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Synthetic Fibres and Their Future

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A TEXTILE fibre is defined as a "slender filament or fine strand of sufficient length, pliability, and strength that can be spun into yarns and woven into cloth." Fibres are distinguished from filaments in that, the latter are processed fibres of continuous length, most conveniently measured in yards or meters, while the length of fibre is usually given in terms of inches or centimeters. Both single or mono-filaments and multifilaments are known. Fibres and filaments, can either be inorganic or organic but from the point of view of textile fabrics only the organic ones are of major importance. These organic fibres are composed of chain molecules, the fibre in its macro-structure being the reflection of its own micro-structure, as has been shown from X-ray studies of fibres by Astbury, Chibnall and other.

Textile fibres may be broadly divided into the divisions, (1) natural fibres and (2) man made or synthetic fibres. The more important natural fibres can be again classified into two groups (1) cellulosic fibres (e.g. Cotton), and (2) protein fibres (e.g. Wool and Silk).

Typical cotton fibre contains 90% cellulose, 80% moisture. 1% mineral matter, 0.5% wax and fats, 0.4% pectic substances. Cellulose is a polymer of β-anhydroglucose, the various monomeric units being linked by 1-4 bridges. In cotton there is a high degree of crystallinity (60 to 70%), that means a predominant preferred orientation in which the molecules are lined more or less parallel to the axis of the fibre, resulting in ease of spinning. Cellulose is also found in wool, grass and other structural cell-walls of plant materials; however, it cannot be directly spun into fibre as in addition to cellulose, it also contains appreciable amounts of non-cellulosic materials which can be removed by treatment with sodium hydroxide, sodium sulphide, calcium bi-sulphite etc., and subsequent bleaching. The purified cellulose so obtained can

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be employed for the manufacture of "regenerated cellulose fibres" usually termed as "rayons."

Silk and wool are protein fibres of animal origin. Proteins consist of the chemical elements C,H,O,N, and usually S. These elements build up the amino-acids which are joined together by the peptide linkage. Several amino acids linked together, end to end, form a long polypeptide chain. A bundle of such straight chains is obviously the simplest configuration that polypeptide chains can assume. Nevertheless only three instances of this are known in nature; one being collagen, which is the principal protein of bones; the other two are the fibroin of silk and the keratin of wool. Though silk and wool are both protein fibres, the tensile strength of silk is greater than that of wool because of its high degree of crystallinity. Wool on the other hand has a more complex structure, as it is a cross-linked macro-molecule with di-sulphide bridges, which imparts specific elastic properties. Proteins are also available from other sources such as oil seeds, milk etc. However, they cannot be directly spun into fibres. They can be dissolved in a suitable alkaline medium and the solution forced through spinnerettes into a precipitating bath and "fixed" by means of formaldehyde or other similar chemical. "Prolon" is a generic term which has been suggested for such regenerated protein fibres. Typical of this class are "Lanitado" a protein fibre from milk casein and "Ardil" from ground-nut protein.

The term synthetic fibres has been often used loosely to include all the man made fibres, but such a usage is rather confusing. The term synthetic should be restricted to those materials made from chemicals of known constitution, by employing the usual chemical reactions. On the other hand, regenerated fibres e.g. "Rayons" and "Prolons" cannot be considered as truly "Synthetic" as their manufcature involves little or no chemical change.

Some of the requirements for an organic substance to attain fibre-forming properties are: (1) It must be a linear polymer (2) the polymer must consist of molecules, with a molecular weight exceeding 10,000 and an average chain length of over 1000 A°, (3) it must have a high degree of symmetry and no bulky side groups, (4) the polymer must be capable of undergoing a high degree of orientation, thereby giving strong fibres (5) the polymer chains must have a high degree of polarity, produced by evenly spaced polar groups in the chain to give good intermolecular cohesion, which leads to high melting-point and the ability to maintain the induced orientation, (6) the structure must not be too rigid, as otherwise a fibre that is inherently too stiff to give good drape, handle and flexibility will result, (7) for good dyeability by conventional methods and for general chemical reactivity it is desirable that the long molecular chain shall have at intervals along its length chemically reactive groups that can serve as anchorages for dye molecules, water and possibly finishing and other agents.

It may be added, however, that not all the linear polymers with the above-mentioned properties can be employed for the production of textile fibres, particularly from the point of-view of manufacture of clothing, as such properties as moisture absorption, ease of washing laundering, ironing etc. have also got to be taken into consideration. In fact, only a few of the polymers are suitable for textile fabrics, though a good many others have got various industrial uses.

Synthetic fibres are closely related to plastics and rubbers in that all the three have got comparable chemical structure. They differ mainly in their elastic properties, and their behaviour on heating. It is however possible either by chemical modification or by physico-chemical admixture to convert fibres into plastics or rubbers, or *vice versa*.

Hence while developing a new fibre, the fibre chemist first synthesizes a linear high polymer, orients its molecules parallel to the fibre axis by any one of the numerous methods, all of which involve stretching of an extruded filament while in a semi-solid condition,—and causes the molecules to adhere to one another by developing strong inter-molecular forces between polar groups previously located at appropriate intervals along the molecule.

For the production of polymers from simple organic substances, two general methods are available.

(1) *Poly condensation in which small* molecules combine with the elimination of water, alcohol or other simple compounds to give the necessary end product. (2) Polymerisation, in which substances containing double bonds are made to combine together as in the production of polyethylene from ethylene.

From the resulting polymers, the textile fibres are produced by one or the other well-known methods of wet, dry or melt spinning.

Among the synthetic polymers, there are five main classes, which have yielded textile fibres of commercial importance.

(1) Polyamides.
(2) Polyesters or modified polyesters.
(3) Poly acrylonitrile.
(4) Poly vinyl alcohol.
(5) Vinyl chloride co-polymers and chlorinated poly vinyl chloride.

Synthetic polyamides are generally referred to as "nylons" and are manufactured from dibasic acids, and diamines or from *w*-amino carboxy acids. Thus the well-known "nylon 66" or just "nylon" is produced by reacting hexamethylenediamine and adipic acid. This forms a "nylon salt" or hexamethylenediammonium adipate. Hexamethylene adipamide obtained from "nylon salt" by removal of a molecule of water is polymerised to get a linear polyamide poly hexamethyleneadipamide. This is then spun into fibre by "melt" spinning, followed by cold drawing and steam salting.

"Nylon 66" was the first, versatile truly synthetic fibre obtained in 1934. By 1945, it had reached an annual production rate of 24,000,000 lbs., second only to "rayon" among manfactured fibres; its production is continuously on the increase.

'Nylon's' rapid acceptance has rested upon its certain desirable properties. Its tenacity ranges from 4.5 to 8.0 mg./den; in the wet state, it retains 85% of its dry strength. It has very high extensibility and uniquely low modulus at low strains. Its resilience characteristics are good. Its first great success was the replacement of silk in women's hosiery yarns, where of course, it is used in the continuous filament form. It has also high resistance to abrasion.

The greatest factor which has helped in the development of "nylon" is its usefulness in industrial and military applications. Threads, ropes, tyre cords, sail cloth, parachute shrouds, body armor etc. are some of its many applications.

The German fibre "Perlon" is manufactured from *w*-caprolactum and has comparable properties to "nylon."

Polyesters: Only one polyester has acquired commercial importance as a fibre and that is polyethyleneglycol terephthalate, prepared from ethylene glycol and dimethyl terephtalate by ester interchain reaction. The properties imparted by the polyester fibre to fabrics are: excellent resilience, resistance to stretch (filament), high abrasion resistance, good texture and appearance, resistance to heat ageing, good chemical resistance and resistance to sunlight (behind glass).

The polyester fibre has an excellent property of draping.

"Dacron" is the trade name of the polyester fibre by Dupont and Co. the same fibre is known by the trade name "Terelyne" (I.C.I.) in England.

In the case of linear polyesters, containing free end hydroxyl groups, super polymers can be built up by treatment with di-isocyanates, when mixed polyester-urethanes are formed. These have got excellent fibre characteristics, but have not acquired commercial importance owing to the difficulties of handling iso-cyanates.

Polyacrilonitrile is manufactured by polymerising acrylonitrile which in turn is made from acetylene and hydrogen cyanide.

"Orlon" which is a typical polyacrylonitrile fibre, is obtained by solvent spinning. A copolymer of acrylonitrile and vinyl chloride is known as "Dynyl." This is also solvent spun. Both "Orlon" has one outstanding property—amazing thus they have high bulking power. Both are superior to "nylon" in tensile strength. They have excellent resistance to solvents, alkalies and acids, and thus have many industrial uses. "Orlon" has one outstanding property—amazing performance in outdoor expouses. It is inflammable after melting. "Dynyl" is the only organic fibre which does not support combustion. "Orlon" retains 85% of pressed crease after wetting. Copolymers of acrylonitrile with either vinyl chloride ("Dynyl") or vinyl acetate ("Acrilan") are also known. These fibres are more convenient to manufacture as they require readily available solvents for spinning. Their properties are of the same order as that of polyacrylonitriles, though their inertness is not as marked.

Polyvinyl alcohol is the only polymer which is prepared indirectly from polyvinylacetate, which in turn is made by polymerising vinylacetate, as monomeric vinyl alcohol is not known. Fibres from polyvinyl alcohol are unique in that they are soluble in water and as such unsuitable for clothing. However, they are used whenever water soluble fabrics are required; also fibres are used in mixed spinning and weaving in order to obtain specific effects in the final fabric from which polyvinyl alcohol is removed by water washing.

Polyvinyl chloride itself is a hard substance difficult to process, but co-polymers of vinyl chloride, vinylidene chloride form the basis of certain synthetic fibres. Alternately, chlorinated polyvinylchloride with about 65% Cl_2 can be employed. Fibres based on vinyl chloride are solvent spun.

A copolymer of vinylchloride and vinylacetate is marketed as "Vinyon" fibre by American Viscose Corporation. "Vinyon" is outstandingly resistant to acids, alkalis and other liquids and gases. It is resistant to water and hence finds use in fish lines and nets. "Vinyon" loses none of its strength when wet. The yarn does not support combustion. "Vinyon" is not attacked by bacteria, molds or fungus. It is an excellent insulator.

Principal applications of "Vinyon" have been in industrial and military fields. It is used as an industrial filter cloth. Because of its resistance to strong acids and alkalis, it can be used in a number of war industries. It can be used in fertilizer plants for the production of ammonium sulphate. It is used also in the production of vitamins and medicines. Acid resistant pump packing is another industrial use of Vinyon.

A similar fibre made from vinylchloride, is reported from Germany. It is called "mineral fibre" and is intended for filter cloth, diaphragms, jointings, fishery applications etc. It is claimed to be not affected by water, to be non-inflammable and mold resistant.

A copolymer of vinylidene chloride and vinyl chloride containing less than 10% of plasticizer and various light stabilizers is given a generic term "Saran"; this is outstandingly resistant to chemicals and solvents.

In attempting to outline the probable pattern of future trends in textile fibres, it is important to keep in mind their present proportionate distribution. In very approximate terms, the natural fibres account for around 87% of the total consumption of fibres, "rayon" for about 10% and synthetic fibres less than 3%. From an economical point of view, it can safely be said that cost of production of synthetic fibres will be generally higher than that of natural fibres. This is the greatest setback on acceptance of synthetic fibres by the common people. Again a recent development having great promise is the chemical treatment of natural fibres and textiles to improve their properties. By the application of suitable resins and other chemicals, cotton can be made stronger and tougher; wool can be made resistant to shrinkage. Many other special properties, such as resistance to fire, water repellency and the like, can be imparted by chemical treatment. Thus natural fibres are improved and new fibres manufactured in entirely new ways.

While it is too early as yet to appraise the full significance of these new synthetic fibres, there can be no question that their ultimate possibilities are tremendous, provided they meet the three basic requirements : (1) availability, (2) reasonable price and (3) superior properties for at least one important application.

So far as India is concerned, it would seem that the principal natural fibres—cotton, wool and silk—may be with us for a long time. Today cotton accounts for more than 70% of the total fibre consumption. Hence it is rather impossible to do away with cotton, and it is not necessary that we should do so as our climate is well suited for cotton clothing.

However, we should equally well realise the importance of the new synthetic fibres, if not for wearing apparels, at least for our defence and military purposes. The basic materials for the synthetic fibres are equally abundant here and every attempt should be made to develop them so as to make the country self-sufficient.

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