of alkali cellulose are mixed with carbon disulphide in a revolving drum. The almost white crumbs turn gradually yellow and then orange as sodium cellulose xanthate is formed (see page 12). The batch is tipped into a dilute solution of caustic soda, forming a thick orange-brown solution. There is a loose association at this stage between the sodium cellulose xanthate and the sodium hydroxide.

The lustre of the rayon is controlled at this stage. If rayon is produced from the sodium cellulose xanthate solution without adding anything to it, the rayon will have a silk-like sheen. Often however, a duller appearance is preferred, and this is achieved by adding a fine white pigment, usually titanium dioxide, to the spinning solution at this point in manufacture.

Ripening

The sodium cellulose xanthate solution (viscose solution) is allowed to stand and ripen for up to a day at a carefully con trolled temperature, during which time it is filtered repeatedly. Some breakdown of the long cellulose molecules into molecules of lower molecular weight takes place, and the viscosity of the solution falls initially.

On further standing, the viscosity of the solution begins to rise again as cellulose is regenerated by the breakdown of some of the sodium cellulose xanthate. If ripening is allowed to continue for a long time, cellulose is deposited from solution. In practice, however, ripening is allowed to 'continue until the solution has reached a state suitable for spinning. It is then subjected to vacuum to remove bubbles of air or other gases which would interfere with the smooth flow of the solution during spinning.

Spinning*

The ripened viscose spinning solution is passed through a final

* In the manufacture of rayon and other man-made fibres, the term 'spinning' has come to be applied to the process of forcing liquid through tiny holes to form the fibre. The same term is used in the case of both natural and man-made fibres for the twisting together of short fibres into yarn.

filtering stage, and then forced through tiny holes bored in a cap of metal forming the spinneret. Spinnerets are made from gold, platinum, palladium, tantalum and other corrosion-resisting metals; platinum alloys are commonly used.

The holes in the spinneret are usually between 0.005 and 0.0125 mm diameter, and each spinneret will be pierced by up to 20,000 of them.

As it emerges from the hole in the spinneret, the jet of viscose enters a coagulating bath containing a mixture of acids and salts, typically of the following composition:

Sulphuric acid 4—12 parts by weight Sodium sulphate 10—22 parts by weight Zinc sulphate 1—5 parts by weight

In the coagulating bath, the sodium cellulose xanthate is con verted back into cellulose. This is insoluble in the liquid of the bath, so that the fine jet of viscose solution is changed into a solid filament of cellulose.

The action of the spinning bath is complex. The sodium sulphate brings about the coagulation of the sodium cellulose xanthate to form a filament. This is then converted to cellulose

by one or other of two routes:
(a) the sodium cellulose xanthate is converted into cellulose

xanthic acid, which decomposes into cellulose.
(b) the sodium cellulose xanthate is converted first into zinc

cellulose xanthate, which is then converted into cellulose xanthic acid and finally into cellulose.

The conversion of zinc cellulose xanthate into cellulose xanthic acid takes place more slowly than the conversion of sodium cellulose xanthate into cellulose xanthic acid, and route (b) is slower than route (a).

In the coagulation of viscose, using a bath as outlined above, the zinc sulphate is in low concentration, and it penetrates only a short distance into the filament in the time that the acid pene trates into the centre of the filament. The bulk of the filament, including, the core, is thus regenerated via the direct route (a). Only the outer layer is regenerated via the slower route (b).

The slower regeneration taking place in the outer layer of the filament results in a more uniform deposition of cellulose, and creates the skin effect that is typical of a regular viscose fibre.

As the core shrinks, the skin becomes wrinkled and the filament acquires its lobed cross-section.

In the production of high-tenacity fibres of all-skin construc tion (see page 43), regeneration retardants are added to the coagulating bath, slowing up the regeneration of cellulose by

the acid, and so allowing the slower route (b) to bring about regeneration throughout the fibre. This effect is intensified by using a higher concentration of zinc salts in the spinning bath. The slower regeneration obtained in this way allows time for stretching and orientation to be carried out more effectively.

There are three ways in which the filaments are treated after leaving the coagulating bath; the processes are known as pot or box spinning, bobbin spinning and continuous spinning, respec tively.

Pot Spinning; Box Spinning

In pot spinning the bunch of filaments from each spinneret is led out of the bath and around a wheel. This wheel - called the godet wheel - pulls the filament from the jet at a controlled speed. It is this speed, together with the rate of extrusion, which determines the diameter of the rayon fibre. The faster it is pulled as it leaves the jet, the thinner the fibre will be.

On leaving the godet wheel, the fibres pass around a second wheel which is moving faster than the first. The fibres are there fore stretched between the two wheels - a process which has a profound effect on the final fibre. This stretching of the still- plastic rayon tends to orientate the molecules of cellulose along the direction of the fibre. The long molecules are packed more tightly together so that their mutual attraction comes into play. They hold strongly to each other, giving a stronger fibre.

The more the rayon is stretched while it is still plastic, the stronger is the fibre. But at the same time, this tight packing of the molecules reduces the 'stretchability' of the fibre, so that excessive stretching will achieve high strength usually at the expense of other desirable properties. The treatment is therefore regulated to suit the conditions the fibre will have to withstand.

After stretching, the fibre passes into a Topham box. This is a hollow container about 18 cm (7 in) in diameter which whirls like

a spinning top. The filament is led through a hole in the top of the box and is flung against the side by centrifugal force. In this way it is pulled continuously through the hole and builds up into a cake of filament inside the box. A mechanical device ensures that the cake is built up evenly from top to bottom, and the spin of the box gives a twist to the fibres, usually about 1.2 turns to the cm (3 turns to the inch).

The Topham box rotates some 10,000 times per minute. The sides are perforated, so that most of the liquid is flung off from the wet fibre cake. Up to 63 m (70 ^d) a minute are fed into the box; it takes several hours to build up a complete 'cake', which is then washed and may be treated with sodium sulphide solution to remove residual sulphur compounds. The fibre is bleached, usually with sodium or calcium hypochlorite or peroxide, rinsed in dilute acid, washed and dried.

Bobbin Spinning

In bobbin spinning, the filaments of rayon emerging from the coagulating bath may be wound without twist on to bobbins. The bobbins, which have perforated barrels, are purified and bleached under pressure. The yarn is then dried and oiled, and after twist ing is wound up again ready for winding into skeins or cones.

Continuous Spinning

In the pot and bobbin spinning processes, packages of viscose filament are collected and then subjected to desulphurizing, bleaching, washing and drying before the rayon is ready for use. The process is thus an intermittent one, in which batches of fila ment are handled separately as they become available.

Batch processes of this type are inevitably costly in labour and operating charges, and the intermittent operating tends to intro duce variations in the quality of the product from batch to batch. In modern industry there is a tendency to favour processes in which the product moves from one stage to the next in a con tinuous stream. Continuous processes of this sort are usually cheaper to operate, and can be controlled to produce a highly uniform product.

It has long been realized that the production of viscose rayon could be adapted to operate on a continuous basis. But many practical problems had to be solved before continuous spinning became a reality. The main difficulty lay in the time required for

purification, bleaching, washing and drying of the filament after leaving the coagulating bath. In the production of rayon by pot spinning, for example, these stages might take 30 minutes or more to complete. And in this time, more than a mile of filament might be spun. If continuously-produced filament took the same time to process, the purification, washing and drying equipment would have to accommodate a comparable length of filament.

The successful development of continuous spinning of viscose was made possible to a large extent by the design of mechanical devices which could hold immense lengths of filament in con tinuous movement as they passed through the processing train.

Industrial Rayon Corporation Process

During the 1930s, many firms experimented with continuous viscose spinning techniques. One of the first to achieve com mercial success was a process developed by Industrial Rayon Corporation, U.S.A., which came into operation at Painesville, Ohio, in 1938.

The problem of handling great lengths of filament during processing was solved by using thread advancing reels of ingenious design. Each reel consisted of a pair of rollers with axes, set on the skew, i.e. not parallel to each other. When filament is fed to one end of a pair of moving rollers of this sort, and passed round the rollers as though round a pair of pulleys, the filament tends to form a spiral which moves along the pair of rollers until it reaches the other end. The direction of movement of the spiral, the distance between the coils, and the length of filament carried, depends upon the angle of skew between the axes of the two rollers.

A pair of skew-set rollers can thus be used for carrying great lengths of filament in a very small space, without physical contact between individual coils of filament taking place. Individual strands of filament can be subjected to processing liquids and environments in a most direct way, by contrast with filaments which are wound together into a cake or other package. This, in itself, reduces the processing time needed for the treatment of continuously-produced filament, as compared with the processing of filament in package form.

In the Industrial Rayon Corporation continuous spinning pro cess, the thread advancing reels consist of pairs of skew-set hollow

rollers which rotate one inside the other. A succession of these reels carries the filament from the coagulating bath and stretching equipment, through desulphurizing, bleaching, washing, oiling and drying stages, until eventually a clean, dry filament is delivered ready for shipment to the textile manufacturer. The technique has now been developed and refined, and Industrial Rayon Corporation continuous spinning machines are in widespread use throughout the world. World rights to the process, excluding U.S.A. and South America, are held by Courtaulds Ltd., U.K.

A modern continuous spinning machine of this type is 6 m (20 ft) high, and has three operating levels. On the top are the coagulating bath and the stretching mechanism, from which the filament moves downward to pass through a train of ten process ing stages. Each stage consists of a thread advancing reel, and during its passage through the reel the filament is subjected to the appropriate processing liquids or environments. Finally, the filament passes through a drying reel enclosed in a heated chamber. The dry filament emerges from this reel and is twisted

and wound on to bobbins which carry up to 4.54 kg (10 lb).
The doffing of the bobbins is automatic, and there is no inter ruption to the operation of the machine. The entire process is continuous, the filament being wound on to the bobbin little more than 5 minutes after being produced in the coagulating bath.

Nelson Process

A continuous spinning process was devised in the U.K. by S. W. Barber and J. Nelson during the early 1930s. By 1934, the process was in operation. It has since been developed by Lustrafil Ltd., and has become known as the Nelson Process.

In the Nelson Process, a combination of two techniques is used to overcome the problem of carrying great lengths of fila ment during the processing stages. Firstly, skew-set rollers are used to carry the filament, as in the Industrial Rayon Process; secondly, the stages in processing are reduced, desulphurizing and bleaching being omitted.

The thread advancing device, in the Nelson Process, is similar in principle to that used in the Industrial Rayon Process, but differs in the details of its operation. The two rollers, instead of rotating inside one another, are arranged one above the other

like the rollers in a wringer, with their axes set on the skew. The rollers, about 1 m (3.3 ft) long, carry more than 100 coils of the filament spiral as it moves from one end to the other.

As the filaments emerge from the coagulating bath, they are carried upwards to pass over the upper roller and then down wards to pass under the lower roller, and so on. The first coils of the spiral are sprayed with acid, and coagulation is com pleted during this first stage. The filament is then washed by water sprays as it moves along the rollers, passing finally over the end sections of the rollers, which are heated. Dry filaments leave the rollers, having spent some 3 minutes traversing from one end to the other, moving through more than 100 coils of the spiral on the way. The dry filaments are twisted and collected on to bobbins, usually by a cap spinning mechanism.

Despite the omission of the desulphurizing stage, filaments produced by the Nelson Process contain only 0.1 - 0.3 per cent sulphur. If, as is usual, the yarn subsequently passes through a wet processing treatment, such as scouring or dyeing, this small proportion of sulphur is removed. If the subsequent handling of the yarn does not include a wet processing operation, the trace of sulphur may be removed easily by washing the fabric.

The use of high quality wood pulp has rendered the bleaching stage unnecessary for most applications, but bleaching can also be carried out if necessary at fabric stage.

American Viscose Corporation Process

This is a high-speed continuous spinning process in which the filaments leave the coagulating bath via a jet of coagulating liquid, in which the filaments move for a distance of about 15 cm (6 in). Filaments then pass round the reels of a thread- advancing mechanism at such a speed that excess liquid is thrown off by centrifugal force. Coagulation of the cellulose continues as the filaments travel along their spiral path, and stretching is carried out when less that 70 per cent regeneration has taken

place.

Kuljian Process

In this process, filaments are carried from the coagulating bath by godet wheels, and pass on to a system of rollers which can be controlled to apply a desired degree of stretch. The filaments are treated as they travel through the roller system, and then

dried by hot air. The dry filaments are wound on to bobbins by a ring spinning mechanism.

Kohorn 'Okomatid Process

A process of continuous spinning devised by Von Kohorn International Corporation, known as the 'Okomatic' Process, carries the yarn forward by means of a system of skew-set glass rollers.

The production of yarns by these continuous spinning pro cesses has now become established practice in the rayon industry. The quality of the yarns is fully equal to that of yarns produced by batch techniques, and the uniformity of the filaments is high. This increased uniformity is reflected in the reduction of breakages during weaving, and consequent improvement in the quality of the fabrics.

MODIFICA TION OF FILAMENT

By manipulation and modification of the spinning process, the physical structure and form of the rayon filament can be changed in many ways.

Cross-Section

The cross-sectional shape of the filament may be varied by extruding through spinneret holes of suitable shape. Modification of filament cross-section is becoming of increasing importance today, as it can cause profound changes in the characteristics of yarns and fabrics. Circular cross-section filaments, for example, are poorer in covering power than lobed cross-sections typical of the normal viscose filament. Many synthetic fibres are now being produced in non-circular forms, such as dog-bone and trilobal cross-sections.

Viscose rayon has been made experimentally in a variety of cross-sectional shapes, and some have become of commercial importance. Straw filaments, for example, are produced by some manufacturers. Flat filaments are made by extrusion of viscose through slit orifices instead of circular ones; these filaments have improved covering power, but tend to be of harsh handle.

The diameter of a filament may be varied continuously between thick and thin, providing rayon filaments which make up into special effect fabrics.

Bubble-filled Filaments

The covering power of viscose filaments may be increased by spinning in such a way that bubbles of air or other gas are trapped inside the filament. This may be done by spinning a viscose solution which has been agitated to produce a form in which air bubbles are entrapped.

In 1976 Courtaulds Ltd marketed a hollow viscose fibre 'Viloft' which is made by generating carbon dioxide inside the filament. The fibre has greatly increased bulk and high moisture absorption. In blends with polyester fibres, it provides increased covering power.

Blends of hollow viscose with cotton are used in shirtings and dress fabrics and for terry towel pile. Hollow viscose fibre is widely used in non-wovens, particularly in fields such as surgical and medical fabrics where high moisture absorption and moisture holding properties are important.

During World War II, a bubble-filled viscose filament called 'BubblefiT was produced in U.S.A. by du Pont, using a technique by which air was injected into the filament as it was extruded. This produced a continuous filament containing discrete bubbles

3—6 mm (i -^{l}A in) long, which was used as a substitute for kapok in life jackets, pontoons, insulated clothing etc.

Spun-dyed Filament and Staple

Control of the spinning process in rayon production enables the manufacturer to mix finely-dispersed pigments with the viscose solution before spinning. The pigments are locked inside the filaments after spinning, providing 'spun-dyed* filaments which are unusually fast to light and to washing. White titanium dioxide is used in this way for dulling the natural sheen of rayon.

Crimp

The spinning qualities of staple fibre are usually enhanced if the fibre has a waviness or crimp (cf. wool), and filaments which are to be made into staple are commonly treated to provide a crimp. This may be done mechanically, for example by passing the filament between gear-like rollers, or chemically by control ling the coagulation of the filament in such a way as to create a fibre of asymmetrical cross-section.

Fine Structure and Appearance

The filament of viscose rayon is smooth and straight. It may be crimped ('Sarille') but there are no convolutions as in cotton. The surface is however, marked by longitudinal channels which are caused by contraction in volume of the filament during coagulation. These channels or striations give the cross-section of viscose rayon a characteristic outline, which is deeply serrated.

When rayon has been dulled with titanium dioxide, or 'spun- dyed' during manufacture, the particles of pigment are seen as dark specks embedded in the filament.

As rayon is a manufactured material, the diameter of the filament can be varied through wide limits. Viscose is commonly

made in a range of dtex. Typical staple fibre dtex are 1.7, 3.3, 5.0, 9.0, 17, 40, 56 (1V4, 3, 4*4, 8, 15, 18, 44, 50 den); staple lengths 32-200 mm (1&-8 in).

Tensile Strength

Ordinary viscose rayon has a tenacity of 18—23 cN/tex (2.0—2.6 g/den) dry; 9.0-13.2 cN/tex (1.0-1.5 g/den) wet. Tensile strength of normal viscose rayon is 2109—3234 kg/cm^2 (30,000- 46,000 lb/in^2).

Elongation

Normal viscose will stretch by about 17-25 per cent of its original length before breaking, and 23-32 per cent when wet.

Elastic Recovery

Cotton and other natural cellulose fibres have little inherent elasticity. Viscose rayon, however, has even less. It has a small elastic stretch of about 2 per cent from which it will recover when relaxed. But more persistent stretching will tend to cause permanent deformation as the long cellulose molecules slide over one another.

Elastic recovery (60 per cent r.h.):

1 per cent extension: 67 per cent

2 per cent extension: 60 per cent

3 per cent extension: 38 per cent

5 per cent extension: 32 per cent

10 per cent extension: 23 per cent

Effect of Moisture

In natural cellulose fibres such as cotton, the cellulose molecules are packed together in orderly fashion wherever alignment of the molecules makes this possible. These ordered, crystalline regions confer strength and rigidity on the fibre; the amorphous regions, on the other hand, where cellulose molecules are arranged in random fashion are responsible for the flexibility, 'stretchability' and swelling properties of the fibre.

When natural cellulose fibres are dissolved during viscose manufacture, the molecules are set free from one another, and are able to move around more or less independently in the liquid. The extrusion of the liquid, followed by coagulation and stretch ing, tends to restore the alignment of the cellulose molecules and encourages the formation of crystalline regions again. In general, however, the molecular line-up is not restored to such a high degree as in the original natural state. Although the filament of viscose rayon consists of cellulose, it differs in this respect from cotton. It behaves in many ways like a cotton in which the cellulose molecules have been shortened (i.e. by chemical action during ripening and ageing) and aligned with rather less precision than in cotton. The actual degree of alignment and crystallinity depends upon the amount of stretch that is given to the filament during manufacture.

The reduced crystallinity of the cellulose in viscose rayon renders the fibre more responsive to water-penetration. The molecules of water can force their way between the loosely organized cellulose molecules in the amorphous regions of the rayon. Viscose rayon will absorb twice as much water naturally from the air as cotton does. Viscose has a moisture regain of 13 per cent under standard conditions. (Water imbibition: 100- 110 per cent.) When soaked in water, viscose rayon will increase in length by 3-5 per cent and swell to double its original volume.

This increased water penetration is reflected in the change in tensile strength when rayon is wetted. Viscose loses as much as half its strength when wet, and is more easily stretched. The strength returns on drying, increasing as the rayon becomes bone-dry.

Thermal Properties

Effect of High Temperature

Rayon is not thermoplastic, and does not melt or become tacky

on heating. It begins to lose strength at 150°C. after prolonged heating, and begins to decompose at 185-205°C. (depending on time factor).

Flammability

Rayon burns readily with a characteristic odour of burnt paper.

Effect of Age

So slight as to be almost nil.

Effect of Sunlight

Viscose rayon withstands exposure to sunlight without discolora tion; prolonged exposure causes a gradual loss of tensile strength. This is more severe if the fibre contains titanium oxide.

Chemical Properties

Acids

Similar to cotton. Viscose rayon is attacked by hot dilute or cold concentrated mineral acids, which weaken and disintegrate the fibre.

Alkalis

Like cotton, viscose rayon has a high degree of resistance to dilute alkalis. Strong solutions of alkali cause swelling, with loss of tensile strength.

General

The cellulose of viscose rayon undergoes some depolymerization during the manufacturing process. The fibre reacts to chemicals in a manner similar to cotton, but is generally more sensitive. It is attacked by oxidizing agents such as high-strength hydrogen peroxide, but will withstand normal hypochlorite or peroxide bleaches.

Effect of Organic Solvents

Viscose rayon is insoluble in most organic solvents; it dissolves in a few complex solutions, such as cuprammonium. Dry cleaning solvents do not have any deleterious effect.

Insects
Viscose is resistant to insect attack but is attacked by silver-fish.

Micro-organisms

Mildews do not readily attack the cellulose of the fibre itself, but will feed on the size that is left on the fibres after processing. Mildews will cause discoloration, and weaken the fibre if the attack is severe.

Electrical Properties

The high moisture absorption of rayon tends to detract from its value for insulation purposes. The dielectric strength of dry fabrics is fair. Under ordinary conditions, viscose rayon does not develop static charges but antistatic agents are usually added if the relative humidity is less than about 30 per cent.

VISCOSE RAYON IN USE

In the man-made fibre field, rayon plays a role similar to that of cotton in the field of natural fibres. It is produced in greater quantity than any other man-made fibre; it is relatively cheap, and has a wide range of applications.

Although viscose rayon is similar to cotton in its cellulosic structure, it provides a range of yarns and fabrics with their own characteristic properties. The cellulose of rayon has been modified to some degree during manufacture, and the alignment of the molecules is not identical with that of natural fibres such as cotton. Also, the fact that rayon is a manufactured material enables us to control the physical characteristics of the final product. We can make the rayon coarse or fine, alter its strength and elasticity, modify its lustre and colour. Moreover, as a manufactured material, viscose rayon is not subject to changing economic and climatic circumstances such as those that affect the properties and price of a natural fibre.

Viscose rayon conducts heat more readily than silk does, and the rayon has a cooler feel against the skin. Viscose is also highly absorbent, and this enhances its value as a clothing material.

The loss of strength which rayon undergoes when wet is probably its most serious shortcoming, but modern resin finishes have done much to overcome this problem. Properly finished rayon garments have high dimensional stability when wet.

The introduction of rayon staple has enabled manufacturers to blend rayon with other natural and synthetic staple fibres, and rayon staple is used very largely in this way. Rayon contributes its moisture absorption and other 'cellulosic' characteristics to blends of stronger and less absorbent fibres, including most of the synthetics. Blends with polyester staple are of particular importance.

Blends of rayon with other fibres may be processed by any of the familiar techniques. Staple lengths are provided to suit particular blends and systems; a 50 mm (2 in) staple, for example, can be handled on cotton machinery and a 100—150 mm (4-6 in) staple may be used with wool.

Cuprammonium Rayon
Cupro is also still described as *cuprammonium rayon* to dis

tinguish it from viscose rayon.

PRODUCTION

In its essentials, the process for making cupro is similar to that used in making viscose. Cellulose is dissolved, and the solution is forced through holes in a spinneret. The jets of solution are coagulated, the cellulose being regenerated as a solid filament.

Raw Material

Cotton linters and wood pulp are both used as raw material in making cupro. Cotton linters is a source of very pure cellulose, and for this reason was preferred initially as raw material. Latterly, however, wood pulp has been used on an increasing scale, largely because of its lower cost. For high quality produc tions, cotton linters cellulose is still used exclusively.

Cotton linters is purified by kier-boiling with dilute caustic soda at about 150°C, followed by bleaching with sodium hypochlorite.

Wood is selected and purified to yield a material of high alpha cellulose content (above 96 per cent).*

Cuprammonium liquor is prepared by dissolving basic copper sulphate in ammonia to form a solution of cupritetrammino hydroxide and cupritetrammino sulphate in the ratio 3 : 1 , containing 3-4 per cent copper and 5-8 per cent ammonia.

*** Alpha cellulose is that which does not dissolve** in 17.5-18.0 **per cent caustic soda solution after** 30 **minutes** at 20°C. It **consists of cellulose which has undergone a minimum of degradation, and** it **is the most satisfactory cellulose for use** in **fibre-manufacture.**

Preparation of Spinning Solution

Purified cotton linters or wood pulp is mixed into cuprammonium liquor at low temperature. Stabilizing agents and caustic soda are added, the latter in sufficient quantity to convert the cupritetrammino sulphate into hydroxide. The cellulose content of the solution is about 10 per cent.

The spinning solution is filtered by passing it through a succession of nickel filter screens. It is then deaerated and is ready for spinning. The solution is stable and may be stored for considerable periods without appreciable deterioration; in this respect, it contrasts strongly with viscose solution.

Spinning

(a) *Batchwise Spinning (Reel or Pot Spinning)*
The filtered spinning solution is pumped to a nickel spinneret, and extruded through holes of 0.8 mm. diameter. The jets of solution emerging from the spinneret holes flow into a glass funnel, where they meet a stream of pure water which is flowing down through the funnel. The water dissolves most of the ammonia and about one third of the copper from the jets, bringing about coagulation of the cellulose to form plastic filaments. The filaments are carried along by the stream of water, and are stretched continuously to form filaments of usually about 1.4 dtex (1.3 den).

The loose thread of filaments emerging from the bottom of the funnel is carried round a guide rod, most of the water being flung off. The thread then passes round a roller which rotates in a trough of sulphuric acid; the remaining copper and ammonia are removed as copper sulphate and ammonium sulphate respectively.

The filaments are then wound either into skeins (Reel Spinning), or into cakes in a Topham box (Pot Spinning). The skeins or cakes are washed to remove acid and any remaining copper sulphate or ammonium sulphate, softened by adding lubricants, and dried. The yarn is commonly given a second wash in soap and oil emulsion, or (if it is to be twisted later) in a soaking bath. It is then dried again.

(b) *Continuous Spinning*
As in the production of viscose rayon, the production of cupro has been modified to operate on a continuous basis. A continuous spinning process was introduced first in Germany and in 1944 in the U.S.A. The following description refers essentially to the U.S. process.

Up to the point at which the filaments emerge from the funnel, the continuous process is virtually identical with the batchwise process. The thread of filaments from the funnel is passed through an enclosed bath of hot dilute acid called the pretreat- ment pan. This continues the coagulation of the cellulose, reducing the filaments to about one third of their original diameter. The oriented filaments of cellulose are sheathed in a film of unaligned cellulose, and this is washed away in the pre- treatment pan. If left, the unaligned cellulose would act as a glue, holding the filaments together.

After leaving the pretreatment pan, the thread of filaments passes through an acid trough where remaining copper is removed as copper sulphate. The acid is washed away as the thread moves through a water trough, and lubricants, sizes etc. are added as required by passing the thread over a preparation roll.

The thread passes through a succession of driers and over a roll which applies coning oil before being wound on to flangeless spools. Untwisted threads may also be wound on to beams which are used directly in warp knitting, or combined to provide a weaver's beam.

Throughout the continuous process, the thread of filament is never handled, and imperfections are thus held at a minimum. The filaments are of highly uniform structure and dimensions, and the properties are excellent. After conditioning for a few days at controlled humidity, the cupro is ready for despatch.

Cupro filaments adhere to each other, and are separated only by a comparatively strong force. Unlike viscose yarns, they may be used for many purposes in an untwisted condition.

A wide variety of cupro yarns is produced, ranging from 17 to to 330 dtex (15-300 den) and more. Weaving and knitting yarns are commonly in the range 56 to 110 dtex (50-100 den).

STRUCTURE AND PROPERTIES Fine Structure and Appearance

Cupro is the most 'silk-like' of all cellulosic yarns. It is smooth- surfaced and shows no markings or striations. In cross-section it is almost round.

The filaments are extremely fine, usually 1.4 dtex (1.3 den), and have been manufactured in 0.45 dtex (0.4 den).

Tensile Strength

The tenacity of cupro is 15-20 cN/tex (1.7-2.3 g/den) dry; 9.7-11.9 cN/tex (1.1 -1.35 g/den) wet.

The tensile strength of cupro is about 2100-3150 kg/cm^2 (30,000-40,000 lb/in^2).

Elongation

Cupro has an elongation of 10-17 per cent when dry and 17-33 per cent when wet.

Elastic Properties

Cupro has an elastic recovery of 20-75 per cent at different elongations.

Specific Gravity

1.54 conditioned at 11 per cent moisture.

Effect of Moisture

Cupro swells in water and loses strength. The moisture regain is 12.5 per cent under standard conditions. The commercial standard is 11 per cent.

Effect of Heat

Decomposition begins at about 250°C. without melting. Yarns and fabrics burn readily, leaving little ash.

Effect of Age

Similar to viscose.

Effect of Sunlight

Prolonged exposure causes some degradation and loss of strength.

Chemical Properties

Acids

The fibres are disintegrated by hot dilute or cold concentrated acids.

Alkalis

Dilute solutions do not have any appreciable effect. Strong solutions cause swelling and degradation.

General

Cupro behaves generally like other cellulosic fibres. It is not affected by weak oxidizing agents or by bleaches such as hypo chlorite or peroxide solutions. Strong oxidizing agents cause degradation.

Effect of Organic Solvents

Like other cellulosic fibres, generally insoluble.

nsects

Cupro is-moderately attacked by some insects.

Micro-organisms

Wet fibre is attacked by mildews.

Electrical Properties

Moderate dielectric strength when dry.

Other Properties

The fibre has a soft silk-like handle and a characteristic lustre.

Cupro is in general more expensive than other man-made cellulosic yarns. Its extra fineness and strength, attractive handle,

End Uses

Cupro is made into chiffons, satins, nets, ninons and all manner of very sheer fabrics. Much of this yarn goes into underwear, dress fabrics and linings. Novelty yarns, such as slub yarns, are used in a great variety of applications, especially as weft..Slub yarns are used in dresswear, sportswear and fine drapery fabrics. A speciality end use lies in the production of yarn-dyed fabrics for high quality silk-like linings, dress and upholstery fabrics. Reel spun yarns are especially suited to these applications; they are produced in skeins ready for yarn-dyeing in the untwisted state. The dyed yarn is used untwisted for the weft and twisted for the warp.

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SCHOOL OF BUILDING & ENVIRONMENT

DEPARTMENT OF FASHION DESIGN

UNIT – III - Elements of Textiles – SFDA1103

Spinning &Various types of Spinning

Spinning is the process of drawing out and twisting of a group or bundles of fibres into a continuous thread or yarn of sufficient strength to be woven or knitted into fabrics.

In the beginning the yarns were spun by mane with bare hands without the aid of any tool and it must have been many centuries before the spindle was evolved for spinning. The spindle or "takli" still survives as a tool hand spinning wool, silk and cotton yarn.

It is the simplest tool which consists of a round disc which is attached in the center to a thin, smooth rod about inches long. The upper end of the rod has a groove or a hook which bulk of the fibres, these are drawn out in a long stand. The spinner while simultaneously pulling the fibres, gives a twist to the spindle and let it go. The spindle whirl around and thus twisting up the pulled fibres makes a continuous thread. The thread is then woven round the rod above the disc. The disc provides the necessary weight which quickens increases and prolonged the revolving of the rod, thereby the twisting of the fibre ensures a strong thread.

Who does not know the "charka" in India. A charka is used for spinning yarn in the handloom industry in India. The yarn spun on the charkha is of various qualities. The famous "Dacca Muslins" which were uncomparable for their fineness but alas are extinct now were woven of a charka yarn. The inimitable soft and light pashmina of Kashmir are still woven of the charkha spin yarn.

Charkhas are of various types. In the textile industries today electrically driven machines are employed for spinning. Several machines are used to complete the process of spinning, which consists of stages such as drawing out of fibre to reduce size and to give slight twist-roving and then spinning. There are two general methods of procedure. In one process, the action of drawing, twisting and winding is continuous and this is called 'ring' spinning and in the other, the drawing and twisting is stopped while the twisted thread is wound up (as in the case of hand spinning) and this is known as 'mule spinning'. The ring spinning is a quicker process and has the advantage of reducing operating cost and increase production, but the mule spun is finer, softer and of greater evenness. In spinning yarns, whether by hand or machine a difference has to be made in the yarn intended for warp and weft or filling. The warp yarn needs a greater amount of twists to produce a strong firm thread which is used for the foundation of the fabric. The yarn is given twists of specified number of turns per inch. At first, a continuous thread or a strand is made from fibres and several of these strands are twisted together to get a final yarn.

SPINNING PROCESS

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. 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.

MELT SPINNING

In this process, a polymer is melted and heated to a suitable viscosity for fiber production.

The melted polymer is pushed through a spinneret, which is a type of die consisting of several small holes.

Each hole produces an individual fiber, and the number of holes on a spinneret defines the number of fibers in the yarn.

The melted polymer fibers then passes through a cooling region and the fibers are combined to form a yarn and a spin finish is applied. The yarn is then drawn using several godets rolls with very good speed and temperature control to orient the molecules in the fibers and eliminate voids, making the yarn stronger. If the polymer is thermoplastic, then melt spinning should be used for higher productivity. Most of the manmade fibers, such as polyester, polypropylene, nylon and PGA, are produced using melt spinning.

REQUIREMENTS OF MELT SPINNING :

The polymer should not be volatile.

The polymer should not decompose in the molten state and the melting point.

Polymer should be 30 degree centigrade less than its decomposition temperature.

FIBER CHARACTERIZATIONS :

Different characterization methods were performed to study the resulting fiber properties, mechanical properties, rheological properties, molecular orientation, and crystalline behavior.

FIBER WHICH PROCESSED BY MELT SPINNING : Polyester, Nylons, Olefins, Polypropylene, Saran, Sulfar etc.

Process Flow Chart of Melt Spinning

Feeding
(Polymer chips)
↓
Melting
↓
Metered extrusion
↓
Cooling and solidification by cold air
↓
Moisture conditioning
↓
Lubrication

↓
Yarn driving
↓
Packaging

ADVANTAGES OF MELT SPINNING :

- Can be used for both staple and continuous filament.
- Direct and simple process.
- No environment pollution.
- No solvent required.
- Non toxicity and no risk of explosion.
- High production speed (2500 – 3000 ft/min).
- Low investment cost.

DISADVANTAGES OF MELT SPINNING :

- Required more proper maintenance of the Moisture content.
- Heat of input is high.

SOLUTION SPINNING

In solution spinning, a polymer is dissolved in a suitable solvent and is extruded inside a coagulation bath containing a non-solvent (immersion-jet wet spinning) or into a heated chamber of air (dry spinning)

WET SPINNING

These processes are used for thermoset polymers such as acrylic, liquid crystalline polymers (Kevlar and Nomex), and polyurethane. In wet spinning, the polymer is dissolved in a solvent at a target concentration to make a polymer solution with the desired viscosity. This polymer solution is then extruded under heat (if needed) and pressure into a liquid coagulation bath. Then fibers are combined as yarn and the yarn is drawn, with very good controls, to orient the molecules in the fibers so that it becomes stronger.

Working Flow Chart of Wet Spinning Process

At first solid polymer and suitable solvent is dissolved in a solution vessel
↓
The solution is then heated in heat exchanger.
↓
The solution is passed/extruded to spinneret which immersed in a coagulation bath/spin bath by pump.
↓
The polymer is chemically regenerated and it is converted into the filament of solid form
↓
The filament is converged and wound on bobbin.
↓

The wended filament is then drawn and finally it is washed & dried and is also wound on suitable package.
↓
Delivery

ADVANTAGES OF WET SPINNING :
Large tows can be handled.
Better than melt and dry spinning for temperature sensitive polymers.

DISADVANTAGES OF WET SPINNING :
Slow process (70 – 150 yd/min).
Washing to remove impurities.
Solvent and chemical recovery is costly.
Lower production rates than melt or dry spinning due to viscous drag.

TYPICAL WET SPUN FIBERS:
Viscose (Rayon)
Cuprammonium rayon

DRY SPINNING
Dry spinning is used to form polymeric fibers from solution. The polymer is dissolved in a volatile solvent and the solution is pumped through a spinneret (die) with numerous holes (one to thousands). As the fibers exit the spinneret, air is used to evaporate the solvent so that the fibers solidify and can be collected on a take-up wheel. Stretching of the fibers provides for orientation of the polymer chains along the fiber axis.
Cellulose acetate (acetone solvent) is an example of a polymer which is dry spun commercially in large volumes. Due to safety and environmental concerns associated with solvent handling this technique is used only for polymers which cannot be melt spun.

Process Flow Chart of Dry Spinning

Feed
↓
Metered extrusion
↓
Solidification by solvent
↓
Evaporation
↓
Lubrication
↓
Yarn driving
↓
Packaging

ADVANTAGES OF DRY SPINNING :
It is suitable for heat sensitive polymer.
The post spinning operation is simple.
High spinning speeds can be easily achieved.
Moderate concentration of polymer is required.
It is relatively flexible process and spinning conditions can be modified.
Suitable for producing fine denier fibers.
No need to wash the fiber.

DISADVANTAGES OF DRY SPINNING :
Investment cost is high.
Slow process
Difficult to achieve exact cross section of fibers.
Additional post spinning process is required.
Toxic and risk of explosion.
Heat input is very high.
Can not be used for staple fiber production

PROPERTIES OF SOLVENT :
Solvent should be volatile.
It should be organic.
It should have low boiling point.
It should be comparatively cheap.
It should be thermally stabilized.

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.

ADVANTAGES OF GEL SPINNING :
Medium speed (up to 1500 m/min).
Suitable for liquid crystalline polymers.

DISADVANTAGES OF GEL SPINNING :
Environmental pollution hazards.
Purification of the filament is needed.
Cumbersome technology.

DRY JET WET SPINNING
In this method the polymer is dissolved in an appropriate solvent to make the fibre solution. This solution is then extruded under heat and pressure into an air gap before it enters a coagulation bath. The produced fibre is then washed and dried before it is heat treated and drawn.
This is an alternative method to wet spinning and is required as spinning directing into the bath, for some fibres, creates microvoids that negatively affect the fibre properties, this is due to the solvent being drawn out of the liquid too quickly. An inert atmosphere may be required to prevent oxidisation in some polymers, if so fibres are extruded into a nitrogen atmosphere.
This method is often required for high performance fibres with a liquid crystal structure. Due to their structural properties their melt temperature is either the same as, or dangerously close to their decomposition temperature, therefore they must be dissolved in an appropriate solvent and extruded in this manner.

ADVANTAGES OF DRY JET WET SPINNING :
High speed of spinning than wet spinning.
High concentration of dope.
High degree of jet stretch ratio.
A greater percentage of solids can be tolerated in spinning solution.
The solvent is removed to greater extent by evaporation into air.
Control of coagulation kinetics by monitoring coagulation bath parameters.

DISADVANTAGES OF DRY JET WET SPINNING :
Due to large amount of heat, it can effect adversely the properties of the produced filaments. It may give a colour effect.
Turbulence in air flow can disturb the regular filament.

ELECTROSPINNING
Electrospinning is a fiber production method which uses electric force to draw charged threads of polymer solutions or polymer melts up to fiber diameters in the order of some hundred nanometers.

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. Electrospinning from molten precursors is also practiced; this method ensures that no solvent can be carried over into the final product.

STEPS OF PROCESSING
When a sufficiently high voltage is applied to a liquid droplet, the body of the liquid becomes charged, and electrostatic repulsion counteracts the surface tension and the droplet is stretched; at a critical point a stream of liquid erupts from the surface. This point of eruption is known as the Taylor cone.
If the molecular cohesion of the liquid is sufficiently high, stream breakup does not occur (if it does, droplets are electrosprayed) and a charged liquid jet is formed.
As the jet dries in flight, the mode of current flow changes from ohmic to convective as the charge migrates to the surface of the fiber.
The jet is then elongated by a whipping process caused by electrostatic repulsion initiated at small bends in the fiber, until it is finally deposited on the grounded collector.

The elongation and thinning of the fiber resulting from this bending instability leads to the formation of uniform fibers with nanometer-scale diameters.

PARAMETERS OF ELECTROSPINNING

Molecular weight, molecular-weight distribution and architecture (branched, linear etc.) of the polymer

Solution properties (viscosity, conductivity and surface tension)

Electric potential, flow rate and concentration

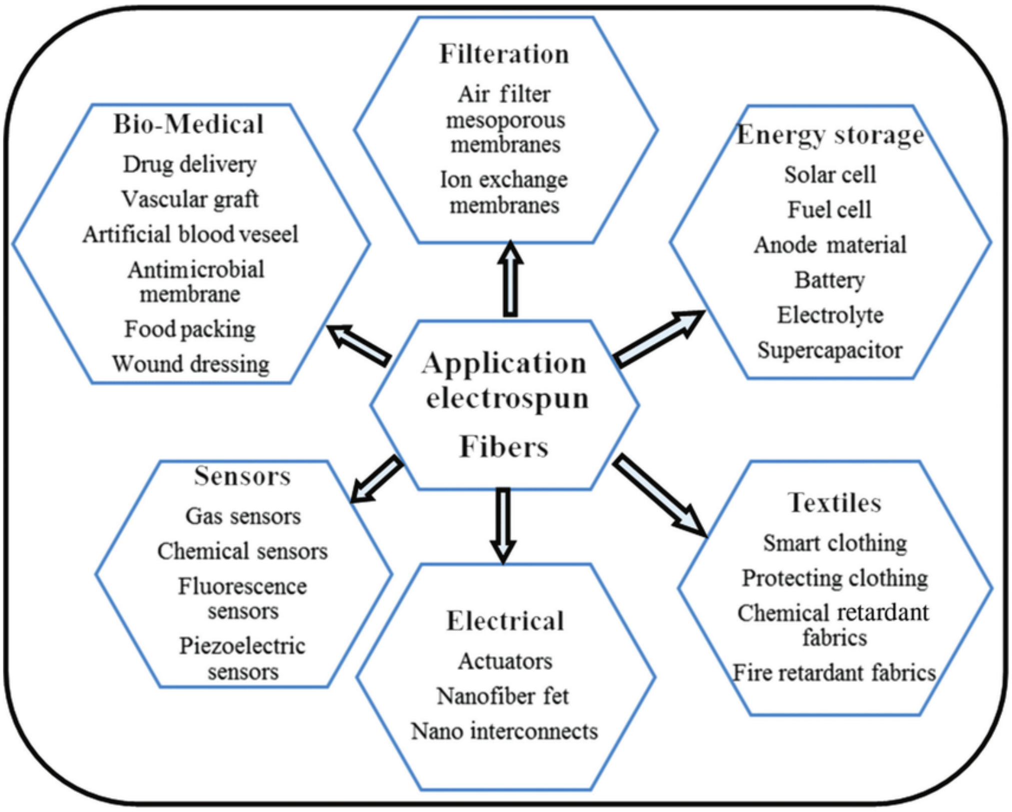
Distance between the capillary and collection screen

Ambient parameters (temperature, humidity and air velocity in the chamber)

Motion and size of target screen (collector)

Needle gauge

APPLICATIONS OF ELECTROSPINNING



From Cotton Pods to Cotton Yarn:

The Spinning ProcessSpinning is a major part of the textile industry. It is a part of the manufacturing process where fiber is converted into yarn, then fabric, which undergoes finishing processes such as bleaching to become textiles.Spinning is the twisting together of drawn out strands of fibers to form yarn, though it is colloquially used to describe the process of drawing out, inserting the twist, and winding onto cones.In simple words, spinning is a process in which we convert fibers by passing throughout certain processes Blow Room, Carding, Drawing, and finally winding into yarns. These yarns are then wound onto cones.

BLOW ROOM

Blow Room is the starting of spinning operation where the fiber is opened, cleaned, mixed, micro dust removed and evened.

<u>Functions of Blow Room:</u>

Opening

- Opening is the first operation within the Blow Room in which the goal is high degree of openness of material with gentle treatment and a fiber loss as less as possible
- Bales of cotton are laid down uniformly in layer
- Machine called Blendomate picks up material uniformly. The parts in this machine:
    - Two supporting rollers: Contain spikes used for picking up bales of cotton and evening them out
    - Pressing Roller: Present in the center of the machine which evens out the cotton
    - Two opening rollers: Cuts the cotton and sucks it into the machineCotton is sucked into this machine and then enters all the other machines
    - The size of lumps is decreased

Mixing

- Homogeneous mixing of cotton takes place
- Blending of fiber material is an essential preliminary in the production of a yarn
- Fibers can be blended at various stages of the process
- However, the starting process is one of the most important stages for blending, since the components are still separate and therefore can be metered exactly and without dependence upon random effects
- Cotton drops on the lattice and it moves forward

Cleaning

- Cotton contains up to 18% trash in most cases. To clean the material, it is unavoidable to remove as much fiber as much waste
- Therefore, it is necessary to measure the amount of the waste removed and its composition. As it is of high importance also called cleaning efficiency
- The cleaning efficiency always has to be optimized and not maximized, since the fiber quality as well as fiber loss is always negatively affected by maximum trash removal
- The waste is collected in a waste trolley

CARDING

Carding is a mechanical process that disentangles, cleans and intermixes fibers to produce a continuous web or sliver suitable for subsequent processing. This is achieved by passing the fibers between differentially moving surfaces covered with card clothing. It breaks up locks and unorganized clumps of fiber and then aligns the individual fibers to be parallel with each other

- Cotton is opened, trash is removed from it and sliver is formed
- The loose cotton is put in a cylinder and then made to enter the carding machine, which is known as DOPHER

Objectives of Carding:

- Open tuft into individual fiber
- Cleaning of cotton by removal of trash and dust
- Elimination of neps and short fibers
- Straightening of fibers
- Sliver formation
- Sliver gets collected in a moving cylinder

DRAWING

- The input sliver is kept in stationary cylinders
- After passing through the draw frame, the combined sliver is collected in moving cylinders
- 6 slivers are converted into a single sliver, hence called unit 6 sliver
- Wider the draw frame, more even is the sliver formed

Objectives of Draw Frame:

- Evenness of sliver
- Gradual parallelisation of fibers
- Homogeneous blending
- Dust removal from slivers
- Hooks in fibers get straightened
- To even out weight per unit length, which is achieved by the Autoleveller

WINDING

The creation of large yarn packages that can be easily unwound, is called winding. This makes using the yarn on subsequent machines easier and more economical.

Objectives of Winding:

- To convert sliver into twisted yarn

- To wind yarn onto the package
- The machine is gear driven which fixes the length of the thread (22,000 yards)
- The machine automatically stops if the sliver(input) breaks or when the fixed length is achieved

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SCHOOL OF BUILDING & ENVIRONMENT

DEPARTMENT OF FASHION DESIGN

UNIT – IV- Elements of Textiles – SFDA1103

Classification of Yarns Properties of Yarn -& Numbering systems

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 or knitting to produce fabric. If you are involved in the apparel industry then you must know the classification of yarn.

Yarn Classification

Classification according to their structure

The yarn may be divided into three types according to their structure. They are as follows:

1. **Single yarn/staple fiber yarn / spun yarn**

By mechanically assembly or twisting of staple fibers together spun yarns are made. Ring spinning, Rotor spinning, wrap spinning, Air-jet spinning etc. machines are used to produce this single yarn or spun yarn.

2. **Ply yarn**

For normal textile and clothing producing single yarn is used. But ply yarns are often needed to obtain special yarn features such as:

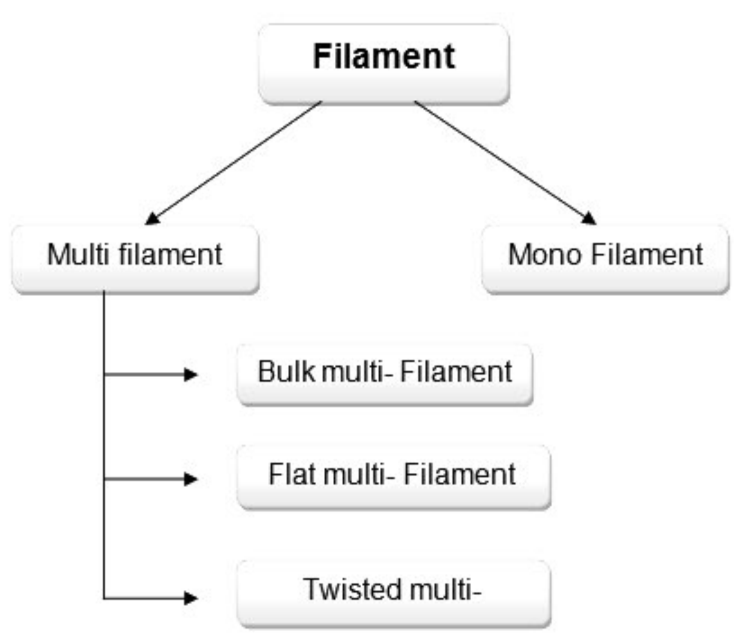
- To ensure high strength
- For gaining special properties.

A ply yarn is sometimes called *folded* yarn also. It is produced by twisting two or more single yarn together.Another is *cabled* yarn which is produced by twisting two or more ply or folded yarn.

The direction of twisting of yarn to make ply yarn is defined as S or Z twist. Generally, the folding twist is in the opposite direction to that of the single yarn.

Filament yarn

The yarn which is made from one or more continuous strands is called filament yarn. In filament yarn, each component filament which is used to make this filament yarn runs the whole length of the yarn.



Mono Filament yarn: Those filament yarns which are made from one filament is called mono filament yarn.

Multi filament yarn: Those filament yarns which are made from more filaments is called multi filament yarn.

Texturing is the main method used to produce the bulked filament yarn. Silk is the only major natural filament.

Spun Yarns

Spun yarns are made from the staple fibres that are twisted together. Spun yarns are characterized by protruding fibre ends. Spun yarns strength is dependent on the cohesive or the clinging power of the fibre and on the points of contact resulting on pressure of the twist. The greater the number of points of contact, the greater is the resistance to the fibre slippage within the yarn.

They are suited to clothing fabric in which absorbency, bulk, warmth or cotton like or wool like textures is desired. When worn fibre ends hold the yarnsawayfromclosecontactfromtheskin,andso fabricsmadeofspunyarn is more comfortable on a hot humid day than a fabric of smooth filament yarns. Protruding ends contribute to a dull fuzzy appearance, to the shedding of lit and to the formation of pills on the surface of the fabric. They also get dirted readily, spun yarn can be given different types of twist based on the end use as napping twist.

Napping twist: This type of yarn is called as low twist, yarn. It has 2.3 turns per inch such low twist results in lofty yarns which allow for napping of fabric. Thus napped fabrics are bulky and provides warmth when used in garments.

Average Twist: It is frequently used for yarns made of staple fibres and is very seldom used for filament yarns. The amount of twist that gives warp yarns maximum strength is referred to as standard warp twist.

Hard twist (Voile twist): When yarns are given 30-40 turns per inch, they are called hard/voile twisted yarns. The hardness of the yarn results when twist brings fibres closer together and more compact.

Crepe Years: Crepe yarns are made of with either staple or filament fibre. Crepe is a French word meaning crinkle. They are made with a high number of turns per inch (40-80) inserted in yarns. This makes the yarn so lively and kinky that the twist must be set before it can be woven or knitted filament crepe yarns are used in fabrics like Georgette and chiffon.

Filament Yarns

The range of filament yarns is as diverse as that of staple yarns. Filaments yarns are divided into two types viz flat continuous filament and textured continuous filament yarn.

(a) Continuous filament yarns are provided from long continuous filaments. Filaments yarns are primarily man-made. Silk is the only natural filament and accounts for less than 1% of the fibre and yarn production. Regular or conventional filaments yarns are smooth and silk like as they come from the spinneret. Their smooth nature gives them more luster than spun yarns, but the luster varies with the amount of the delusturing agent used in the fibre spinning solution and the amount of twist in the yarn. Filament yarns have no protruding ends, so they do not shed lint; they resist pilling and fabrics made from them tend to shed soil easily.

(b) Textured continuous yarn are man-made continuous filament yarns that are been modified by subsequent processing to introduce crimps, coils, loops or other distortions into the filament or with high twist or low twist. The addition of twist increases bulk texturing gives slippery filaments the aesthetic property of spun yarns by altering the surface characteristics and creating space between the fibres. It also improves the thermal and moisture absorption of filament yarns.

According to the number of parts in Yarns

1. Simple Yarn.

In the construction of simple yarn, only one kind of fibre is used. The manner in which the fibres are twisted will be the same throughout the length of the yarn. Yarns are known as simple, ply or cable depending upon the number of strands they contain.

2. Single Yarn

In this, a number of fibres are twisted together into a continuous length. The yarns consists of one kind of fibre. This type of yarn is the one usually found in most standard fabrics for clothing and household use and purposes.

3.Ply yarn

Two or more than two single yarns are twisted together to form a ply yarn. These yarns are known as multiple strand yarn. If two single yarns are twisted together, the resulting yarn is known as two-ply yarn. If three are twisted together three-ply yarn and so-on.

4. Cord/Cable

It is made by a third twisted operation, in which ply yarns are twisted together. Some types of sewing threads and some ropes belong to this group. Cords are seldom used in apparel fabric, but used in industrial weight fabrics.

Double Yarn

This consists of two or more single strands treated as one in the weaving process, but the strands are not twisted together. These are used for ornamental effect as the low twist yarns produce luster and softness.

NoveltyYarns

The construction of these yarns is of complex nature and is varied in many ways. These yarns are usually ply yarns of different kinds of fibres or of different colours and are irregular rather than smooth single strand or yarn of various colours, sizes of fibres may be twisted together to form complex yarn. Another variety is brought about in this kind of yarn by varying the tension or speed after intervals of certain length. Thus allowing one part to loop or twist around the other. Novelty yarns are also constructed from simple yarn by varying the amount of twist. The complex type of novelty yarn is used with two objects in view one is to combine different fibres eg. Cotton and rayon may be blended with or covered by wool or silk. This lowers the cost of production. The other objective is to produce a novelty yarn. For the construction of novelty yarns, at least one or two single yarns are use. One forms the foundation yarn known as a base or the core and the other, The effect of yarn which is wound or looped round the first one. A third yarn called binder yarn is often used to fasten or tie the effect yarn to the foundation yarn. These types of yarns are mostly used for drapery, up hoistery fabrics.

Types of Novelty Yarns

Slubyarn: This is a yarn made with thick and thin placing by varying the amount of twist in the yarn at regular intervals. They are found in drapery and upholstery fabrics.

Flock yarn: These are frequently called as flake yarns. These are usually single yarns in which small amount of fibres either different colours or luster or both are inserted into the yarn and held in place by twist of base yarn eg: tweed fabric. This gives a spotted and short streaky appearance.

Thick and thin yarns: These are similar to slub yarns but these are made from filament like slub prepared from staples. The pressure forcing the spinning solution is varied the filament is thick in some places and thin in some.

Boucle Yarn: These are characterized by a projecting from the body of the yarn at fairly regular intervals. There are 3 ply yarns. The effect yarns forms irregular way surface and binder ties it to the base. It has twisted core yarn.

Loop and curl yarn, Gimp yarn: Gimp is same as boucle but the effect

yarn is regular semi circular appearance, while in loop.

Snarl yarn or spike yarn: This is made in the same way as loop yarn using a highly twisted effect yarn, which forms snarls rather than loops.

Knop (button) yarn/knot/Nub/Spot yarn: This feature prominent bunches of one or more of the component yarn at regular or irregular intervals. This is made on a special machine that permits the base yarn to be held almost stationary while the effect yarn is wrapped around it several times to build upon enlarged segment with brightly coloured fibres added at the enlarged spot.

Seed or Splash: They resemble knops or knot yarns but the knot segments

are tiny in seed yarn and elongated in splash yarn.

Cloud: A two coloured yarn, in which both yarns take in turn to obscure or cloud the other, giving the appearance of an intermittent color change.

Spiral or Corkscrew : It is made by twisting together two ply yarns that differ in size, type or twist. These two parts may be delivered to the twister at different rates of speed.

Chenille Yarn: These create special effects chenille means caterpillar in French. The yarn has a cut pile effect which is bound to the core on the loom warps are arranged in groups (2-6) which are interlaced in a cross weaving manner. Weft is inserted in a normal manner. These are cut into wrap way threads

Metallic Yarn: These are primarily decorative. The plastic coasting on it resists tarnishing but care must be taken while pressing as pure metals are soft, their thin films are used over a core yarn that has replaced gold and slivers now. There are two methods of pressing.

Yarn twist: Twist is the spiral arrangement of the fibres around the axis of the yarn. Revolving one end of the fibre strand while the other end is held stationary produces twist. Twist binds the fibres together and gives the spun yarn strength. It is a way to vary the appearance of fabrics. The number of twists is referred to as turns per inch. They have a direct bearing on the cost.

Twist is the spiral arrangement of the fibres around the axis of the yarn. Revolving one end of the fibre strand while the other end is held stationary any produces twist. Twist binds the fibres together and to gives the yarn. Higher twist whichyieldslowerproductivity.

Direction of Twist

The direction of twist is described as s-twist and z-twist. A yarn has S- twist if when held in a vertical position, the spiral confirm the direction of slope of the central portion of the letter “Z”. Z-twist is the standard twist used for weaving yarns. The majority of single yarns are spun with twist in Z-direction.

The Amount of Twist varies with

1. The length of fibres
2. The size of the yarn
3. The intended use

Yarn Number

Yarn number is a measure of the fineness or size of a yarn expressed either as mass per unit length or length per unit. Yarn Count and Yarn Size are synonymous with Yarn Number.

DirectNumberingSystem

Fineness of yarn is measured in weight per unit length.

Denier

It is defined as weight in grams of 9000 meters length of yarn. As the number increases, the yarn gets thicker or coarser and is mainly used for filament yarns.

Tex

It is defined as weight in grams of 1000 meters length of yarn. As the number increases, the yarn gets thicker or coarser. It is applicable for all types of fibers, yarns and global markets.

IndirectNumberingSystem

Fineness of yarn is measured in length per unit weight.

Cotton count-Ne

Defined as number of hanks weigh in 1 pound weight of yarn 1 Hank = 840 yards

As the number increases, the yarn gets thinner or finer. It is mainly used for cotton spun yarn, silk spun yarn, manmade / synthetic spun yarn and cotton/synthetic blended spun yarns.

Metric count-Nm

Defined as number of units weigh in 1 kilo gram weight of yarn 1 unit = 1000 meters

As the number increases, the yarn gets thinner or finer. It is mainly used for woolen and worsted yarns.

Yarn Twist

Range

Coarser Medium Finer Super finer

End uses

Heavy weight fabrics like denim, canvas

Sheeting, drill, gingham, matte and hopsack

Light weight fabrics like shirring's, sheets

Very light weight fabrics like shirring's, sheets, voile, percale

Twist is the spiral arrangement of fibers around the yarn axis. Twist binds the fibers together and contributes strength to the yarn. The amount or degree of yarn twist is measured in number of turns per inch (TPI).

Degree of yarn twist the following characteristics of fabrics ·Hand ·Appearance ·Texture ·Drape ·Durability

Yarn Numbering System

There are two systems of expressing yarn number or yarn count.

Direct yarn numbering system (mass/unit length)

❷ Indirect yarn numbering system (length/unit mass)

Direct yarn numbering system

In a direct yarn counting system, the yarn number or count is the weight of a unit length of yarn. This means the higher the yarn count number, the heavier or thicker the yarn. It is fixed length system. This system is generally used for jute or silk yarn.

The following formula is used to calculate direct yarn count system.

$$N_d = \frac{W \times l}{L}$$

Where, w=yarn number or count

W=the weight of the sample (yarn) in units of the system at the official regain

L=length of the sample, and

l=unit of length of the system

Major direct numbering System

Denier: In the direct Denier system, the yarn count number indicates “the weight in grams of 9000 meters of yarn”.

e.g. 30D indicates that 9000 meters of yarn weight 30 grams.

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DEPARTMENT OF FASHION DESIGN

UNIT – V- Elements of Textiles – SFDA1103

Woven, Knitted and Nonwoven Fabrics Construction Methods

Fabrics are produced mostly from yarns. Few fabrics are directly produced from fibers. In Indian market 70% of the fabrics are produced by weaving. Among the other fabrics that is non woven fabrics lace making is worth mentioning along with needle punched and tufted fabrics. Felts are fabrics made directly from fibers without making yarns where fusible use is mostly emerging now a day.

The fabric construction process determines the appearance and texture the performance during use and care and cost of fabrics. The process often determines the name of the fabric for eg: felt lace, double knitt and jersey. The cost of fabrics in relation to the construction process depends upon the number of steps involved and the speed of process, the fewer the steps the faster the process, the cheaper is the fabric.

The fabric construction methods includes

Weaving,

Knitting

Non woven fabrics.

Yarn is turned in to fabrics of garments by weaving, knitting, or felting.

Fabrics are woven in long lengths from 40 to 100 or more yards and from about 20 to 60 inches in width. For a fabric to have strength and compactness combined with a fair degree of elasticity, the warp and filling threads must be interlaced. This interlacing is called weaving and it is done on a loom.

An interlacing where the filling threads are passed alternatively over and under the warp threads is called as a plain weave. It is the simplest of all weaves.

If the fillings threads are passed one over and 2 under or more warp threads will result in twill fabrics. The surface of such fabric has pattern of parallel diagonal ridges.

If the warp threads or filling threads are considerably thicker then the rib- weave is produced.

Thus the very large number of variations of methods for interlacing the warp and filling threads makes to weave the wide variety of fabrics each of which has special properties and uses.

The beam of the warp threads is placed at the back of the loom and the threads are drawn from it across the loom from back to front to be wound on another roller. For the weaving of plain cloth, the threads are drawn through the eyes of two sets of heddles.

The filling threads pass over and under alternate warp threads which are lifted and lowered by the corresponding heddles.

Toe cop with the filling threads is placed in a shuttle which is moved or thrown from side to side across the loom. Each pass of the shuttle lays one filling threads. The comb like reed described earlier beats the filling threads tight against the preceeding fill threads, as the fabric is woven it is slowly wound on to a roller in front of the loom.

The following lists includes some of the most common weaves:
1. Plain weave (a) Rib weaves (b) Basket weave
2. Floating weave (a) Twill weave (b) Satin weave (c) Sateen weave. And its variations

Introduction of weaving

The principles of weaving are known very clearly perhaps a long ago as 400BC our ancestors knew how to make baskets and mats by interlacing twigs., reeds, and grasses. Later they learnt how to twist together short fibers, such as wool and cotton, to form yarn and to weave the yarn in to cloth on a loom, primitive looms were built around a convenient horizontal tree-branch, over whichthewarpthreadsweretied. Thelowerendsofthethreadswerefastened to tie them in position.

Wovenfabricsaremadefromtwoormoresetsofyarnsinterlacedat right angles to each other the lengthwise yarns are called warp or ends and the crosswiseyarnsarecalledweftorfillingorpicks. Neatfirmedgesareformed on both sides along the length of the fabric when filling yarn turns at the edges during weaving. They are commonly referred to a "selvedges".

Weaving is done on a machine called loom. The way filling yarn interlaces with the warp yarns produces designs in woven fabrics. Weaving is the mode of interlacement of filling with warp.

All woven fabrics are based on three types of weaves which are termed as basic weaves. The three basic weaves are plain, twill and satin. Most of the other weave are variations or combinations of these three weaves.

Loom and its classifications

The classification of loom is here. We found conventional, automatic and modern loom. According to the classification found in the textile history, we can classify it as three main classes as follows. The basic function of a loom is only making fabric. But for different types of fabric we use different types of loom. Therefore one type of loom works with its own method. So we can classify loom as, conventional or shuttle, automatic and modern looms.

1. **Conventional / Shuttle**
   Conventional means general. The first and the ancient looms are like the conventional loom. It is derived by a shuttle. So the other name of a conventional loom is shuttle loom. We call it shuttle loom because, it has a shuttle and the shuttle does the main operation. There are different types of conventional loom found in textile manufacturing process. Conventional loom needs to operate with manual operation. Following are the different conventional or shuttle loom types mostly used in textile manufacturing.

   I. **Plain**
   II. **Twill**
   III. **Dobby**
   IV. **Jacquard**
   V. **Special (Pile, Gauge, Tri-axial etc.)**
2. **Automatic**

   Automatic loom works automatically. It has a system by which it works. Here only need to set program and maintain the output. There are different automatic looms in textile manufacturing. The another name of automatic loom is power loom. The use of a power loom is like fully automatic. Only need to set a program and it will run automatically. That is why we call it automatic loom or power loom.

3. **Modern / Shuttle-less**
   Modern loom is one kind of automatic loom. There are different types of modern loom in textile industry. Each machine differs from others because of functionality. We describe it from other experts because of using modern loom. Modern looms do the shedding, picking, biting in a algorithm. Different types of motion occurs in a modern loom. The motions are like, primary, secondary and auxiliary motion. Primary motion consist of shedding, picking and beat up operation. In secondary motion we found take up and let off operation. Like that in auxiliary motion we found warp stop and weft stop operation. Now a days we are using following modern looms.

   I. **Missile/ Projectile Looms**
   II. **Rapier Looms**
   III. **Air-Jet Looms**
   IV. **Water-jet Looms**

Shuttle Looms

For many years weaving machines depended on shuttle as the primary device for weft insertion. Shuttle is a device that contains a bobbin on which filling yarn is wound. The shuttles are available in different shapes depending on the type of loom they are to be used. Shuttle looms are among the oldest kind of looms. They are versatile and effective but there are certain disadvantages. As the shuttle passes over warp ends during every picking cycle, it causes abrasion, which lead to thread breakage. So it cannot be used for weaving finer count yarn fabric varieties. Compared to more modern looms they are also slow and noisier. Shuttle looms can be power looms which are used in mill sector or could be different varieties of handloom which are usually used by artisans

Shuttleless Looms

Shuttle less looms were developed to overcome the problems of Shuttle looms. These looms were faster and also reduced the breakage of yarn during weaving. Finer fabric qualities like shirting and dress material could be manufactured with these looms. The modern looms use three prominent devices for pick insertion. This is the first proven Shuttle less loom developed in 1950s in Switzerland. The projectile is like a bullet which grips the weft and carries it through the shed and returns empty. It can be used to make wide variety of basic fabrics, but it requires the yarn to be smooth and uniform to reduce friction.

Rapier Looms

Rapiers, used to insert the weft, are of two types - Single Rapier and Double Rapier. Single rapier is one long rapier device that carries the weft from one side of the loom to other and returns back empty. Whereas in double rapier, one rapier feeds the weft halfway through the shed to another rapier, which then carries it across rest of the way. The double rapiers could be rigid, flexible or telescopic.

Airjet Looms

The looms use jet of air to propel the weft yarn across the shed of the loom. These looms are faster and also less noisy than the shuttle looms, rapier and projectile loom. The filling yarn is also under less tension. Airjet looms are used for producing wide variety of fabrics.

Waterjet Looms

The jet of water is used to carry the weft yarn across the shed of the loom. These looms are faster and operate at less noise level like air jet looms. But the disadvantage is that they are restricted to produce the fabrics that do not readily absorb water such as nylon, polyester, etc.

Modern Looms

Innovative approach to weaving has been introduced through several design modifications of shedding and picking components of the traditional weaving machine.

Circular looms

These looms are designed to produce circular fabrics. In these looms shuttles are used that circulate the pick in the shed, which is formed around the machine. The circular looms at present are primarily used for bagging material.

Parts of the loom

Heald Shaft

This part is related to the Shedding Mechanism. It can be made up of wood or metal. It carries number of heald wires, at the center of which is the heald eye. The ends of warp sheet pass through these heald wires. The number of Heald shafts used in weaving depends on the Repeat of the weave. The main functions of heald shafts are:

It helps in shed formation
It helps in identifying the broken warp thread.
It determines the order of lifting and lowering the warp ends for a pick

Reed

It is a metallic comb which is made up of number of wires. The gap between these wires is known as Dent. The reed performs the following functions:

It pushes the last inserted pick to the fell of the cloth.

It keeps the warp ends in its position and avoids entanglement.

It determines the fabric density, i.e. the number of ends per inch of the fabric.

- Warp Beam
  This is also known as the Weaver's Beam. The warp sheet is wound on to this beam and it is fixed at the back of the loom.

- Back Rest
  Back Rest or Back Beam is above the weaver's beam. It acts as a guide to the warp sheet coming from the weaver' beam and also as a sensor for sensing the warp tension

- Breast Beam
  The breast beam or the front rest is between the temples and the cloth roller at the front of the loom and it acts as a guide for the cloth being wound on to the cloth

roller. The front rest along with the back rest keeps the warp sheet and cloth in the horizontal position and maintains proper tension to facilitate weaving

Cloth Beam

It is also called as cloth roller. The woven cloth is wound on to this roller. This roller is at the front of the loom

BASIC OPERATIONS IN WOVEN CLOTH PRODUCTION

The weaving process consists of three basic operations which form a continuous cycle whether in the simplest hand-loom or in the most complex automatic loom. These Primary Motions of Weaving are as follows:.

Shedding

- The separation of the warp threads into upper and lower layers forming a Shed, or a tunnel, through which the weft is passed

Picking

- The insertion of the weft thread, which traverses across the fabric, through the shed

Beating-up

- The carrying forward of the last inserted pick or weft, to the fell of the clothThe picking and the beating-up operations are fixed no matter what type of fabric is being produced, but the shedding motion is variable and can be described as the heart of weaving as it is here that the nature of the interlacing or the weave, is decided. The different shedding motions are described further in the chapter. In addition to the three principal operations, several ancillary motions are required for control purpose. Some of these are mechanical devices connected with the safety and the continuity of weaving operations, but influence of some motions can alter the cloth appearance considerably. These Auxiliary motions are as follows:

  - Warp Let-Off -
    This determines the rate at which the warp is fed forward and the tension of the warp yarn. The tension is largely responsible for the configuration of warp ends in the cloth and two fabrics of identical design but woven with varying degrees of tension may appear different and may possess different characteristics

  - The Cloth Take-Up -
    This determines the speed of cloth withdrawal and therefore, the density of spacing of the weft picks (i.e. the Picks per inch) in the cloth
    The other mechanisms are as follows:

  - Warp-Protector motion -
    This stops the loom to prevent excessive damage to the warp threads, cloth, and reed if a shuttle becomes trapped between the top and bottom shed lines and the reed is failing to complete its traverse.

  - Warp and Weft-Stop Motion -
    This will stop the loom almost immediately if a warp end or a weft thread breaks, thus avoiding defects in the fabric.
    Yarns must remain completely parallel from warp beam to cloth beam and not cross each other. If they do cross each other it may cause warp yarns to break, which ultimately results in fabric defects.

WEAVING

The weave structure in the fabric is determined by two factors.

The order in which the warp threads are threaded in the heald shafts and in the reed.

The combination of heald shafts raised or lowered at a time, and the sequence in which the heald shafts are raised or lowered

IMPORTANT WEAVING TERMINOLOGIES

- Fabric Density
  The fabric density is defined as the number of ends and picks in a unit of a fabric. It is measured as ends per inch and picks per inch

- Ends per inch (EPI)
  This is defined as the number of ends in one inch of the fabric. To get the required warp density, reeds of different counts are used.

- Reed Count
  The Reed Count is defined as number of dents in two inches. Through each dent, two, three or more ends can be passed. So for example, if you are using a Reed Count of 32s, it means there are 16 dents in one inch, so with 2 ends per dent, the EPI would be 32 (16x2=32). Reeds of different counts are available which help in making fine or thick cloth or changing the number of ends per dent can help to achieve open or close fabric.

- Picks per inch
  This is defined as the number of picks in one inch of the fabric. The density of picks can be varied by changing the take-up speed. If the take-up speed is high then Picks per inch is less. This is so because as the fabric is wound at the greater speed the picks are being laid further apart, where as if the take up is slow then the picks per inch is higher as the fabric is now being wound at a slower speed.

- Total warp ends
  This is defined as the total number of ends across the width of the fabric. This is a product of the Ends per inch of the fabric and Width of the fabric to be woven.
  For example, if the EPI of the fabric is 30 and 60 inch wide fabric is to be woven, then the Total Warp Ends will be equal to 1800 (30x60)

Selvedges: In most of the materials the edges, which are known as selvedges, are made with heavier and more closely placed warp yarns. Selvedges is generally 1⁄4 to 3⁄4 inches wide on fabrics.

The yarns are usually the same as those in the rest of the fabric except that they are made firmer and stronger by increasing the size or count of the way yarns in selvedge. Fused selvedges are found on fabrics made from the heat sensitive fibre. The application of heat melts and then seals the fibre together at the edges.

Count of the Cloth : Count is the technical term used to indicate the number of warp and the weft (the filling yarn or picks) in one square inch of fabric as it comes from the loom. If warps are 90 and the wefts are 80, the count written as 90 x 80 and a fabric in which the warp yarns and weft yarns are more in number it is called as high count fabric. A very low count fabric is one in which the warp and the weft yarns number 28 and 24 respectively example in surgical gauze. The exact number of warp and the weft yarns in a square inch of fabric can be counted with the help of an ordinary magnifying glass held over a tightly stretched piece of cloth. But all this is not necessary if the aim is only to judge whether the cloth is of a high or low count. If the weave is a very close one and tiny spaces are visible between the weave and the cloth it could be a closely woven fabric.

If the fabric is held against the light, the closeness of the weave or its porositycanbeeasilyobserved. Thread count is anindication of the closeness of weave and can be used by the consumer in judging quality, ravelling, durability and potential shrinkage. Fabrics with close weave generally shrink less.

Balance of cloth

Low count fabrics are woven with a fewer interlacing per square inch to make the fabric light-weight. Due to this a porous structure is formed. The balanceoffabricisdeterminedbytheproportionofwarpyarntoweftyarns. If the number of warp and weft yarns is nearly the same in a square inch the fabrics have a good balance for a example, gingham with a count of 96 x88 and guage with the count of 28 x 24 are material with a good balance but the shirting with 100 warps and 50 picks has a poor balance. A fabric with a poor balance when held against the light will show more yarns running in one way that is length wise only. Such a fabric is not good as it does not stand hard, wear and many washings. Thestrengthofthefabriccanbetestedbytightlyholdingandstretching a piece of fabric, and rubbing it repeatedly using thumbs. If any yarn slips out its place and the tiny spaces between the weave gets enlarged, it indicates that the fabric is not as strong as it looks.

Yarns

Warp and filling have different characteristics and the fabric performs differentlyinthewarpandfillingdirection. Strongeryarnsareusedinthewarp- wise direction as they undergo more tension and friction than weft yarns.

Most fabrics stretched less in the warp direction. Warp yarns lie straight in the fabric because of loom tension. They show less crimp. Warp yarns tend to be stronger with higher twist. Decorative or special function yarns, yarns with slack twist, yarns with little twist are usually the filling yarns.

Grain

The grain indicate the direction of the warp or weft yarns. Length wise grain is a position along the warp yarns and parallel to selvedges crosswise grain is along the filling yarn.

Weaves

Weaves are named according to the system or design followed in interlacing warp and weft yarns. The basic weave used in fabric construction are: Plain weave, Twill weave and Satin weave. These are the foundation weaves and form the basis of all other types of wea

Plain weave

Plain weave is the simplest of all the weaves. About seventy percent of the woven fabrics available in the market today are woven in plain weave or it variations. Itisformedbyinterlacingwarpandfillingyarnsinapatternofover one and under one. (fig-1) In the first row the filling yarn moves over the first warp yarn and under the second, over the third, under the fourth and so on. In the second row, the filling yarn moves under the first warp yarn and over the second warp yarn. These two rows are repeated to get the pattern of plain weave.

Plainweavefabricshavenorightorwrongside. Plainweaveprovidesa widescopeforintroducingvariationsinthefabrics byuseofyarnsofdifferent colours, different textured yarn and also by use of thick and thin yarns. Fabrics can be produced in large variety, with different degrees of yarn twist and with different degrees of tensions in the loom. Fabrics made by tightly twisted warp and loosely twisted weft make it easy for a napping finish to be given to it. Example: flannelettes,stripedmaterial,plaidsaremadebyusingdifferentcoloured yarns at intervals eg. ginghams. Plainweaveismadeinterestingbyprintingandembossing. Plainweaving also allows the use of many different finishing processes to produce varieties and different styles of fabrics.

Plain weave is used in the construction of the fabrics from almost all the textile yarns cheapest to produce. It is the most serviceable of all weaves as fabrics,with this weave are easy to wash, dry clean, wear well and are comparatively inexpensive.

Plain weave fabrics

Cotton : Calico, cambric, canvas, cheese cloth, chintz, cotton, crepe, flannelette, gingham, long cloth, muslin, organdy, seersucker and voile.

Linen Wool Silk Rayon Voile

Cambric,dresslinen,handkerchieflinenandtoweling Crepe, Flannel
Chiffon, crepe de chine, crepe georgette, taffeta and voile.

Chiffon, crepe, georgette, seersucker, organdy, taffeta and

Plain Weave Variation

Rib weave:It is the variation of the plain weave. In this heavier yarn sare used is the warp than those is the weft and this produces a ribbed effect. Some times the order is reversed and the heavier yarn is used in the weft. Eg. Faille grass grain, broad cloth, poplin are some of the examples.

Basket Weaves

Basket weaves is a balanced weave. In this two or more yarns in both warp and filling are treated as one and interlaced as in plain weave. The fabric withbasketweavehave. Flenthandifthecountisnotveryhighthefabricis even porous and pliable. However, fabrics with arrangements such as 3x3, 4x4, 6x6 snag easily. This weave is used in material for sports coats and suits. This is a comparitively loose weave and therefore the fabrics are more likely to shrink.

Twill weave

This weave forms Wales diagonally across the face of the cloth. This is brought about by the interlacing of warp and filling yarns with a progression of one at the point of interlacing

Example : If the first filling covers warp yarns 2,3,4,5,6,8 and 9 goes under 1,4,7, then the second filling will go over 1,3,4,6,7,9 and 10 and then goes under 2,5,8, and so on. The simplest form of the twill weaves is made by throwing the filling yarn over a two warp yarns, then under one, over two under one and so on. At least three harnesses should be used in the loom to weave the fabric. Thedirectionofdiagonalintheweavecanbecreatedfromrightupper hand or left upper hand called as right hand left hand twills respectively.

Avariationofthisweaveis“Herringbone”structure. Inthisthediagonal direction is purposefully reversed creating a design resembling the backbone of fish. Thus it is termed as herringbone.

Another variation is made from a diamond pattern. Variations are also introduced by using yarns of different sizes, qualities and colours. Twill weave has fewer point of interlacing than plain weave. So it permits closer packing of warp yarns to produce heavier fabrics which results in longer wear.

Twill weave produces strong material because of the tightly yarns which are used to bring out the diagonal effect and the compactness of its construction. Twill weave fabrics are mostly expensive because of their elaborate construction on but they are strong, stand hard and long wear. This weave is generally used in wool and cotton fabrics where durability is a prime necessity. Twill weave fabrics do not show dirt or dust as much as the fabric woven in plain weaves do and are therefore more suitable for dresses, men’s shirts and suits and children garments.

The side on which diagonal effect is more prominent is the right side of the cloth. But when twill-weave fabrics are finished by “napping” the napped side is the right side.

Twill Weave On Fabrics

Cotton : Denim drill, gabardine, jean, khaki, serge.
Linen :Tablelinen,towels,drills,andticking
Wool : Broadcloth,cashmereflannelgabardine,tweed,serge,worsted Silk : Twill, serge.

Satin Weave

Satin weave fabrics are characterized by lustre and smooth surface. They are similar to twill fabrics except that the floats are long and diagonal lines are not visible.

Satin weave is one in which each warp yarn floats over four or more number of filling yarns and go under one fifth yarn with a progression of interlacement by more than one, thus avoiding the formation of the diagonal lines whichwillinterferewiththelustreofthefabrics. Thelongerfloatspermitcloser package of yarns and thus satin fabrics normally contain more number of yarns than plain weave fabrics.

Satin fabrics have a right and wrong side. A high count of yarns in the fabric provides strength, durability, body and firmness. Their smooth surface provide more lustre. Low count fabrics are not durable and tend to ravel more.

Sateen Weave

Avariationofsatinweaveissateenweave. Itischaracterisedbyhaving filling yarn floats on the surface. These are less lustrous and less durable as filling yarns are generally weaker compared to warp yarns.

Suitability of Weaves Various End Uses

When suitability is a major factor, the consumer should carefully consider the end use or the purpose for which the fabric is to be used Plain weave fabrics are firm and considered to be more serviceable as they are laundered or dry cleaned, comfortable to wear and convenient. They are versatile, ranging from light weight fabrics to heavy weight fabrics.

Light weight or sheer fabrics are suitable mainly for children’s dresses, blouses, summer shirts, sarees and glass curtains, medium weight fabrics are mainly used for shirt,women-dresses,pyjamas and aprons. Heavy fabrics are used for upholstery materials, suiting etc.. All plain weave fabrics are easily sew able and are excellent for creating styles through mix and match.

Ribbed fabrics are suitable mainly for furnishings and basket weave fabrics are suitable for shirting’s and furnishings.

Twill weave fabrics have interesting surface due to diagonal lines on the surface and are also durable. They do not show much soil and required only little ironing. So they are suitable for work and sports clothes.(They are mainly used for menswear even in wool.).They keep up the shape well and so are excellent for suitings.

Satin fabrics are not suitable for daily wear due to the presence of long floats. They can be selected for occasional evening wear for women appearance and style govern the satin,hence they are more expensive. They are considered to be best lining fabrics for coats and shirts because they slide easily over other fabrics.

SHEDDING MECHANISM

Tappet Shedding Mechanism -
In this the heald wires are not operated singly but are attached to heald frame and hence rise or fall together with the movement of the shaft. The tappet system is used to control the shedding where, due to simplicity of interlacing; only few heald shafts are required. But this imposes limitation on length of design. For these reasons tappet principle of shedding is employed mainly for high speed production of standard cloths where changes of structure are infrequent, and simplicity offers some advantage.

Dobby Shedding Mechanism -
Here as well, the heald wire are attached to heald shaft like for tappet shedding, but this system offers considerably greater scope for producing figured effects and are often capable of controlling up to 24 healds.

Jacquard Shedding Mechanism

These looms allow weaving of complex patterns. They are used for weaving designs which are beyond the scope of Dobby Shedding like brocades, damask, etc. i.e. the designs which consists of more than 24 different order of interlacing. In these looms there are no heald shafts. Each heald wire is controlled separately by the Jacquard mechanism and hence thousands of ends can work in different fashion and repeat upon similar number of picks

Knitting

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

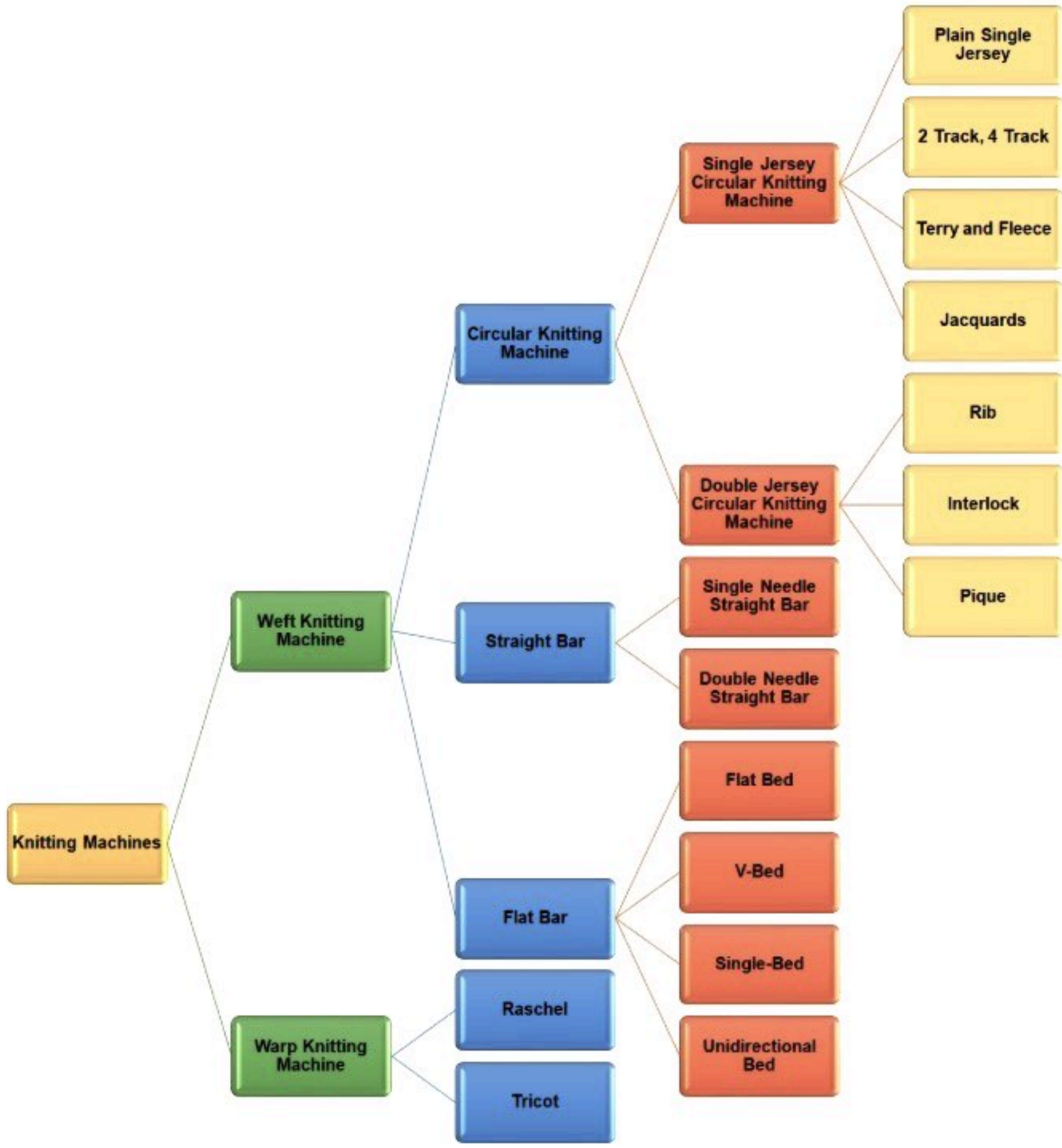
Weft or filling knits are constructed from one yarn that is fed into knitting machine needles in a horizontal direction.The circular knitting machine creates a spiral effect as it produces a fabric in tabular form. Because of this spiral characteristic, it is often difficult to have the wales and courses of the knit fabric form a perfect 90-degree angle match.

Weft Knitting Machine

Weft Knitting Machines are used to make weft knitted fabrics by just a single yarn. Knitting in weft is a more common method than warp knitting. In Weft knitting, the looms are knitted horizontally in a circular form from left to right of the fabric. Weft knits are made from a yarn fed into the circular knitting machine needles.

Warp Knitting Machine

On the other hand, Warp knitting is done by knitting in a zigzag pattern along the fabric area. While weft knitting is done by knitting across the fabric, Warp knitting is accomplished by running knits through adjacent wales or columns.



Weft Knitting Machine:

Circular Knitting Machine

-
  - **Single Jersey Circular Knitting Machine**

    Plain Single Jersey
    2 Track 4 Track
    Terry and Fleece
    Jacquards
-
  - **Double Jersey Circular Knitting Machine**

    Rib
    Interlock
    Pique

- **Straight Bar Knitting Machine**

  Single Needle Straight Bar Knitting Machine

Double Needle Straight Bar Knitting Machine

- **Flat Bar Knitting Machine**
  - Flat Bed or V-Bed
  - Single-Bed
  - Unidirectional Bed

Warp Knitting Machine

Raschel Knitting Machine
Tricot Knitting Machine

Circular Knitting Machine

A Circular Knitting machine is one of the most popular knitting machines in use today. Circular Knitting Machines used to create apparels in large volumes and fast production rates is simple. Fabrics are knitted in spiral and cast on. The circle of stitches are joined forming seamless tubes. The layers it produces are counted on as the number of rows.Machines of this type can produce a wide range of diameter from 12 inches to 60 inches. It can knit a variety of sportswear and fashion clothing and apparel in an incredibly fast rate.

Application of Circular Knitting Machine

This kind of machine is made for manufacturing fabrics of:

- Jackets
- T-shirt
- Ladies tops
- casual wear
- Suits
- Dresses
- Bath robes
- Dressing gowns
- track suits
- Upholstery
- jogging suits
- Jersey,
- Lily
- Jersey blister
- Single lacoste

Single Jersey Circular Knitting Machine

The Single Jersey Circular knitting machine is a modern machine and has a simpler design than the Rib Machine (Double Jersey Circular Knitting Machine). Also called Plain Circular Latch Needle Machine, it consists of a set of latch needle and a set of the sinker. Both revolve along different knitting cam systems that cause a calculated and accurate up and down motion. This mechanism also involves the movement of the yarn feeders that are placed at equal intervals along the circumference of the knitting machine cylinder.

Plain Single Jersey Circular Knitting Machine

Simply put, this machine is the simplest circular knitting machine containing only 1 track of cams that produces plain single jersey fabric. Only one set of latch needle is used. The cylinder, sinker and latch needle revolve along the stationary knitting cam systems producing the desired density, thickness and ideal properties of the fabric.

2 Track, 4 Track Single Jersey Circular Knitting Machine or Multi-track Single Jersey Circular Knitting Machine

Two and Four Track Single Jersey Circular knitting machines can produce a variety of fabric designs for its configuration is specially constructed for high production purposes. Material ranges from cotton, yarn, pique fleece, two-thread fleece, T/C, synthetic fibers and mini-jacquard. With this machine, you can flexibly choose the number of cams for different fabric demands.

Terry and Fleece Single Jersey Circular Knitting Machine

Fleece fabric, like comforters, towels, bathrobes and some winter coats are quickly made with the Terry Single Jersey Circular Knitting Machine.

Terry Knitting Machines makes plain fabric on one side with the back loop inserted with a number of wales (2-3 wales). The back area is brushed as to make the fabric warm and tingly. The threads used can be fine at the top and course for the back.

Jacquard Single Jersey Circular Knitting Machine

Jacquard Single Jersey Circular knitting machine is designed with a three-position needle selection options – knit, tuck, and miss, allowing complex Jacquard fabric patterns to be made.

Jacquard fabric is the most intricately styled fabric as it has a raised texture design that usually include flowers, brocade, matelassé, paisleys, damask and animal patterns.

Double Jersey Circular Knitting Machine

This type of circular knitting machine has two forms, known as Rib Machine or Interlock Machine. In the Double Jersey Circular Knitting Machine, two sets of needles are contained in the machine.

The cylinder has one set and the dial has the other set of the needle. The dial and cylinder needles are arranged in a perpendicular manner. Cylinder cams and Dial cams are two different set of cams takes control of the knitting action. This arrangement can either be interlocked or ribbed while producing the fabric.

Rib Circular Knitting Machine

The most notable feature of the Rib Circular Knitting Machine is the rib structure it forms on the fabric. A rib structure is formed by the face and back loops occurring along the coarse successively while the loops of the wales remain the same.

Two sets of needles are used in a perpendicular position with each other. Both the dial and cylinder revolves with the cam systems of the feeders remaining stationary. Cylinder needles move vertically while the dial needles move horizontally.

Interlock Circular Knitting Machine

Interlock is a 1×1 rib variant structure. Two sets of needles work in both cylinder and dial that accomplishes at least two processes. With Interlock Circular Knitting Machines, purl structures can also be made. These Purl fabrics are knitted on specialized machines allowing dual-ended latch needles and special devices of drive them and form intermeshed loops in two directions.

Pique Circular Knitting Machine

Pique Circular Knitting Machines manufacturer textures with the waffle weave look of Pique fabric. This type of fabric differs from your jersey clothing as it has a rough-look texture whereas jerseys have flat and smooth surfaces.

Straight Bar Knitting Machine

Straight bar knitting machine have bearded needles on a vertical bar. Movement is controlled by the accurately constructed cam system. Divisions are equally distributed along the length of the machine in a number of heads. Each knitting head can knit separately in a uniform way along the garment panel.

Single Needle Straight Bar Knitting Machine

Straight bar frames usually have a single needle bar. This configuration, however, makes it incapable of knitting rib welts.

Double Needle Straight Bar Knitting Machine

Double-needle straight bar knitting machines have horizontal and vertical needle bar for knitting rib welts, but the performance of these machines are much slower than the previous machine type.

Flat Bar Knitting Machine

Flat Bar Knitting machines are most suitable for flat or 3D creations but is also applicable in creating tubular knits like circular knitting machines. In this type of fabric knitting machine, the needles are arranged on a straight bar. The mechanism follows a back and forth movement of the carriage containing the yarn feeders through a horizontal path.

Application:

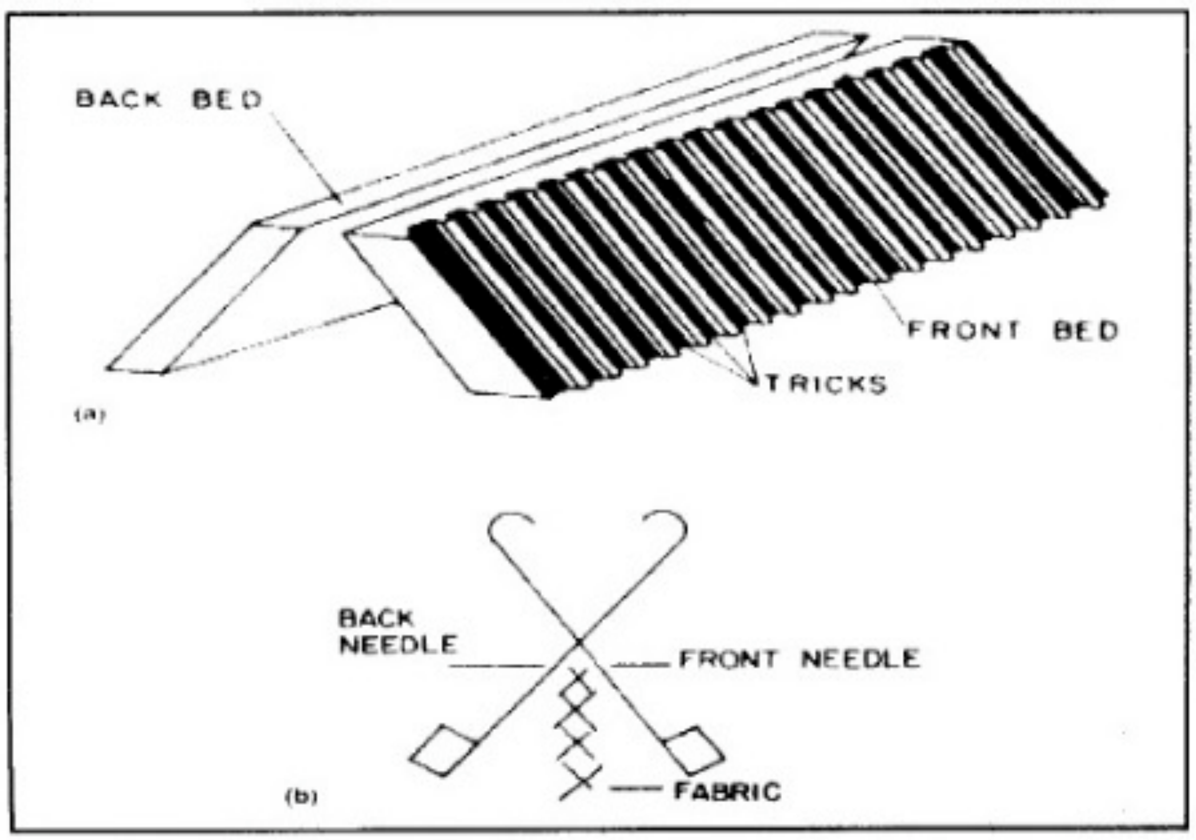
- Collars

- Arm bands
- Sweaters

Flat Bed or V-Bed Flat Knitting Machine

A “Flat” or Vee Bed knitting machine has two flat needle beds having an upside-down “V” formation. Needle beds can stretch up to 2.5 meters wide. A forward and backward movement of the carriage known as the Head or Cambox works to move the knit, tuck and transfer stitches.

This type of machine can make complex knit designs and sophisticated stitching. Knitting speed can be up to 0.5 m/s.

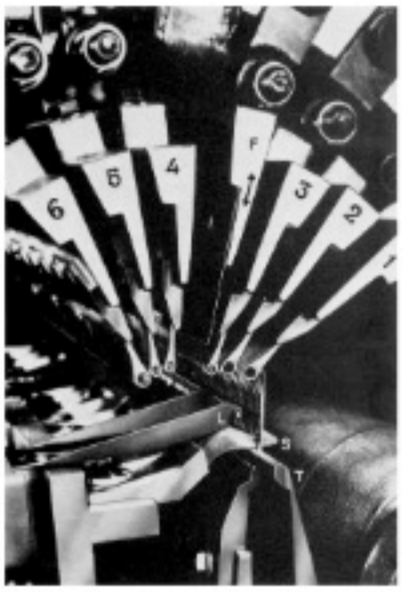


Raschel Warp Knitting Machine

Raschel Warp Knitting Machine makes warp knits to form fabrics. In comparison with the other warp knitting machine, the Tricot, Raschel uses coarser yarns. In fact, there has recently been interest in knitting staple yarns on these machines.

The mechanism is as follows. The warps are twisted and locked with a loop from a succeeding warp. This will then be shifted back by another warp to the preceding layer of knitting. Needles move in a steel plate known as the trick plate. It functions to limit the top level of loops.

The pull of the yarn and sinkers limit the loops. This type of machine has locking belts relatively perpendicular to the plane of the shaking motion or shogging motion.



Application of Raschel Warp Knitting Machine

- Lace fabric and trimmings
- Military fabrics
- Outdoor applications such as backpacks, pockets and pouches
- Bag
- Coats
- Dresses

Tricot Warp Knitting Machine

Tricot machines produce warps knitted fabrics that are finer than Raschel Machines. Compound needles are used in this type of machine. Warp yarns are fed to the needles through the situated guide bars by the shogging motion of the machine.

Application of Tricot Knitting Machines

- Swimwear
- Underwear
- Sportswear
- Gloves

1. Flat or Jersey Knit Fabric

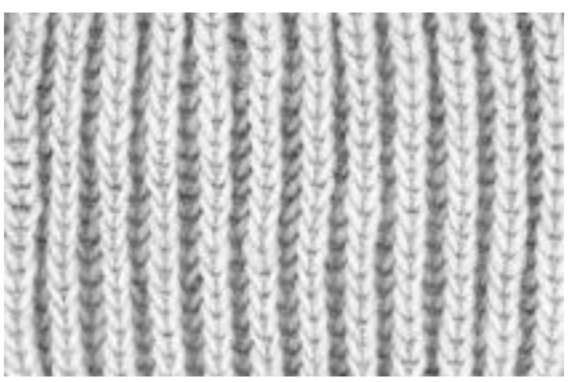
2. Flat or Jersey Knit fabrics have visible flat vertical lines on the front and dominant horizontal ribs on the back of the fabric. The flat or jersey knit stitch is used frequently, it is fast, inexpensive, and can be varied to produce fancy patterned fabrics. A major disadvantage of regular flat knits 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.

3. Purl Knit Fabric

4. 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.

5. Rib Stitch Knit Fabric



6. 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.

7. Interlock Stitch Knit Fabric

8. 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.

9. Double Knit Fabric

10.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.

11. Warp Knitted Fabric

12.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.

13. Tricot Knit Fabric

14.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.

15. Raschel Knit Fabric

16.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.

17. Cable Knit Fabric

18.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.

19. Bird’s Eye Knit Fabric

20.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.

21. Pointelle Knit Fabric

22. 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.

23. Intarsia Knit Fabric

24. 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.

25. Jacquard Knit Fabric

26. 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.

27. 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.

28. Knitted Terry Fabric

29. 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.

30.

31. Knitted Velour Fabric

32.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.

33. Sliver Knit Fabric

34.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.

35. Fleece Knit Fabric

36.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.

Non woven fabrics

Non woven fabrics are made by the any process other than weaving. They are defined as textile materials made directly from fibers and held together as fabrics by different methods. The first non woven was introduced in 1942. There are two generally categories of nonwoven's1.Durable2.Disposable.

Durable: The materials are not manufactured or intended to be thrown away after the single or limited number of applications. Examples include apparel interlining, carpet backings etc.

Disposable: these materials are manufactured with the intention of being thrown away after the single or limited number of applications. Examples include disposable diapers, head rests, surgical gowns, filters etc.

Semi durable non wovens: Some items might be considered as semi durable like hand wipes. The major fiber used in non wovens for the disposable is rayon while the major fibers for durables include rayon, polyster, olefin others used are nylon, vinyl, acrylic, cotton for creating non woven's a web of fibers is first made. This means that fibers are laid by machines in random manner to form this layer called web. Later these webs are laid over each other and are then hold in place by

- Needle punching

- Bonding by means of adhesive heat.

Needle punching is a mechanical process which enlarges the fibers in the web by punching them with needles. This is the most in expensive method such non woven are used in floor covering in filters.

Bonding is a method where 2 or 3 more layers of fiber webs are made to stick to each other by adhesives. These are used in disposable items such as protective gowns, hats etc.

Bonding by means of heat can be done when the fibre webs contain at least 30% fibers. Since these synthetics soften by heat, heat is applied so that the fibers bond with each others forming a non woven. These non woven provide shape to cut parts of garments. So this webs can be used ad interlinings.

Felting

Wool is a probably most ideal for felting because the fibers swell in moisture, interlock and remainin the condition when pressed and shrunk when the fibers have been selected and if necessary blended with cotton or man made fibers they are cared in to a flat sheet or bat. Bats are placed first one way and then the other layers until the desired thickness is reached. Allowance has to be made for shrinkage because steam and pressure of heavy pressures in the process of felting may increase the bats as much as 20% thickness. To make the felt fabric stronger and more compact the fabrics is placed in warm soapy water where it is pounded and twisted. For heavy felt a weal acid is used instead of warm soapy water. The cloth is then ready for finishing process consisting of scouring, dyeing possibly pressing or shearing and treatment with special functional finishes to make it water repellent moth proof and shrinks create and fine resistant. Felt is made for men and a women's hat's, women's skirts, rests and slipper tables covers.Paddling and lining's woven felts have the irplace primarily in the industrial field.

Nets and braids

Netin geometrically shaped figured mesh fabric made of silk,cotton, nylon, polyester, rayon and other man made fiber. It comes in different sizes of mesh and in various weights. On the other hand machine made net is closely related to warp knitting because it is constructed on either a tricot or Rachel warp knitting machine. The first nets to be made by machine were the warp knitted tricot that appears about the middle of the 18th century.

Another type of net in the knotted square mesh type with knots with 4 corners to form the mesh. Originally made by hand and used by fisherman it is now made by machine. These modern fish nets of linen cotton by man made fibers are used for glass curtaining in contemporary living rooms, sun porches and dens.

Braids

This is a method of interlacing 3 or more yarns or bias cut strips of cloth over and under one another to form a flat or tabular fabric. These braided textiles bands which are relatively narrow can be used as belts, pull cards for lights and for trimming for uniforms and dress tapes for pajamas' and some shoe laces. Several width of plastic and straw braiding can be sewen together to make hat

shapes similarly by braids of fabrics or yarns may be sewn together to make braided rugs.

Felt: Felt is the oldest known textile. Wool and related animal fibers such as camel, goat, and hair have unique feature of enlargement when subjected to heat, moisture and rubbing agitation. This property is the base of felt fabric.

lt is made directly from fibers treated in machines designed to accomplish the felting action(heat,moistureandagitation).Despite of wool, rayon or cotton can also be used.

Felt does not fray or ravel. It can be blocked to shape in all directions because it has no gain. It has good excellent shock absorbing and sound absorbing tendencies. It has poor drapability and low tensile strength it cannot be torn but only be cut like woven fabrics it has no gain.

Lace fabrics : Lace is a fabric consisting of decorative design created with thread s or yarns on a net like open background. They may be full of fabric width when used in making dresses or evening wear etc.

(a) Trimming laces: A wide variety of patterns available in laces used for trimming. They are produced having narrow width ranging from 1cm or less width. They are available at various costs and available at the range of average consumer. They are used as decorative materials, apparels, household materials.

(b) Nylon net laces: These laces generally contain a net background on which patterns are made. They are machine made, less expensive and are mostly used as curtains.

The elasticity pose difficulty in cutting and stitching. The pattern should be properly placed over the fabric, taking care not to stretch the fabric and while cutting also avoids the stretching of fabrics.

As the lace fabrics are delicate they require gentle handling sewing and care. Hand sewing is most commonly employed as machine pucker the lace and makes it unsightly. Hand washing is mostly recommended to preserve the delicacy of lace fabric. A mild detergent should be employed while washing these fabrics.

It is the most complicated of all textile making processes. They are considered as fabrics of luxury and delicacy though some are machine washable.

The leavers' machine produces the most finest and most intricate of machine made laces. They are of specific style, type or range weight.

Tufted fabrics: It is another type of the pile fabrics not produced by weaving or knitting. Tufted fabrics are produced by needling extra yarn into an already woven fabric of a relatively open weave construction.

Machine for tufting are multi-needle machines and are capable of producing a tufted needle material. They are made only in relatively heavy weight mostly used for carpeting.