

WHAT IS FIBER?

The basic element of a textile structure are Fibers and Filaments. Fibers are the core of textile materials. We can say that, the fibers are **the main foundation of any textile building as all the fundamental properties, behavior, characteristics** are mainly **depend on the type of fiber being used in the construction of manufacturing.**

DEFINITION

A unit of matter, either natural or manufactured, that forms the basic element of fabrics and other textile structures.

“A fiber is characterized by having a length at least 100 times its diameter or width.”

The term refers to units that can be spun into a yarn or made into a fabric by various methods including weaving, knitting, braiding, felting, and twisting. The essential requirements for fibers to be spun into yarn include a length of at least 5 millimeters, flexibility, cohesiveness, and sufficient strength. Other important properties include elasticity, fineness, uniformity, durability and luster.

FILAMENT

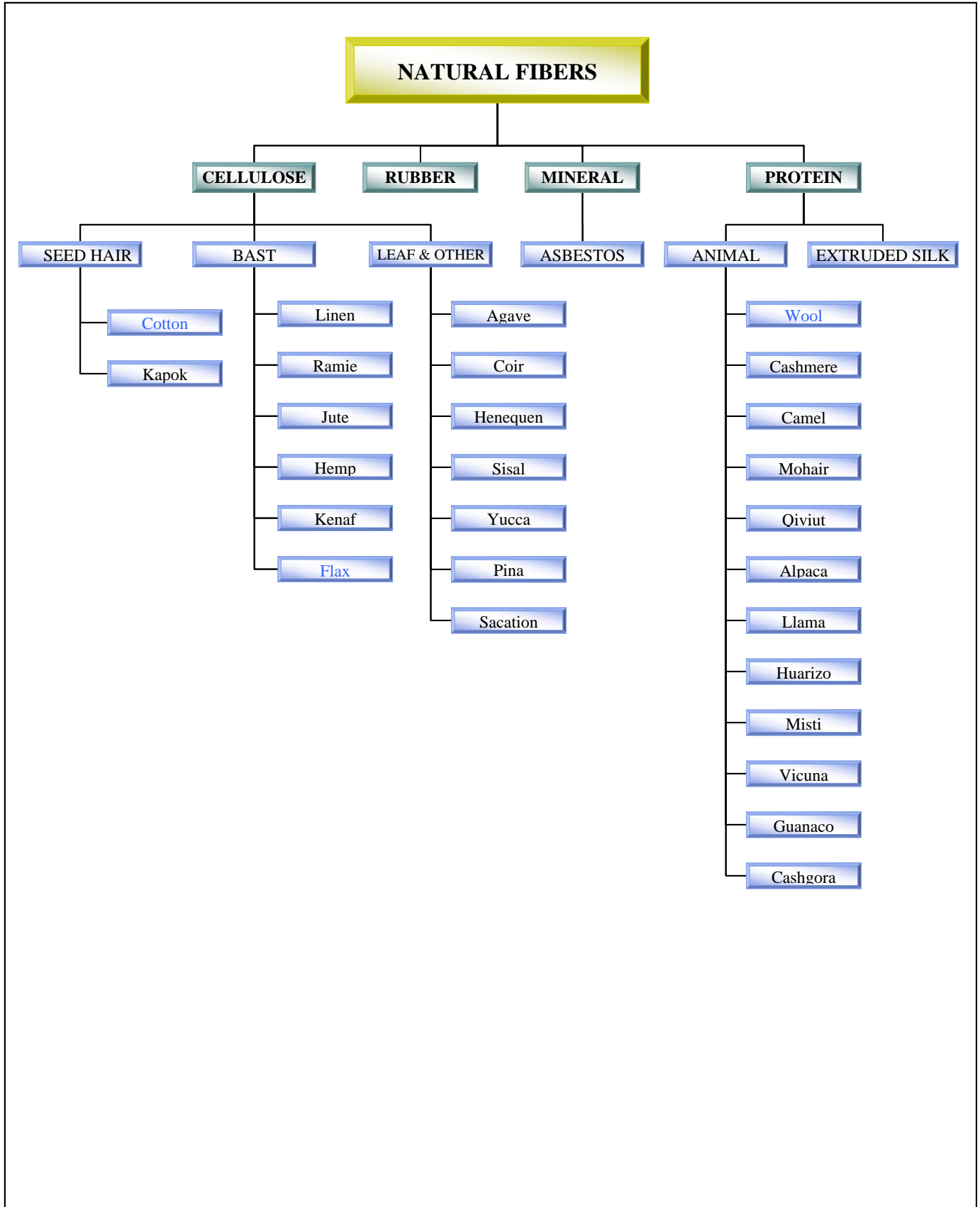
A fiber of an indefinite or extreme length such as found naturally in silk. Manufactured fibers are extruded into filaments that are converted into filament yarn, staple, or tow.

FIBER CLASSIFICATION

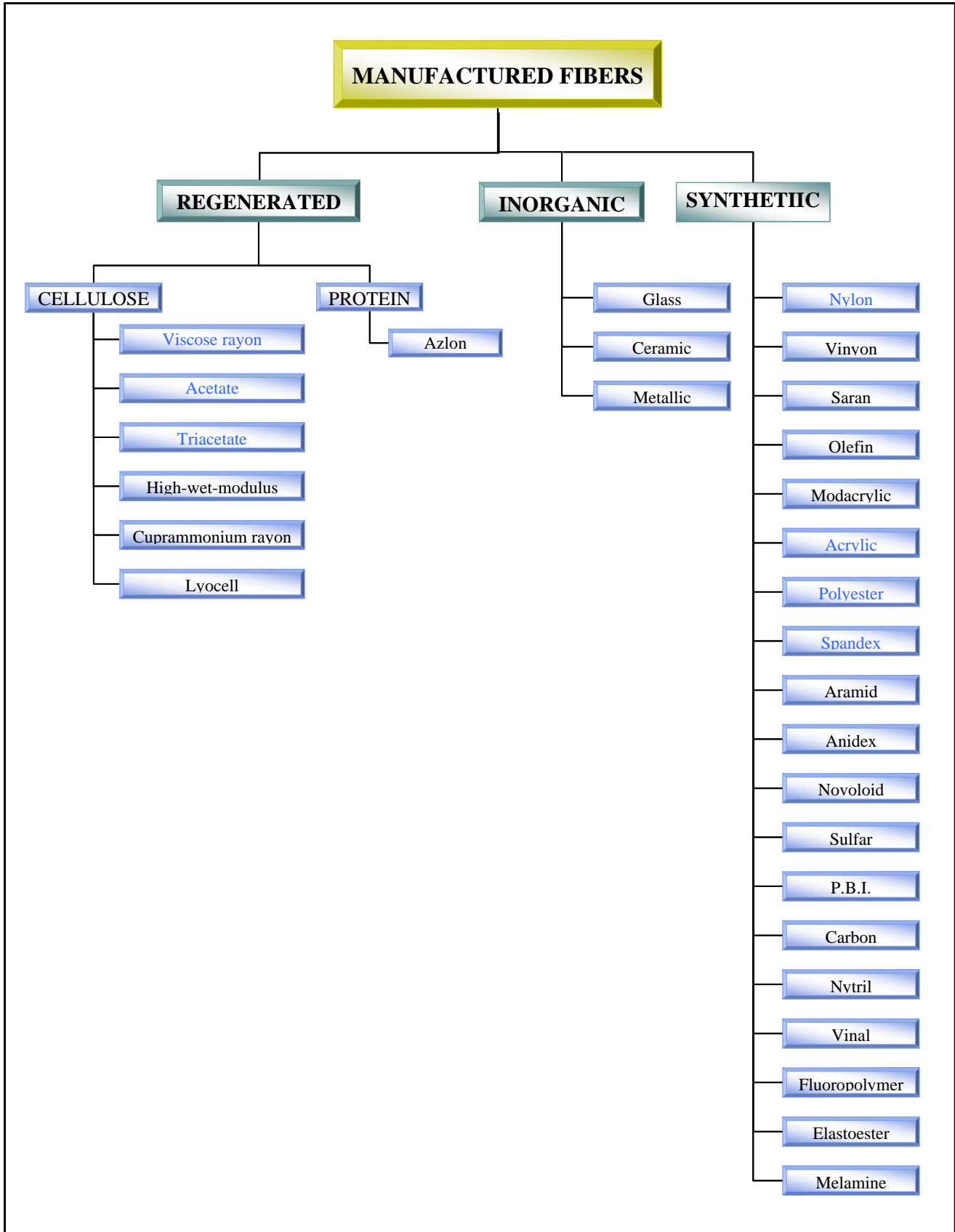
Fibers are divided into two major parts which are as follows:

1. Natural fibers
2. Manufactured fibers

Fiber's classification



Fiber's classification



	cross-section	molecular structure	refractive index	color	shape	luster	crimp	length (cm)	diameter & fines	specific gravity	breaking tenacity (g/d) strength		modulus (g/d)	elongation at break
			n_a, n_r								standard	wet		
COTTON			1.578 1.532	white to tan	U or kidney bean shape	low (due to the natural twist, see longitudinal view).	low	2.0-6.35 (0.7-2.5)*	16-20 microns	1.54	3.0-5.0	3.3-6.4	60 (high modulus)	low (8% to its original length)
EGYPTIAN/SEA ISLAND								3.81-6.35 (1.5-2.5)*						
AMERICAN UPLAND								2.1-3.5 (0.8-1.4)*						
SOUTH ASIA								2.0-3.1 (0.78-1.25)*						
WOOL			1.553 1.542	varys white, light beige, yellow, brown, black	elliptical (almost round)	low (b/c of scaly, rough surface)	high. natural 3-D Crimp	2.5-36 (1-14)*	8-70 microns	1.32	1.0-1.7	0.8-1.6	25 (low)	high. 30-40
MERINO AUSTRALIAN								2.5-7.5 (1-3)*	20 μm					
CORRIEDALE (French Rambouillet)								7.5-9.0 (3-3.6)*	20-30 μm					
ENGLISH LEICESTER								10-36 (4-14)*	25-40 μm					
SPANDEX			---	usually bright. Any	usually round. Any	high	low	any	fine	1.20-1.21	0.6-0.9	0.6-0.9	v.low. (easily stretchable)	v.high. (500-600)%
POLYESTER staple and filament			1.720 1.540	bright & white	any. Dependant on the manufacturing process	high	low	any	any	1.38	filament. 7.0 2.5-5.0	4.0-7.0 staple. 4.0 2.5-5.0	high. (b/c of aromatic rings, which stiffed the fiber)	filament. moderate staple. high
ACETATE staple and filament			1.474 1.479	bright & white	irregular, multiobed	high. De-luster by titanium oxide	low	any	any	1.32	1.2-1.5	0.8-1.2	low. Same as rayon	low (max. 5% to its original length)
TRI-ACETATE				same	same	same	same	same	same	1.3	1.1-1.3	0.8-1.0	same	better
VISCOSE RAYON staple and filament			1.539 1.519	usually white in color	irregular circle with serrated edges	high. De-luster by titanium oxide	medium	any	any	1.50-1.53	0.73-2.6	0.7-1.8	low	high
NYLON (NYLON 6) staple & filament			1.528 1.519	bright & white	any. Dependant on the manufacturing process	high. De-luster by titanium oxide	smooth	any	any	1.14	filament. 9.5 2.5-3.0	5.0-8.0 staple. 6.0 2.0-2.5	low. But strong	high
NYLON (NYLON 66) staple & filament			same	bright & white	any. may be trilobal or multiobal	same	same	any	any	1.14	filament. 6.0 3.5-7.2	2.6-5.4 staple. 3.0 3.2-6.5	same	higher
ACRYLIC staple and filament			1.5 1.5	bright & white	any. Dependant on the manufacturing process	high. De-luster by titanium oxide	made crimped to blend with wool	any. Dependant	any	1.14-1.19	2.0-3.5	1.8-3.3	moderate to low. Easy to blend	good (25% to its original length)
FLAX			1.596 1.528	light cream to dark tan	irregular. Central canal. Smaller lumen than cotton	moderate. (b/c more smooth than cotton). Beeted to increase luster	moderate	12.7-76.2 (5-30)*	15 to 18 microns	1.54. (same as cotton)	5.5-6.5 (stronger than cotton b/c more crystallize & its polymers more oriented)	6.0-7.2	high	low. (lower than cotton b/c fibrils lacks)

elastic recovery	flexibility	resiliency	moisture regain (%)	electrical conductivity	heat conductivity	burning characteristics	Tg (°C)	Tm (°C)	effect of acids	effect of bases	oxidation	swelling of fibers in water (cross-sectional area %)	dimensional stability	abrasion resistance	resistance to micro-organism	resistance to insects
low	good. Bends	poor (H bonds b/w chains breaks and reformed in new position.	7-11 15-18 (mercerized cotton)	good (enough to evade static charge).	high	usually turns yellowish or scorch. Burns, does not melt. Grey ash	230	none	attacked by hot dilute or cold concentrated acid solutions	excellent resistance to alkalis.	chlorine bleaches destroys.	42 46 (mercerized cotton)	shrinks when wet.	low	mildew forms, especially fabric store in damp, warmth, dark condition	not attacked by moths, beetles, attacked by silver fish especially when heavily starched
low. (e.g. elbows/knees stretched)	moderate	excellent (almost wrinkle resistant, naturally)	15-18 (naturally hydrophobic, b/c of scaly structure)	poor. (static charge builds only in very dry weather)	low	burns slowly, self extinguisher when flame removes.	---	none	excellent resistance to acids, except in very strong concentrations	attacked by dilute or concentrated base solutions	chlorine bleaches destroys. Should be washed with mild detergents (alkali free).	25	usually shows progressive shrinkage	low	mildew not forms, unless fabric store in damp condition	attacked by pests, moths, beetles, b/c cross linking in wool attracts them
excellent	excellent	excellent	0.75-1.3	poor. (but compensate when blended with other fiber)	difficult to assess. (b/c blends with other fibers)	in flame, burns with melting	165	230-270	good. Acid fumes may cause yellowing	fair	good. Strong Cl compounds degrade & yellowed	---	good, when heat-set	good	excellent	excellent
good. (from low stretch)	moderate to low.	excellent	0.4	low	low	in flame, burns with melting. When flame removes self-extinguishes	125	285	moderate to good	adversely affected by strong bases	no harmful effects	---	good, when heat-set	good	excellent mildew not forms, but bacteria may grows in soiled & wicked fiber	excellent. not attacked by pests, moths, beetles
low	moderate	moderate	6	moderate	moderate	in flame, burns relatively slow with melting. Residue, beads at burned area	90. lower than PET	258	resist weak acids. attacked by strong acids	strong base converts to cellulose. Resist weak bases	oxygen bleach, no harmful effect	---	shrinks on laundering. Relaxation shrinkage	poor. Non-durable	mildew forms, especially fabric store in soiled condition	not attacked by moths, beetles, attacked by silver fish especially when heavily starched
moderate	same	better. (wrinkle resistant)	4	moderate to high	moderate	in flame, burns relatively slow with melting.	100	299	same	same	same	---	better	same	more resist to mildew	same
low	moderate	poor. (wrinkle badly)	11-15	high	high	Burns, does not melt. Residual grey ash	---	none	poor. attacked by dilute or concentrated acids	poor. attacked by dilute or concentrated bases	chlorine bleaches destroys.	50-115	high shrinkage	poor. Non-durable	attacked by mildew & rot-producing bacteria	attacked by silver fish
high. Better than nylon 66	good. Widely use in stretchable garments.	excellent. Wrinkle resistant	4.5	low. (builds static charge)	low	in flame, burns with melting. When flame removes self-extinguishes	205-210	240-260	resist weak acids. attacked by strong acids	attacked by hot concentrated bases	no harmful effects to dry-cleaning solvents	1.6-3.2	good. Shrinks at high temp.	excellent	not attacked by mildew & rot-producing bacteria	excellent. not attacked by pests, moths, beetles
high	same	same	4.0-4.5	low	low	in flame, burns with melting. When flame removes self-extinguishes	220-230	260-280	same	same	same	same	same	more better.	same	same
low. Varies.	moderate to low.	good. Crimped excellent	1.3-2.5	low	low	in flame, burns with melting. Continues after flame removed. Residue, black beads at burned area	90	232-258. not typical	good. except nitric acid, (b/c dissolve in it)	good to weak bases. Degrade by NaOH(conc)	no harmful effects from dry-cleaning solvents	---	good, when heat-set	low. (lower than other synthetics)	excellent. Mildew not harms	excellent. Not attacked by moths, beetles
low. (lower than cotton b/c fibrils lacks)	low. Brittle, stiff. Resist bending	low. (lower than cotton b/c fibrils lacks). Wrinkles badly	11-12 (b/c more wicker than cotton)	high	high. Better than cotton	in flame, burns does not melt. Resists more than cotton	---	---	attacked by hot dilute or cold concentrated acid solutions	excellent resistance to alkalis.	no harmful effects from organic solvents used in dry-cleaning	---	shrinks when wet. Shows relaxation shrinkage	low. (b/c stiff)	mildew forms, especially fabric store in damp, warmth condition	not attacked by moths, beetles, silver fish if unstarched

properties tabel

fibers

prolonged exposure to sun-light	dye ability	trade marks ND MANUFACTURE RS
loss of strength. (weakens, discoloration) Aging	with almost all types of except acid and disperse dyes	USA MEXICO BRAZIL RUSSIA FEDERATION INDIA CHINA PAKISTAN EGYPT
loss of strength. (Detroit's, discoloration) Aging		
resist degradation, but may discolor.		
resists. Very slow. Aging	disperse and azoic dyes formed in situ.	AIRLAN
loss of strength. (Detroit's, discoloration) Aging		
loss of strength. Resist aging		
loss of strength. Discoloration . Faster than cotton. Slow aging.		
degrades. Resist aging if keep away from sun-light		
degrades. Resist aging		
excellent. No loss of strength Very slow aging		
loss of strength. Aging. Better than cotton		

ORGANIC COTTON

1. INTRODUCTION

The conventional cultivation of cotton leads to massive environmental and health problems. Around the world, more **toxic insecticides are used on cotton than on any other crop**. A sustainable alternative is the certified organic cultivation of the "white gold". The farmers have only a chance to convert their production into a controlled organic cultivation of cotton if there is sufficient demand for organic cotton. Although laborious in the beginning, the conversion is worthwhile.

Cotton provides about *half of all global fibre requirements*. In addition to the six big producers (US, China, India, Pakistan, Uzbekistan, Turkey) cotton is produced in over 60 countries. It is an important source of income for millions of small farmers and contributes significantly to the national economy of many developing countries (*in my view it is the back bone of world's economy & there is no doubt that it contributes more than 80% GDP to our country (PAKISTAN)*).

The size of the global cotton-growing area has not changed much since the 1930s but average yields have increased threefold through the intensive use of synthetic chemicals, irrigation and the use of higher-yielding plant varieties. **Conventional cotton is very prone to insect attacks** and large quantities of the most toxic insecticides are used in its production. Cotton accounts for about **25%** of the **global insecticides market** by value and about **10%** of the **pesticides market**.

DRAW BACK WITH CONVENTIONAL COTTON PRODUCTION

The intensive use of toxic insecticides and other toxic chemicals in cotton has caused serious health and environmental impacts, which includes

- farmer and farmworker poisonings,
- water contamination,
- micro-organism disorderment,
- and many other living things defacements such as birds and marine organism.

ORGANIC COTTON CAN BRING HEALTH AND ENVIRONMENTAL IMPROVEMENTS

So serious are the negative impacts of chemical-intensive agricultural production, that momentum for change has grown considerably in recent years. The trend toward more environmentally friendly production methods is supported by a variety of interests

including farmers wanting to escape the chemical treadmill, enlightened companies under pressure of increased environmental regulation and competition, and informed consumers calling for greater social and environmental accountability. The burgeoning consumer interest in organic food production has now expanded into other areas of organic production including cotton fibre produced in organic systems.

Organic cotton is produced in organic agricultural systems that produce food and fibre according to clearly established standards. Organic agriculture prohibits the use of toxic and persistent chemical pesticides and fertilizers, as well as genetically modified organisms. It seeks to build biologically diverse agricultural systems, replenish and maintain soil fertility, and promote a healthy environment

THE EXPANDING ORGANIC COTTON MARKET

Organic cotton is now grown in 18 countries but still represents only a tiny fraction of the total global cotton production - less than 0.1%. The biggest producers in 2001 were Turkey, the United States, India and Peru. Smaller experimental projects are also expanding in size and numbers.

The textile sector in general is facing price competition as never before. Many companies are seeking comparative advantage in the quality of their products and in 'greening' themselves - and organic cotton is a way of achieving these objectives. The challenge is to communicate the health and environmental benefits of organic cotton production and processing to consumers so that their interest will be expressed in their buying preferences.

SPANDEX

1. INTRODUCTION

As the premiere synthetic stretch fabric, Lycra spandex is the trade name for DuPont's version of the long-chain polymeric fiber. Invented at DuPont by American scientist Joseph C. Shivers in 1959, spandex sprang on the market as a replacement for rubber

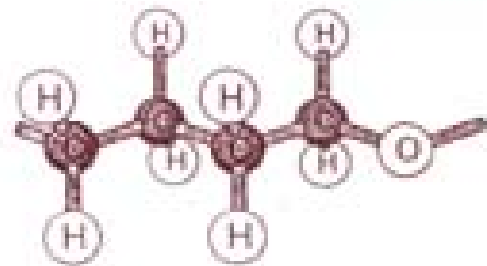
The FTC defines spandex fiber as *"a manufactured fiber in which the fiber-forming substance is a long-chain synthetic polymer comprised of at least 85% of segmented polyurethane."* It is an elastomer, which means it can be stretched to a certain degree and it recoils when released. These



fibers are superior to rubber because they are stronger, lighter, and more versatile. In fact, spandex fibers can be stretched to almost 600% of their length.

2. SPANDEX CHEMISTRY:

This unique elastic property of the spandex fibers is a direct result of the material's chemical composition. The fibers are made up of numerous polymer strands. These strands are composed of two types of segments: long, amorphous segments and short, rigid segments. In their natural state, the amorphous segments have a random molecular structure. They intermingle and make the fibers soft. Some of the rigid portions of the polymers bond with each other and give the fiber structure.



When a force is applied to stretch the fibers, the bonds between the rigid sections are broken, and the amorphous segments straighten out. This makes the amorphous segments longer, thereby increasing the length of the fiber. When the fiber is stretched to its maximum length, the rigid segments again bond with each other. The amorphous segments remain in an elongated state. This makes the fiber stiffer and stronger. After the force is removed, the amorphous segments recoil and the fiber returns to its relaxed state. By using the elastic properties of spandex fibers, scientists can create fabrics that have desirable stretching and strength characteristics.

3. CHEMICAL PROPERTIES

Basic characteristics

- Chemical composition	segmented polyurethane urea
- Specific gravity	1.05 as a clear polymer, 1.20 as pigmented polymer
- Moisture regains	1.5%
- Softening point	390F/190C
- Melting point	437F/250C
- Finish composition	silicone oil with a metal stearate

Thermal performance

- Dry heat setting temperature/efficiency	188C-204C/370F-400F/60%-100%
- Aqueous heat setting	104C-110C/220F-230F/80%-100%
- Boiling water	fiber retracts to original denier/modulus
- Molding temperature	196C-207C/385F-405F

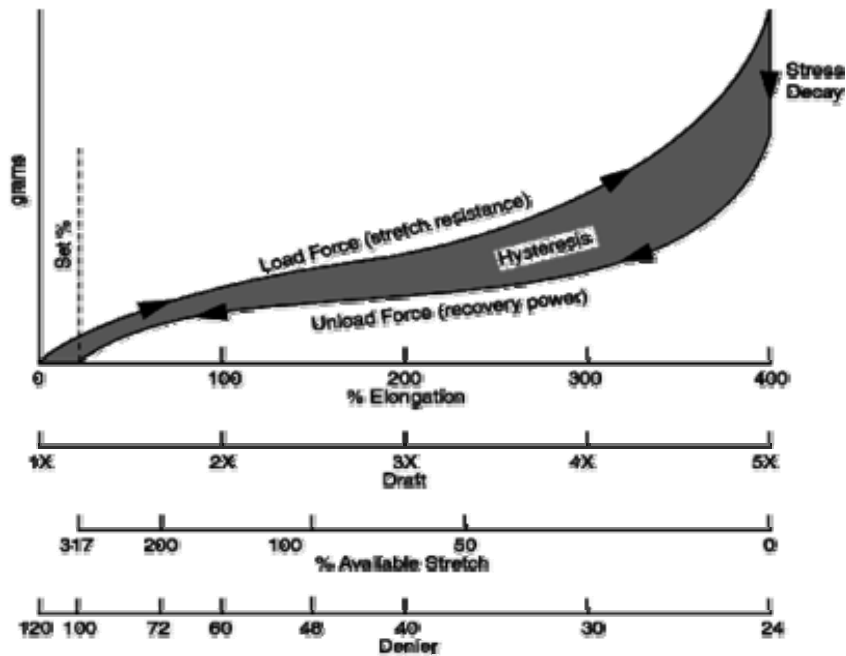
Chemical resistance

+ Good	aliphatic solvents water solutions of acids above pH 3.0 and bases below pH 11.0 per-oxygen bleaches saturated oils such as mineral oil non-phenolic dye carriers
- Poor	aromatic solvents acids at below pH 3.0 and bases above pH 11.0 chemicals containing active chlorine (sodium hypochlorite) unsaturated oils such as linseed, body oils, animal fats heavy metal salts (e.g. aluminum, chromium, zinc)

Environmental performance

- Spandex contains stabilizers that provide resistance to discoloration and eventual degradation by ultraviolet light, sunlight, and atmospheric pollutants (oxides of carbon, nitrogen or sulfur).
- Spandex, as polyurethane, burns when ignited by an external flame. It continues burning until oxygen is no longer available.

4. STRESS - STRAIN CHARACTERISTICS



5. PHYSICAL PROPERTIES

DENIER / DECITEX	20/22	20/22	30/33	30/33	40/44	40/44	70/78	70/78	140/156
LUSTER	Clear	Semi-Dull	Clear	Semi-Dull	Clear	Semi-Dull	Clear	Semi-Dull	Clear
FILAMENT	2 - 3	2 - 3	3	3	4	3 - 4	5	5	10 - 12
ELONGATION %	490 - 500	460 - 515	490 - 500	480 - 515	490 - 540	450 - 540	540 - 570	505 - 550	500 - 550
TENACITY cN	25 - 30	23 - 26	35 - 37	31 - 33	42 - 47	41 - 47	72 - 80	65 - 70	130 - 138
LOAD POWER TP 200, cN	3.7 - 4.2	4.0 - 4.2	5.5 - 6.0	5.5 - 6.0	7.0 - 7.4	6.3 - 8.0	8.8 - 10	8.9 - 9.2	15 - 17
UNLOAD POWER TM 200, cN	0.55 - 0.60	0.53 - .060	0.80 - 0.85	0.75 - 0.80	1.0 - 1.1	1.0 - 1.1	1.7 - 1.8	1.7 - 1.8	3.4 - 3.5
STRETCH ON TUBE %	18.5 - 19.6	16.6 - 17.7	12.5 - 14.7	10.5 - 14.7	11.5 - 13.0	9.0 - 13.5	11 - 12	11 - 12	5 - 9

6. SPANDEX PRODUCERS AND THEIR TRADEMARKS

Manufacturer	Trademark
Bayer	Dorlastan™
DuPont	Lycra®

7. ADVANTAGES:

- Incomparable fit and comfort.
- Freedom of movement.
- Crease recovery.
- Stretch ability of up to 600%.
- Enduring shape retention.
- Lightweight.
- Not, damaged by perspiration, body oils, and most chemicals; strong.
- Can withstand wear.
- No static or pilling problems
- Abrasion resistant

8. DISADVANTAGES:

- Chlorine type bleaches will turn white garments yellow
- Damaged by heat.

9. USES: CLOTHING

Girdles, panty hose, support stockings, socks, swimwear, belts, suspenders.

POLYESTER

1. INTRODUCTION

The first viable polyester fiber (Terylene) was developed by English chemists, [J. R. Whinfield](#), and [J.T. Dickson](#), in 1941. It was first sold in the U.S. as [Dacron®](#) in 1951 and is now the most widely used fiber, even surpassing cotton.

Polyester is strong and resistant to shrinking, stretching, creasing, insects and most chemicals. The specific properties, however, vary significantly depending on the type of polyester fiber. Many are modified to increase flame, crush or oil resistance.

The fiber cross section is often made into different shapes to change the feel and appearance of the fibers.

2. WHAT IS POLYESTER?

The FTC defines [polyester fibers](#) as “a manufactured fiber, in which the fiber-forming substance is any long- chain synthetic polymer composed of at least 85% by weight of an ester(HO—R—OH of a substituted [aromatic](#) carboxylic acid, including but not restricted to substituted terephthalic units (p-HOOC-C₆H₄COOH)”.

3. POLYESTER CHEMISTRY:

In polyester fibers the long chain of PET are arranged in amorphous and crystalline regions, the extent of which is dependent on the amount of drawing during manufacture. Polyesters do not crystallize as easily as nylon because of its aromatic rings. In addition, there are no polar groups in the polyester polymers to form hydrogen bonds.

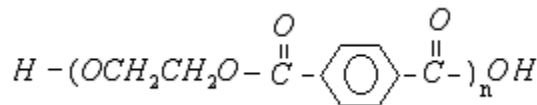
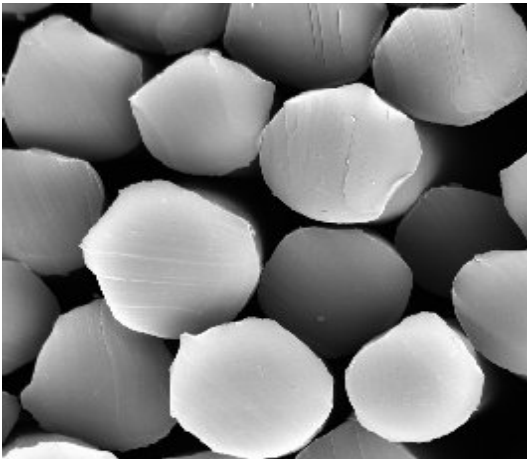


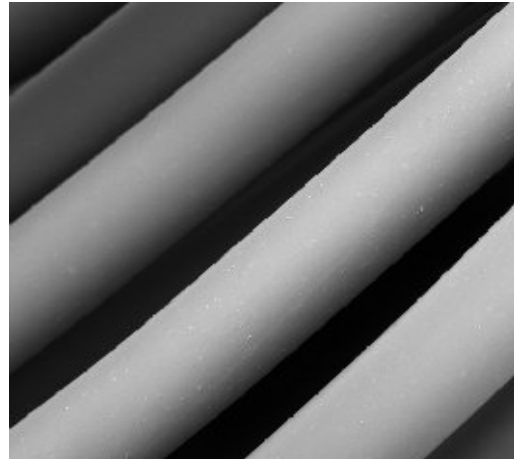
Fig. 1

Many of the polyester properties dependent upon of its [AROMATIC RING](#) and non presence of [POLAR GROUP](#) such as

Strength
Modulus
Moisture regain/Absorbency
Resiliency



Cross-sectional view Fig. 2a



longitudinal view Fig. 2b

Examples of cross section modified:

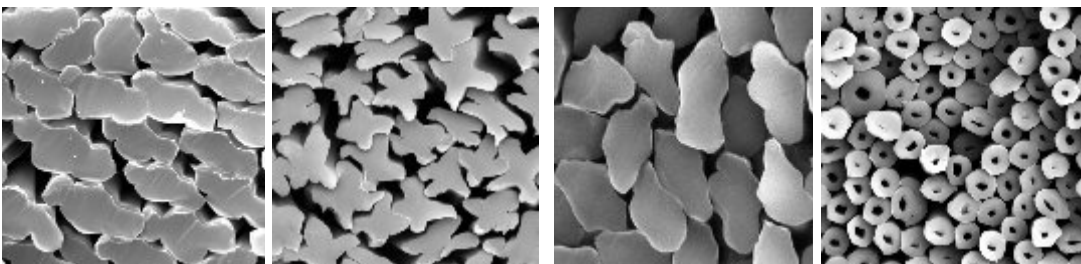
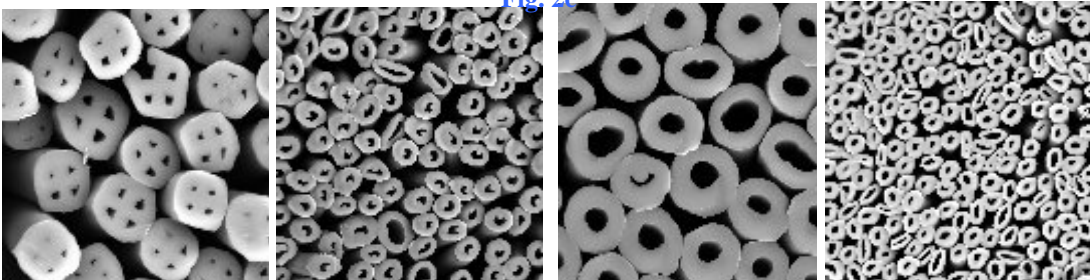


Fig. 2c



Polyester is primarily used in clothing and home furnishings. It is often blended with wool, cotton, rayon, or flax.

4. POLYMER FORMATION

Polyethylene Terephthalate (PET) is a condensation polymer and is industrially produced by either terephthalic acid or dimethyl terephthalate with ethylene glycol.

- (a) Terephthalic Acid (PTA), produced directly from p-xylene with bromide-controlled oxidation.
- (b) Di-methyl Terephthalate (DMT), made in the early stages by esterification of terephthalic acid. However, a different process involving two oxidation and esterification stages now accounts for most DMT.

- (c) Ethylene Glycol (EG) initially generated as an intermediate product by oxidation of ethylene. Further ethylene glycol is obtained by reaction of ethylene oxide with water.

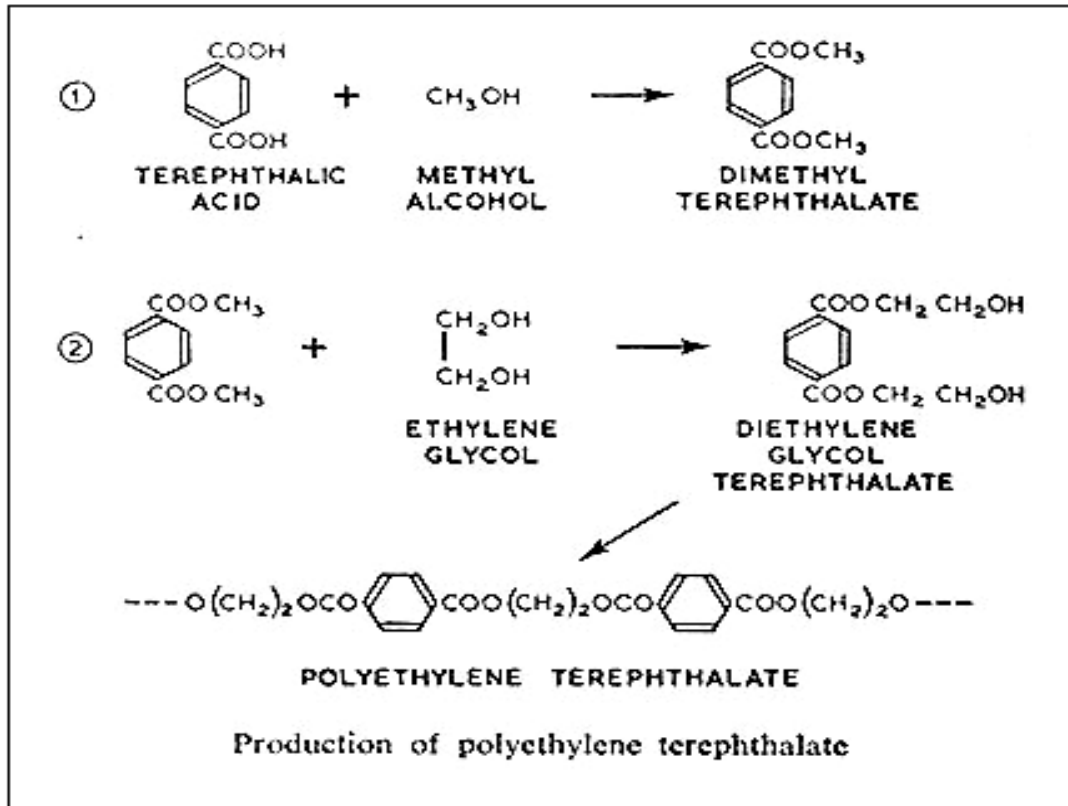


Fig. 3: Production of polyethylene terephthalate

5. FIBER FORMATION

The sequences for production of PET fibers and yarns depend on the different ways of polymerization (continuous, batch-wise, and solid-phase) and spinning (low or high windup speed) processes.

5.1. SPINNING PROCESS

The degree of polymerization of PET is controlled, depending on its end-uses. PET for industrial fibers has a higher degree of polymerization, higher molecular weight and higher viscosity. The normal molecular weight range lies between 15,000 and 20,000. With the normal extrusion temperature (280-290°C), it has a low shear viscosity is 1000-3000 poise. Low molecular weight PET is spun at 265°C, whereas ultrahigh molecular weight PET is spun at 300°C or above. The degree of orientation is generally proportional to the wind-up speeds in the spinning process. Theoretically, the maximum orientation along with increase in productivity is obtained at a wind-up speed of 10,000m/min. Although due to a voided skin, adverse effects may appear at wind-up speeds above 7000m/min.

5.2. DRAWING PROCESS

To produce uniform PET, the drawing process is carried out at temperature above the glass transition temperature (80-90°C). Since the drawing process gives additional orientation to products, the draw ratios (3:1-6:1) vary according to the final end-uses. For higher tenacities, the higher draw ratios are

required. In addition to orientation, crystallinity may be developed during the drawing at the temperature range of 140-220°C.

6. POLYESTER FIBER FLOW CHART

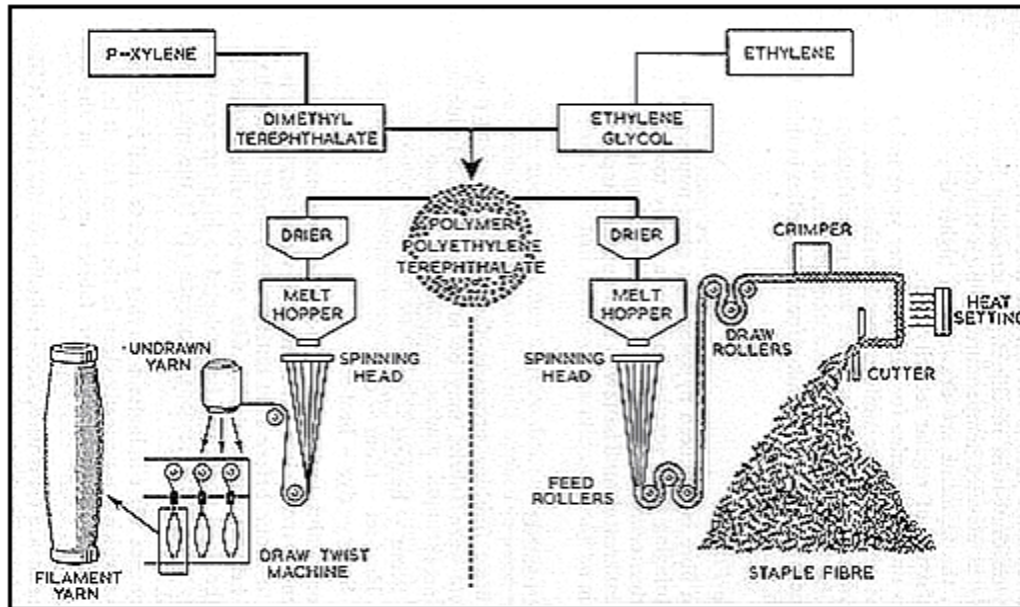


Fig. 2: Polyester fiber flow chart

7. THE LATEST POLYESTER PRODUCTION (RESEARCH METHOD)

Dr Boncella and Dr Wagner at The University of Florida are two scientists involved with the study to reveal a method for [manufacturing polyester from two inexpensive gases: carbon monoxide and ethylene oxide](#). The polyester most commonly used today is referred to as PET or polyethylene terephthalate. Scientists have been successful in producing low molecular weight polyester using carbon monoxide and ethylene oxide, but researchers still lack the catalyst - a substance that speeds up chemical reactions - needed to make the reaction work more efficiently. They are looking for the chemical compound that will take molecules of low DP and create larger ones. Although they have had success in the research so far, they have yet to produce commercially useable polyester from the inexpensive gases. If this is successful, then these research findings can be used to replace the current polyester product, getting the same performance for a lower price. Finally, we all know that research requires patience and a long-term effort.

8. CHARACTERISTICS OF POLYESTER

- Strong
- Resistant to stretching and shrinking
- Resistant to most chemicals
- Quick drying
- Crisp and resilient
- Wrinkle resistant
- Mildew resistant
- Abrasion resistant
- Retains heat-set pleats and crease

- Easily washed

9. RELATIONSHIP BETWEEN STRUCTURE, PROPERTIES & PROCESSING PARAMETERS OF PET FIBERS

Properties of polyester fibers are strongly affected by fiber structure. The fiber structure, which has a strong influence on the applicability of the fiber, depends heavily on the process parameters of fiber formation such as spinning speed (threadlike stress), hot drawing (stretching), stress relaxation and heat setting (stabilization) speed.

As the stress in the spinning threadlike is increased by higher wind-up speed, the PET molecules are extended, resulting in better as-spun uniformity, lower elongation and higher strength, greater orientation and high crystallinity. Hot drawing accomplishes the same effect and allows even higher degrees of orientation and crystallinity. Relaxation is the releasing of strains and stresses of the extended molecules, which results in reduced shrinkage in drawn fibers. Heat stabilization is the treatment to "set" the molecular structure, enabling the fibers to resist further dimensional changes. Final fiber structure depends considerably on the temperature, rate of stretching; draw ratio (degree of stretch), relaxation ratio and heat setting condition. The crystalline and non-crystalline orientation and the percentage of crystallinity can be adjusted significantly in response to these process parameters.

10. MECHANICAL PROPERTIES

As the degree of fiber stretch is increased (yielding higher crystallinity and molecular orientation), so are properties such as tensile strength and initial Young's modulus. At the same time, ultimate extensibility, i.e., elongation is usually reduced. An increase of molecular weight further increases the tensile properties, modulus, and elongation. Typical physical and mechanical properties of PET fibers are given in Table 1.

Table 1: Properties of Polyester Fibers

Property	Filament yarn		Staple and tow	
	Regular tenacity ^a	High tenacity ^b	Regular tenacity ^c	High tenacity ^d
Breaking elongation	24-50	10-20	35-60	17-40
Elastic recovery at 5% elongation, %	88-93	90	75-85	75-85
Specific gravity	1.38	1.39	1.38	1.38
Moisture regain, %	0.4	0.4	0.4	0.4
Melting temperature, °C	258-263	258-263	258-263	258-263

^aTextile-filament yarns for woven and knit fabrics.

^bTire cord and high strength, high modulus industrial yarns.

^cRegular staple for 100% polyester fabrics, carpet yarn, fiberfill, and blends with cellulosic blends or wool.

^dHigh strength, high modulus staple for industrial applications, sewing thread, and cellulosic blends.

Shrinkage varies with the mode of treatment. If relaxation of stress and strain in the oriented fiber is allowed to occur through shrinkage during fiber manufacture, then shrinkage at the textile processing stage is reduced. Polyester yarns held to a fixed length under tension during heat treatment are less affected with change in modulus, and reduced shrinkage values can still be obtained. This is very important in fiber

stabilization. PET shows nonlinear and time-dependent elastic behavior. It recovers well from stretch, compression, bending, and shear.

The formation of small fuzz balls of entangled fibers (pills) on the fabric surface can be a serious problem. Fuzz formation may be affected by friction, stiffness, breaking strength and abrasion resistance. Shape, fineness, stiffness, recovery, friction and elongation influence entanglement of fibers. Another property, important especially to the apparel industry, is crimp stability or crimp compression. Generally, the tighter the packing of molecular chains, the stiffer and more mechanically resistant the fiber is.

11. CHEMICAL PROPERTIES

Polyester fibers have good **resistance** to weak **mineral acids**, even at boiling temperature, and to most strong acids at room temperature, but are dissolved with partial decomposition by concentrated sulfuric acid. Hydrolysis is highly dependent on temperature. Thus conventional PET fibers soaked in water at 70°C for several weeks do not show a measurable loss in strength, but after one week at 100°C, the strength is reduced by approximately 20%.

Polyesters are highly **sensitive to bases** such as sodium hydroxide and methylamine, which serve as catalysts in the hydrolysis reaction. Methylamine penetrates the structure initially through non-crystalline regions, causing the degradation of the ester linkages and, thereby, loss in physical properties. This susceptibility to alkaline attack is sometimes used to modify the fabric aesthetics during the finishing process. The porous structures produced on the fiber surface by this technique contribute to higher wet-ability and better wear properties.

Polyester displays excellent resistance to oxidizing agents, such as conventional textile bleaches, and is resistant to cleaning solvents and surfactants. Also, PET is insoluble in most solvents except for some polyhalogenated acetic acids and phenols.

PET is both hydrophobic and oleophilic. The hydrophobic nature imparts water repellency and rapid drying. But because of the oleophilic property, removal of oil stains is difficult. Under normal conditions, polyester fibers have a low **moisture regain** of around **0.4%**, which contributes to **good electrical insulating properties** even at high temperatures. The tensile properties of the wet fiber are similar to those of dry fiber. The low moisture content, however, can lead to static problems that affect fabric processing and soiling.

12. OPTICAL PROPERTIES

PET has optical characteristics of many thermoplastics, providing bright, shiny effects desirable for some end uses, such as silk-like apparel. Recently developed polyester micro-fiber with a linear density of less than 1.0 denier per filament (dpf), achieves the feel and luster of natural silk.

13. DYEING PROPERTIES

Because of its rigid structure, well-developed crystallinity and lack of reactive dyesites, PET absorbs very little dye in conventional dye systems. This is particularly true for the highly crystalline (highly drawn), high tenacity, high modulus fibers. Polyester fibers are therefore dyed almost exclusively with disperse dyes.

A considerable amount of research work has been done to improve the dyeability of PET fibers. Polymerizing a third monomer, such as dimethyl ester, has successfully produced a cationic dyeable polyester fiber into the macro-molecular chain. This third monomer

has introduced functional groups as the sites to which the cationic dyes can be attached. The third monomer also contributes to disturbing the regularity of PET polymer chains, so as to make the structure of cationic dyeable polyester less compact than that of normal PET fibers. The disturbed structure is good for the penetration of dyes into the fiber. The disadvantage of adding a third monomer is the decrease of the tensile strength.

A new dyeing process for polyester fiber at low temperature (40°C and below) has been reported. This method employs a disperse dye in a micro-emulsion of a small proportion of alkyl halogen and phosphoglyceride. The main advantage of this method is low temperature processing, but there remains the environmental problem that is produced by using toxic carriers.

Another approach has been introduced by Saus et al. The textile industry uses large amounts of water in dyeing processes emitting organic compounds into the environment. Due to this problem a dyeing process for polyester fiber was developed, in which supercritical CO₂ is used as a transfer medium [21]. This gives an option avoiding water discharge. It is low in cost, non-toxic, non-flammable and recyclable. When dyed in an aqueous medium, reduction clearing is to be carried out to stabilize color intensity, which produces more wastewater. Reduction clearing is not carried out following supercritical dyeing. Other advantages are better control of the dyeing process and better quality of application achieved.

14. OTHER PROPERTIES

Polyester fibers display good resistance to sunlight but long-term degradation appears to be initiated by ultraviolet radiation. However, if protected from daylight by glass, PET fiber gives excellent performance, when enhanced by an UV stabilizer, in curtains and automobile interiors. Although PET is flammable, the fabric usually melts and drops away instead of spreading the flame. PET fiber will burn, however, in blends with cotton, which supports combustion

15. APPLICATIONS

DuPont Company produced the first U.S. commercial polyester fiber in 1953. Since polyester fiber has a lot of special characteristics, most of them are used in the following three major areas:

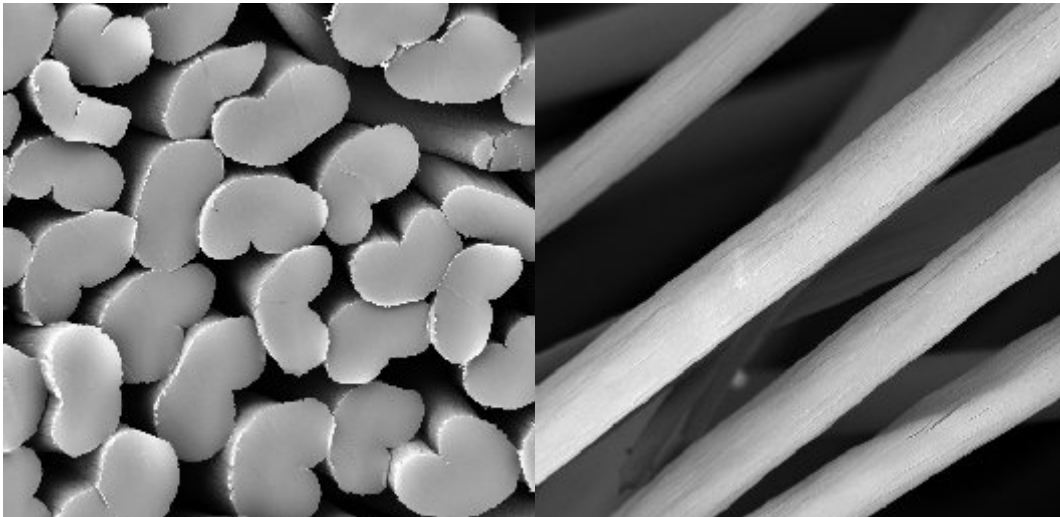
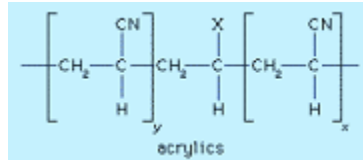
- Apparel: Every form of clothing
- Home Furnishings: Carpets, curtains, draperies, sheets and pillowcases, wall coverings, and upholstery
- Other Uses: Hoses, power belting, ropes and nets, thread, tire cord, auto upholstery, sails, floppy disk liners, and fiberfill for various products including pillows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

- In Fiberfill applications polyester fibers are used inside seat cushions, back pillows, mattresses and waterbeds, decorative and throw pillows, outdoors furniture and even hand-stuffed custom upholstery.

ACRYLIC

1. INTRODUCTION

A manufactured fiber in which the fiber forming substance is any long-chain synthetic polymer composed of at least 85% by weight of acrylonitrile units i.e.



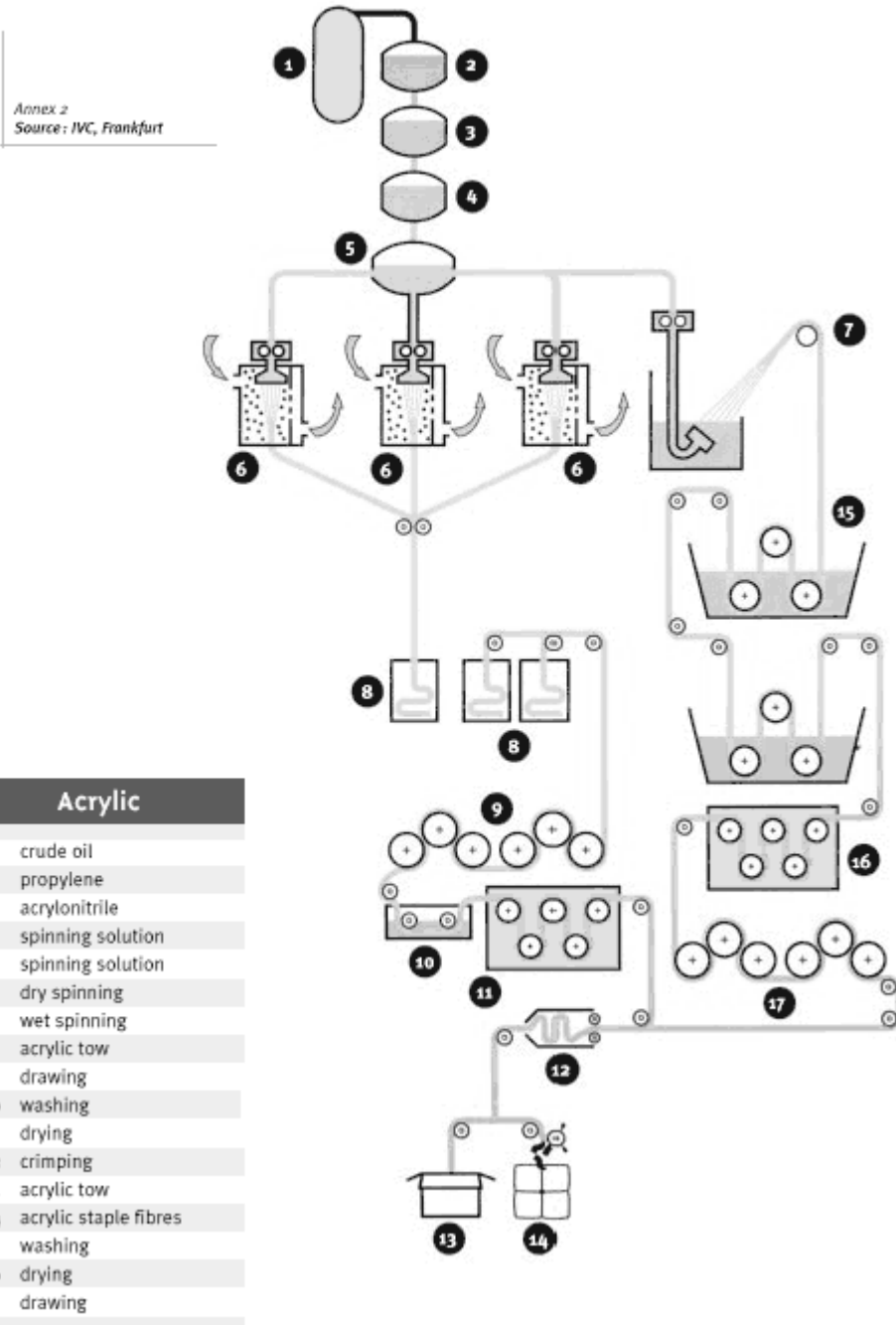
Acrylic is a soft drape-able fabric, which provides warmth without being heavy. It takes color beautifully. Although acrylic has traditionally been a fall/winter fabric, with a wonderful resemblance to wool, acrylic has recently been used in developing some lightweight circular knits and blends which lend themselves to trans-seasonal dressing as well. Acrylic is comfortable to wear. It feels like wool. Yet, it is easy care and is machine washable or dry cleanable.

Acrylic is a synthetic fiber often used as a substitute for wool. It is a strong, warm fabric that drapes well. It is used to make sweaters, tracksuits and linings for boots, gloves, jackets and slippers. It is also a favorite fiber for knitting sweaters, baby clothes, hats and all the garments knitters love to make.

Common trade names for Acrylic are Acrilan and Orlon. Orlon is the trademark of the Du Pont Company, which started producing Orlon for use by the Services during World War II. It was launched for civilian use after the war, in 1947. It began to be used in great volume in the 1950's

ACRYLIC FIBER PRODUCTION

Acrylic fibers are produced from acrylonitrile, a petrochemical. The acrylonitrile is usually combined with small amounts of other chemicals to improve the ability of the resulting fiber to absorb dyes. Some acrylic fibers are dry spun and others are wet spun. Acrylic fibers are modified to give special properties best suited for particular end-uses. They are unique among synthetic fibers because they have an uneven surface, even when extruded from a round-hole spinneret.



SOME MAJOR USES

- **Apparel:** Sweaters, socks, fleece wear, circular knit apparel, sportswear and children's wear
- **Home Furnishings:** Blankets, upholstery, pile; luggage, awnings, outdoor furniture
- **Other Uses:** Craft yarns, sail cover cloth, wipe cloths
- **Industrial Uses:** Asbestos replacement; concrete and stucco reinforcement

FIBER CHARACTERISTICS

- Outstanding wick-ability & quick drying to move moisture from body surface.
- Flexible aesthetics for wool-like, cotton-like, or blended appearance.
- Easily washed, retains shape.
- Resistant to moths, oil, and chemicals.
- Dye-able to bright shades with excellent fastness.
- Superior resistance to sunlight degradation.
- Sensitive to heat
- Static and pilling can be a problem
- Resilient; retains shape; resists shrinkage, & wrinkles

ACRYLIC PRODUCERS AND THEIR TRADEMARK

Manufacturer	Trademark
Biofresh® anti-microbial fiber	Sterling Fibers
Cresloft®	Sterling Fibers
Duraspun®	Solutia
MicroSupreme® (warm)	Sterling fibers
MicroSupreme® (cold)	Sterling fibers
Piltrol®, low pill fiber	Solutia
Weatherbloc®	Solutia
Dralon™	Bayer Inc.

RAYON

1. INTRODUCTION

Rayon is the oldest commercial manmade fiber. The U.S. Trade Commission defines rayon as "*manmade textile fibers and filaments composed of regenerated cellulose*". The process of making viscose was discovered by C.F.Cross and E.J.Bevan in 1891. The process used to make viscose can either be a continuous or batch process. The batch process is flexible in producing a wide variety of rayon, with broad versatility. Rayon's versatility is the result of the fiber being chemically and structurally engineered by making use of the properties of cellulose from which it is made. However, it is somewhat difficult to control uniformity between batches and it also requires high labor involvement. The continuous process is the main method for producing rayon. Three methods of production lead to distinctly different rayon fibers:

1) Viscose rayon 2) Cuprammonium rayon 3) Saponified cellulose Acetate.

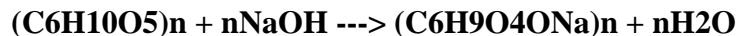
Of the methods mentioned, the viscose method is relatively inexpensive.

2. VISCOSE RAYON

The process of manufacturing viscose rayon consists of the following steps mentioned, in the order that they are carried out: **(1) Steeping, (2) Pressing, (3) Shredding, (4) Aging, (5) Xanthation, (6) Dissolving, (7) Ripening, (8) Filtering, (9) Degassing, (10) Spinning, (11) Drawing, (12) Washing, (13) Cutting.**

The various steps involved in the process of manufacturing viscose are shown in **Fig. 1**, and clarified below.

(1) Steeping: Cellulose pulp is immersed in 17-20% aqueous sodium hydroxide (NaOH) at a temperature in the range of 18 to 25°C in order to swell the cellulose fibers and to convert cellulose to alkali cellulose.



(2) Pressing: The swollen alkali cellulose mass is pressed to a wet weight equivalent of 2.5 to 3.0 times the original pulp weight to obtain an accurate ratio of alkali to cellulose.

(3) Shredding: The pressed alkali cellulose is shredded mechanically to yield finely divided, fluffy particles called "crumbs". This step provides increased surface area of the alkali cellulose, thereby increasing its ability to react in the steps that follow.

(4) Aging: The alkali cellulose is aged under controlled conditions of time and temperature (between 18 and 30°C) in order to de-polymerize the cellulose to the desired degree of polymerization. In this step the average molecular weight of the original pulp is

reduced by a factor of two to three. Reduction of the cellulose is done to get a viscose solution of right viscosity and cellulose concentration.

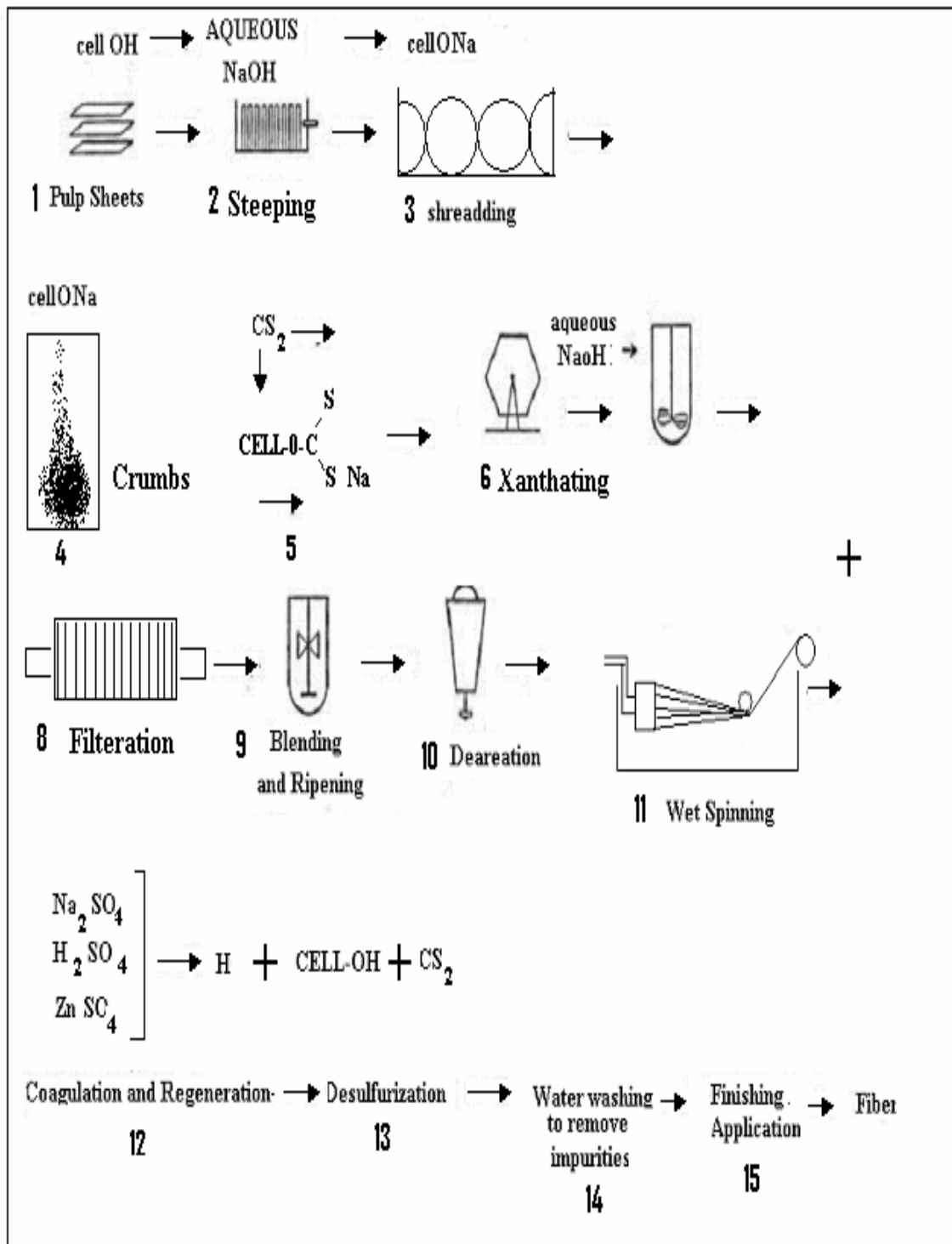


Figure 1: Process of manufacture of viscose rayon fiber

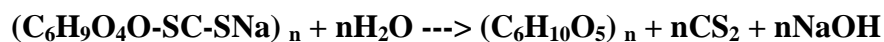
(5) Xanthation: In this step the aged alkali cellulose crumbs are placed in vats and are allowed to react with carbon disulphide under controlled temperature (20 to 30°C) to form cellulose xanthate.



The **orange** cellulose xanthate crumb is dissolved in dilute sodium hydroxide at 15 to 20 °C under high-shear mixing conditions to obtain a viscous orange colored solution called "viscose", which is the basis for the manufacturing process. The viscose solution is then filtered (to get out the insoluble fiber material) and is deaerated.

(6) Dissolving: The yellow crumb is dissolved in aqueous caustic solution. The large xanthate substituents on the cellulose force the chains apart, reducing the interchain hydrogen bonds and allowing water molecules to solvate and separate the chains, leading to solution of the otherwise insoluble cellulose. Because of the blocks of un-xanthated cellulose in the crystalline regions, the yellow crumb is not completely soluble at this stage. Because the cellulose xanthate solution (or more accurately, suspension) has a very high viscosity, it has been termed "viscose".

(7) Ripening: The viscose is allowed to stand for a period of time to "ripen". Two important processes occur during ripening: Redistribution and loss of xanthate groups. The reversible xanthation reaction allows some of the xanthate groups to revert to cellulosic hydroxyls and free CS₂. This free CS₂ can then escape or react with other hydroxyl on other portions of the cellulose chain. In this way, the ordered, or crystalline, regions are gradually broken down and more complete solution is achieved. The CS₂ that is lost reduces the solubility of the cellulose and facilitates regeneration of the cellulose after it is formed into a filament.

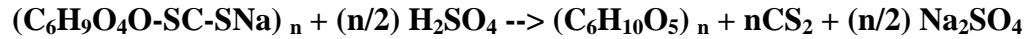


(8) Filtering: The viscose is filtered to remove un-dissolved materials that might disrupt the spinning process or cause defects in the rayon filament.

(9) Degassing: Bubbles of air entrapped in the viscose must be removed prior to extrusion or they would cause voids, or weak spots, in the fine rayon filaments.

(10) Spinning - (Wet Spinning): Production of Viscose Rayon Filament: The viscose solution is metered through a spinneret into a spin bath containing sulphuric acid (necessary to acidify the sodium cellulose xanthate), sodium sulphate (necessary to impart a high salt content to the bath which is useful in rapid coagulation of viscose), and zinc sulphate (exchange with sodium xanthate to form zinc xanthate, to cross link the cellulose molecules). Once the cellulose xanthate is neutralized and acidified, rapid coagulation of the rayon filaments occurs which is followed by simultaneous stretching and decomposition of cellulose xanthate to regenerated cellulose. Stretching and decomposition are vital for getting the desired tenacity and other properties of rayon. Slow regeneration of cellulose and stretching of rayon will lead to greater areas of crystallinity within the fiber, as is done with high-tenacity rayon.

The dilute sulphuric acid decomposes the xanthate and regenerates cellulose by the process of wet spinning. The outer portion of the xanthate is decomposed in the acid bath, forming a cellulose skin on the fiber. Sodium and zinc sulphates control the rate of decomposition (of cellulose xanthate to cellulose) and fiber formation.



Elongation-at-break is seen to decrease with an increase in the degree of crystallinity and orientation of rayon.

(11) Drawing: The rayon filaments are stretched while the cellulose chains are still relatively mobile. This causes the chains to stretch out and orient along the fiber axis. As the chains become more parallel, inter-chain hydrogen bonds form, giving the filaments the properties necessary for use as textile fibers.

(12) Washing: The freshly regenerated rayon contains many salts and other water-soluble impurities, which need to be removed. Several different washing techniques may be used.

(13) Cutting: If the rayon is to be used as staple (i.e., discrete lengths of fiber), the group of filaments (termed "tow") is passed through a rotary cutter to provide a fiber which can be processed in much the same way as cotton.

3. CUPRAMMONIUM RAYON

It is produced by a solution of cellulosic material in cuprammonium hydroxide solution at low temperature in a nitrogen atmosphere, followed by extruding through a spinnerette into a sulphuric acid solution necessary to decompose cuprammonium complex to cellulose. This is a more expensive process than that of viscose rayon. Its fiber cross section is almost round.

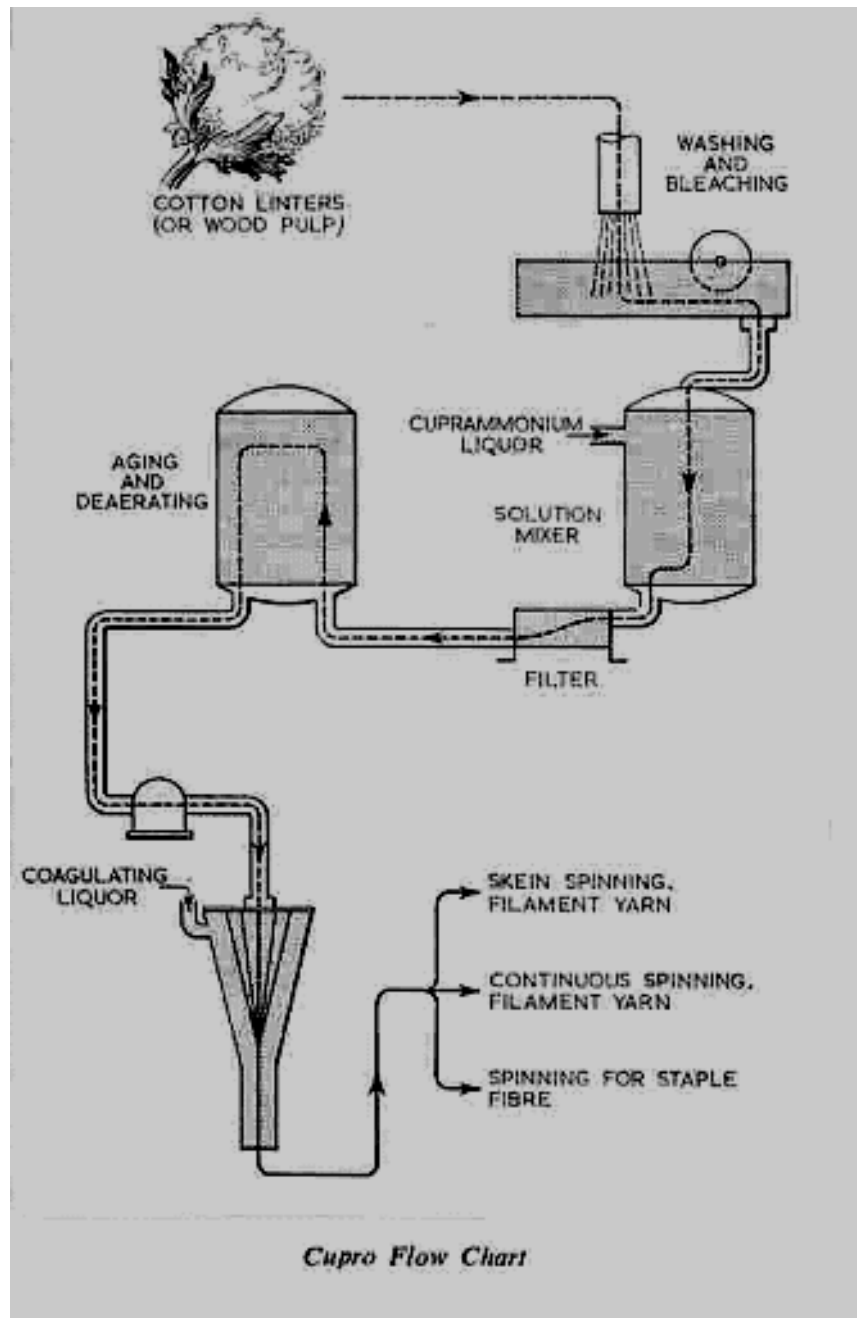


Fig. 2: Cupro flow chart

4. SAPONIFIED CELLULOSE ACETATE

Rayon can be produced from cellulose acetate yarns by saponification. Purified cotton is steeped in glacial acetic acid to make it more reactive. It is then acetylated with excess of glacial acetic acid and acetic anhydride, with sulphuric acid to promote the reaction. The cellulose triacetate formed by acetylation is hydrolysed to convert triacetate to diacetate. The resultant mixture is poured into water which precipitates the cellulose acetate. For spinning it is dissolved in acetone, filtered, deaerated and extruded into hot air which evaporates the solvent. A high degree of orientation can be given to the fiber by drawing because of the fact that cellulose acetate is more plastic in nature. Its fiber cross section is nearly round, but lobed.

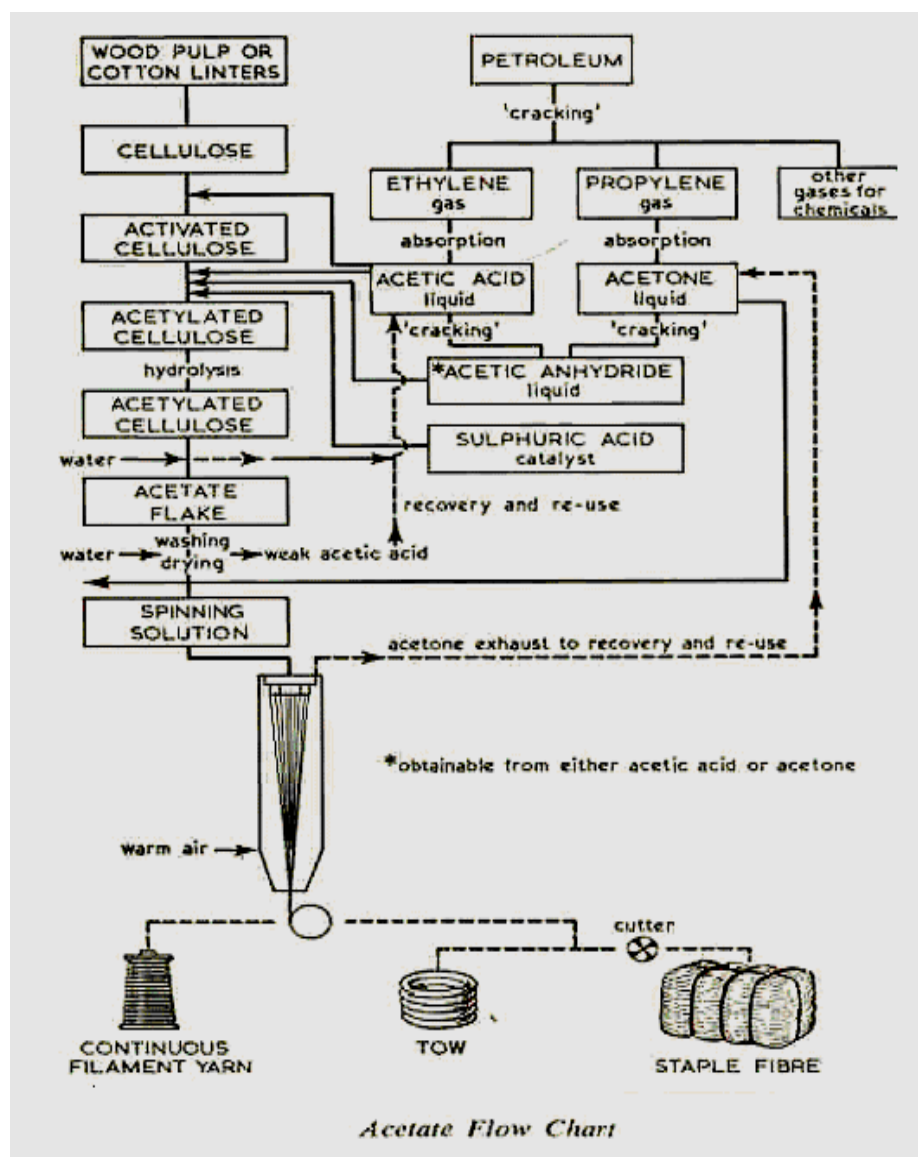


Fig. 3: Acetate flow chart

5. STRUCTURE OF RAYON

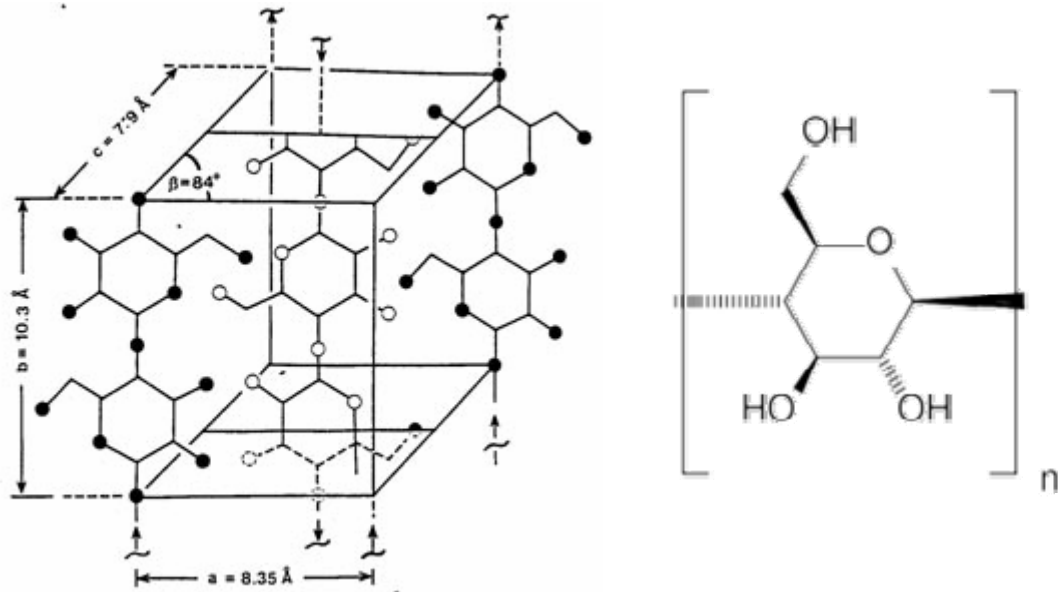


Fig 4. Structure of unit cell of cellulose

6. PROPERTIES OF RAYON

Variations during spinning of viscose or during drawing of filaments provide a wide variety of fibers with a wide variety of properties. These include:

Fibers with thickness of 1.7 to 5.0 dtex, particularly those between 1.7 and 3.3 dtex, dominate large-scale production.

Tenacity ranges between 2.0 to 2.6 g/den when dry and 1.0 to 1.5 g/den when wet.

Wet strength of the fiber is of importance during its manufacturing and also in subsequent usage. Modifications in the production process have led to the problem of low wet strength being overcome.

Dry and wet tenacities extend over a range depending on the degree of polymerization and crystallinity. The higher the crystallinity and orientation of rayon, the lower is the drop in tenacity upon wetting.

Percentage elongation-at-break seems to vary from 10 to 30 % dry and 15 to 40 % wet. Elongation-at-break is seen to decrease with an increase in the degree of crystallinity and orientation of rayon.

6.1. THERMAL PROPERTIES

Viscose rayon loses strength above 149°C ; chars and decomposes at 177 to 204°C . It does not melt or stick at elevated temperatures.

6.2. CHEMICAL PROPERTIES

Hot dilute acids attack rayon, whereas bases do not seem to significantly attack rayon. Rayon is attacked by bleaches at very high concentrations and by mildew under severe hot and moist conditions. Prolonged exposure to sunlight causes loss of strength because of degradation of cellulose chains.

Abrasion resistance is fair and rayon resists pill formation. Rayon has both poor crease recovery and crease retention.

7. RAYON FIBER CHARACTERISTICS

- Highly absorbent
- Soft and comfortable
- Easy to dye
- Drapes well

The drawing process applied in spinning may be adjusted to produce rayon fibers of extra strength and reduced elongation. Such fibers are designated as high tenacity rayons, which have about twice the strength and two-third of the stretch of regular rayon. An intermediate grade, known as medium tenacity rayon, is also made. Its strength and stretch characteristics fall midway between those of high tenacity and regular rayon[13].

8. SOME MAJOR RAYON FIBER USES

Apparel: Accessories, blouses, dresses, jackets, lingerie, linings, millinery, slacks, sportshirts, sportswear, suits, ties, work clothes;

Home Furnishings: Bedspreads, blankets, curtains, draperies, sheets, slipcovers, tablecloths, upholstery;

Industrial Uses: Industrial products, medical surgical products, nonwoven products, tire cord

Other Uses: Feminine hygiene products.

9. DIFFERENT TYPES OF RAYONS

Rayon fibers are engineered to possess a range of properties to meet the demands for a wide variety of end uses. Some of the important types of fibers are briefly described.

9.1 HIGH WET MODULUS RAYON

These fibers have exceptionally high wet modulus of about 1 g/den and are used as parachute cords and other industrial uses. Fortisan fibers made by Celanese (saponified acetate) have also been used for the same purpose.

9.2 POLYNOSIC RAYON

These fibers have a very high degree of orientation, achieved as a result of very high stretching (up to 300 %) during processing. They have a unique fibrillar structure, high dry and wet strength, low elongation (8 to 11 %), relatively low water retention and very high wet modulus.

9.3 SPECIALTY RAYONS

9.3.1 FLAME RETARDANT FIBERS

Flame retardance is achieved by the adhesion of the correct flame- retardant chemical to viscose. Examples of additives are alkyl, aryl and halogenated alkyl or aryl phosphates, phosphazenes, phosphonates and polyphosphonates. Flame retardant rayons have the additives distributed uniformly through the interior of the fiber and this property is advantageous over flame retardant cotton fibers where the flame retardant concentrates at the surface of the fiber.

9.3.2 SUPER ABSORBENT RAYONS

This is being produced in order to obtain higher water retention capacity (although regular rayon retains as much as 100 % of its weight). These fibers are used in surgical nonwovens. These fibers are obtained by including water- holding polymers (such as sodium polyacrylate or sodium carboxy methyl cellulose) in the viscose prior to spinning, to get a water retention capacity in the range of 150 to 200 % of its weight.

9.3.3 MICRO DENIER FIBERS

Rayon fibers with deniers below 1.0 are now being developed and introduced into the market. These can be used to substantially improve fabric strength and absorbent properties.

Cross section modification: Modification in cross sectional shape of viscose rayon can be used to dramatically change the fibers' aesthetic and technical properties. One such product is Viloft, a flat cross sectional fiber sold in Europe, which gives a unique soft handle, pleasing drape and handle. Another modified cross section fiber called Fiber ML (multi limbed) has a very well defined trilobal shape. Fabrics made of these fibers have considerably enhanced absorbency, bulk, cover and wet rigidity all of which are suitable for usage as nonwovens.

9.3.4 TENCEL RAYON

Unlike viscose rayon, a straight solvation process produces Tencel. Wood pulp is dissolved in an amine oxide, which does not lead to undue degradation of the cellulose chains. The clear viscous solution is filtered and extruded into an aqueous bath, which precipitates the cellulose as fibers. This process does not involve any direct chemical reaction and the diluted amine oxide is purified and reused. This makes for a completely contained process fully compatible with all environmental regulations.

9.3.5 LYOCELL

Lyocell is manufactured using a solvent spinning process, and is produced by only two companies -- Acordis and Lenzing AG. To produce Lyocell, wood cellulose is dissolved directly in n-methyl morpholine n-oxide at high temperature and pressure. The cellulose precipitates in fiber form as the solvent is diluted, and can then be purified and dried. The solvent is recovered and reused. Lyocell has all the advantages of rayon, and in many respects is superior. It has high strength in both dry and wet states, high absorbency, and can fibrillate under certain conditions. In addition, the closed-loop manufacturing process is far more environmentally friendly than that used to manufacture rayon, although it is also more costly.