Man-Made Fibres
The Way From Production To Use

Industrievereinigung
Chemiefaser e.V.

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Looking back at the history of man-made fibres

As early as 1665 the Englishman Robert Hooke came up with the idea of making artificial fibres from a viscous liquid mass.
His idea, though, remained a utopia for more than two centuries. Only in 1884 did Count Chardonnet succeed for the first time in producing artificial silk from dissolved cellulose.

Count Hilaire de Chardonnet (1839–1924)

From the natural fibre to the man-made fibre

When the German chemist Hermann Staudinger was able to prove that natural fibres are based on large chain-shaped molecules, he laid the foundation for the development of modern man-made fibres. That was in 1925.

Prof. Dr. Hermann Staudinger (1881–1965)

An idea takes on a concrete form

Under the direction of the chemist Carothers, a group of American scientists succeeded in synthetically producing a spinnable polyamide. It was the birth of the world-famous product “Nylon“. Five years later the first nylon stockings could be purchased.

Dr. Wallace H. Carothers (1896–1937)

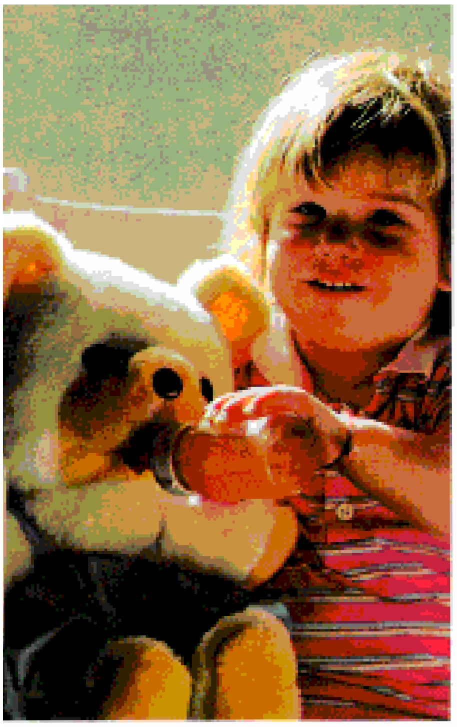
The beginning of a new era

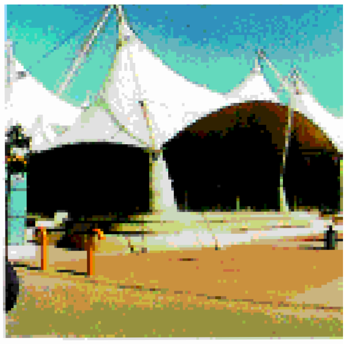
The first perlon fibres were spun by the IG Farben in 1933. In the same year Bayer and Kurz discovered the basic compound for acrylic fibres.

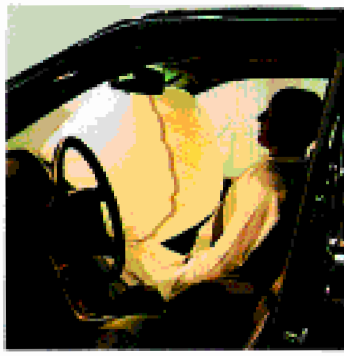
After the Second World War, an invention by Whinfield and Dickson in England, realized 1941, enabled first the successful production of polyester fibres.

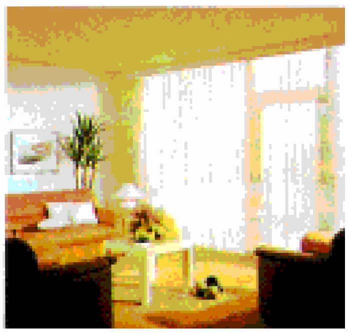
A triumph of science and technology

The triumphal march of man-made fibres was unstoppable. With the production of fibres as successful as ACRYLIC, POLYAMIDE, POLYESTER, ELASTANE and VISCOSE, new opportunities were opened up for everyone, affecting the quality, as well as the enjoyment of life. Today, the world of clothing, sports and leisure, as well as that of technology, medicine and interior design, would be unthinkable without man-made fibres.









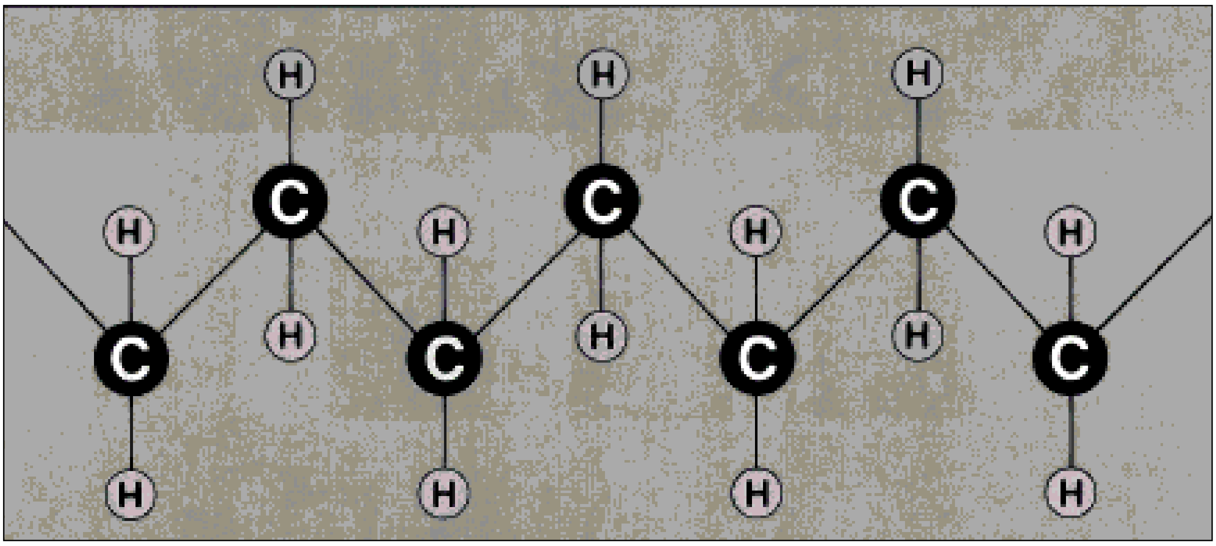
The structure of chain molecules

All fibres used for manufacturing textiles, whether natural or man-made, are made up of chain molecules.

Model of a chain molecule

The building blocks of single molecules

Every molecule in the chain consists of identical chemical elements or combinations of these elements: these are carbon, hydrogen, oxygen and nitrogen.



The emergence of chain molecules

Every single one of these molecules must be able to enter into chemical reactions at both ends. Only then it is possible to form a chain, the chain molecule consisting of hundreds and thousands of molecules linked together.

What all fibres have in common

The starting point is always nature (the sun), regardless of whether natural- or man-made fibres.

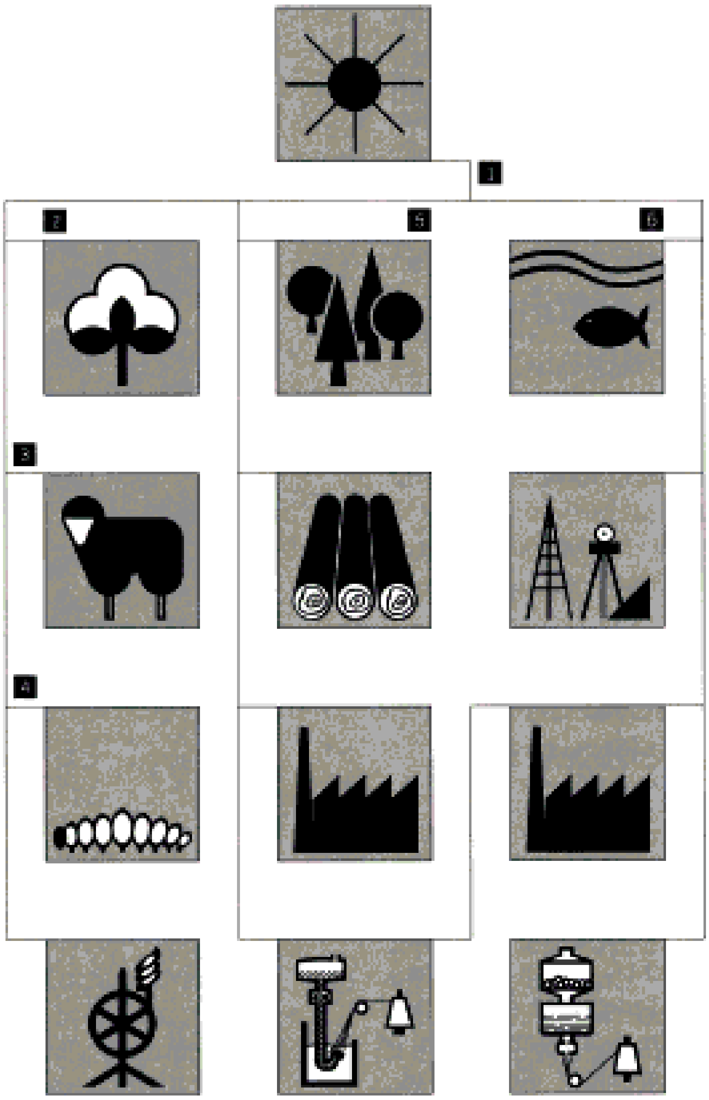
The main outlines in the production of fibres:

1
In addition to other basic compounds, sunlight causes the synthesis of dextrose in plants, which is the fundamental building block of the cellulose molecule.

2
Cellulose constitutes the fundamental structure of cotton plants, which are the source of the cotton fibre.

3
Nutrients in feed are transformed into chemical compounds which form the basis for the growth of wool and hair.

4
The silk worm collects a protein depot from its nourishment which is spun to endless threads through its glands.



5
After being treated with chemicals, the short fibres contained in wood are transformed into a watery solution and then pressed through spinnerets. After drying, cellulosic fibres are obtained.

6
The raw materials for synthetic fibres generally stem from crude oil, which originates from the transformation of huge quantities of marine organisms.

The main difference between man-made fibres and natural fibres

In contrast to natural fibres, the composition and structure of man-made fibres can be humanly shaped. This lends man-made fibres special properties and renders them useful for many different purposes.
In the case of requiring high, little or low absorbancy, maximum tensile strength, elasticity or stretchability, heat or cold resistancy - man-made fibres are able to fulfil almost any wish.

The subdivsion of man-made fibres

We distinguish between synthetic and cellulosic man-made fibres.

The cellulosic fibres

The primary material of cellulosic fibres is cellulose. Cellulose is the most common organic compound in nature. It is synthesised under the influence of sunlight by a reaction of carbon dioxide with water in plants. This process is called photosynthesis. The fundamental building block of cellulose is the glucose molecule.

The synthetic fibres

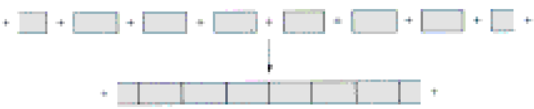
Synthetic fibres are also produced from an organic substance, namely crude oil. Crude oil originates from the transformation of huge quantities of marine organisms.

Producing the primary materials

In order to manufacture man-made fibres, viscous, stringy liquids are needed. The matter that results from dissolving or heating (e.g. from a substance in granular form) is called the spin mass.

POLYMERISATION

This way of joining macromolecules is only possible with single molecules which have a double bond between two carbon atoms (CH_2=CH_2). But these alone cannot create an interconnecting molecular bond. To do this they need the support of substances which are known as catalysts. These catalysts initiate the interconnection process by ensuring that the double bond between the two carbon atoms opens up to create a single bond -CH_2-CH_2-. The open single bond stimulates another carbon double bond to open and so on. The -CH_2-CH_2-groups link up and a macromolecule is formed. This process continues until it is stopped by the chemist. He achieves this by introducing molecules which have no intention of encouraging further interlinking of the molecules. By this he can determine the length of the macromolecule and thereby the specific fibre properties. This is how "customised" fibres are created. Schematically, polymerisation can be illustrated as follows:



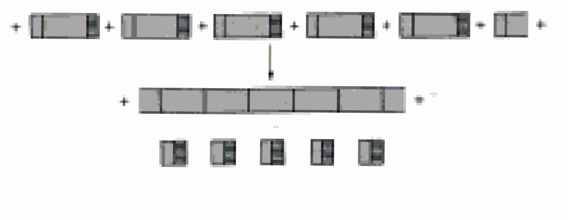
Many identical small reactive molecules line up in a large long-chain molecule, or macromolecule.
Depending on the polymerisation process, fibres, e.g. polyamide 6 (PA 6), acrylic (PAN), polyvinylchloride (CFL) and polypropylene (PP) fibres are produced.

The methods of transformation

Today, three manufacturing processes are primarily used to obtain spinnable material: POLYMERISATION, POLYCONDENSATION and POLYADDITION.

POLYCONDENSATION

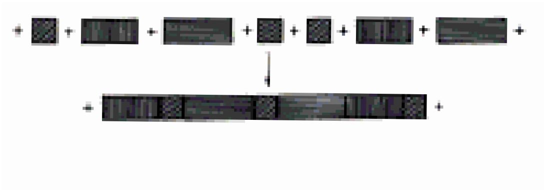
In this process, only those single molecules can be formed that have reactive atomic groups on both ends capable of reacting with other atomic groups (molecules with bifunctional groups). If the linking molecules are different, for example the one containing an alcohol group and the other an acid group (e.g. a carboxilic acid group), the result is an ester. Normally water molecules split off in the process. Illustrated schematically:



Two different types of molecules link up and produce a by-product (mostly water). This process applies, for example, to polyester (PES) and polyamide 6.6 (PA 6.6).

POLYADDITION

In this process, two different types of single molecules link up to form a macromolecule. Instead of splitting off by-products, an alternating dislocation of the hydrogen molecules takes place. Illustrated schematically:



This is how, for example, elastane fibres (EL) are made.

Preparing the spin mass

The primary materials synthesised by polymerisation, polycondensation and polyaddition must be processed so that they can be formed into fibres. To do this, they are dissolved into a liquid or heated to transform them into a syrup-like, viscous mass. The resulting spinnable substance is called a polymer.

The types of man-made fibres

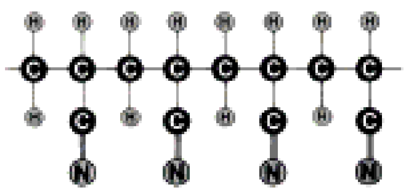
As a rule, a distinction is made between fibres from synthetic polymers and those from cellulosic polymers.
The ACRYLIC-, POLYAMIDE-, POLYESTER-and ELASTANE FIBRES belong to the fibres made from synthetic polymers.
In the case of man-made fibres manufactured from cellulosic polymers the main distinction is between VISCOSE- and ACETATE FIBRES.

ELASTANE FIBRES

These fibres are produced by polyaddition and are usually spun in the dry spinning process.

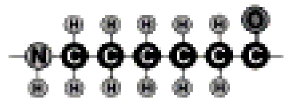
ACRYLIC FIBRES

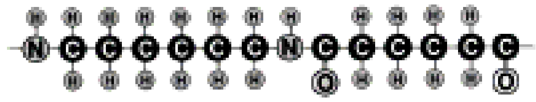
This fibre is produced using the polymerisation process. The two spinning processes employed are dry spinning and wet spinning.



POLYAMIDE FIBRES

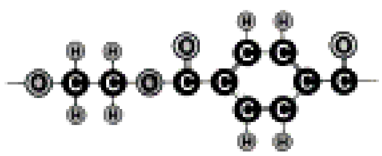
The polyamide fibres most often used in utility textiles are polyamide 6 and polyamide 6.6. Polyamide 6 is produced by applying the polymerisation process, polyamide 6.6 by the polycondensation process. Both are spun with the melt spinning process.





POLYESTER FIBRES

Polyester fibres result from the polycondensation process. When spinning, the melt spinning process is employed.

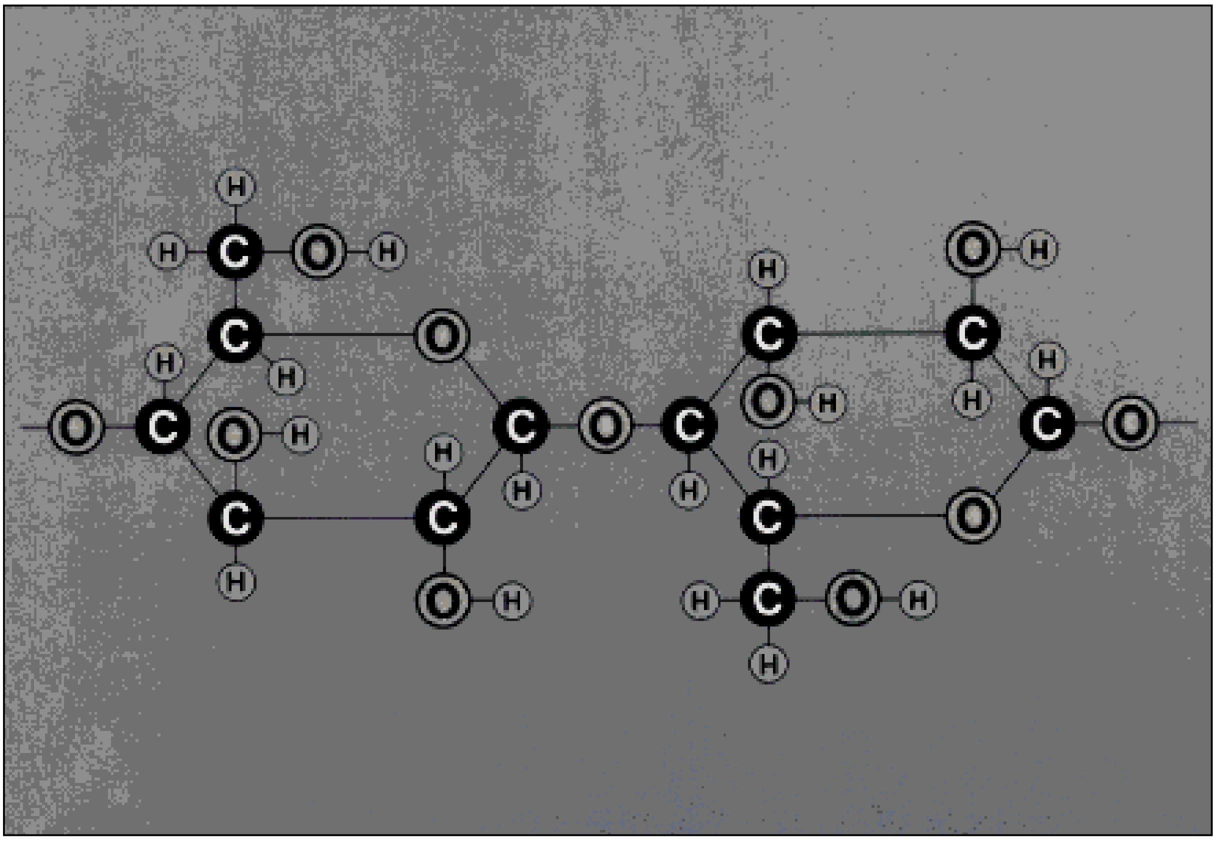


VISCOSE FIBRES

The primary material for the cellulosic spin masses is cellulose from trees cultivated on plantations.
For fibre production a spin mass is needed in which the cellulose is dissolved. For this purpose the pulp boards are immersed in sodium hydroxide. By treating it further with carbon disulfide, a spinnable mass is obtained: viscose. Viscose fibres are wet spun.

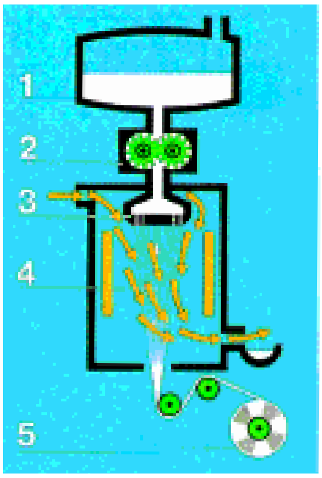
ACETATE FIBRES

In this process the cellulose is subjected to a permanent transformation by a reaction with acetic acid.
By further chemical treatment cellulose acetate is finally achieved.
This dry, grainy substance is dissolved in acetone to form a spin mass from which the acetate filaments are spun in the dry spinning process.



The spinning process

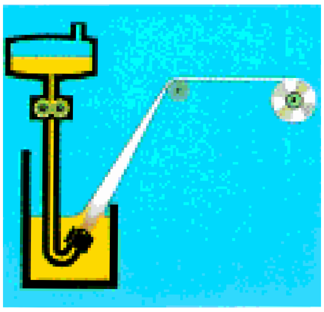
In order to produce filaments (endless yarns) from the spin mass, various spinning processes are employed. The spinnable matter is pressed through the extremely small openings of a spinneret. Upon exiting the spinneret, the filaments produced are either gathered to a filament yarn and spooled, or joined to form tows.



The spinning processes consist of common basic processes which can be seen in the illustrations: the container holding the spin mass (1) – the spin pump for dosing the spin mass (2) – the spinneret (3) – a medium in which the filament is formed (4) – the device used for gathering and spooling the filament (5).

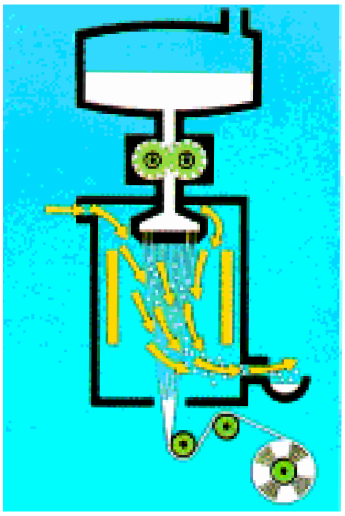
THE WET SPINNING PROCESS

In the wet spinning process the spin mass is pressed into a so-called coagulating bath which ensures that the filaments clot (coagulate).



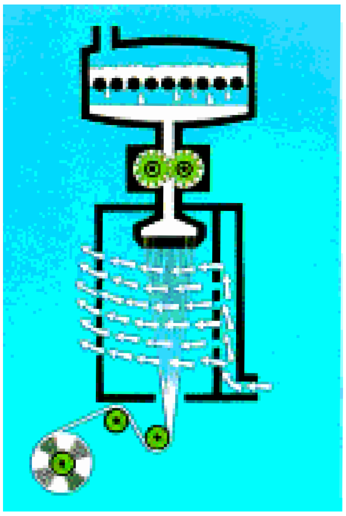
THE DRY SPINNING PROCESS

In the dry spinning process the spin mass exits the spinneret into a spinning duct into which warm air is blown. This causes the solvent to evaporate and the filaments to solidify.

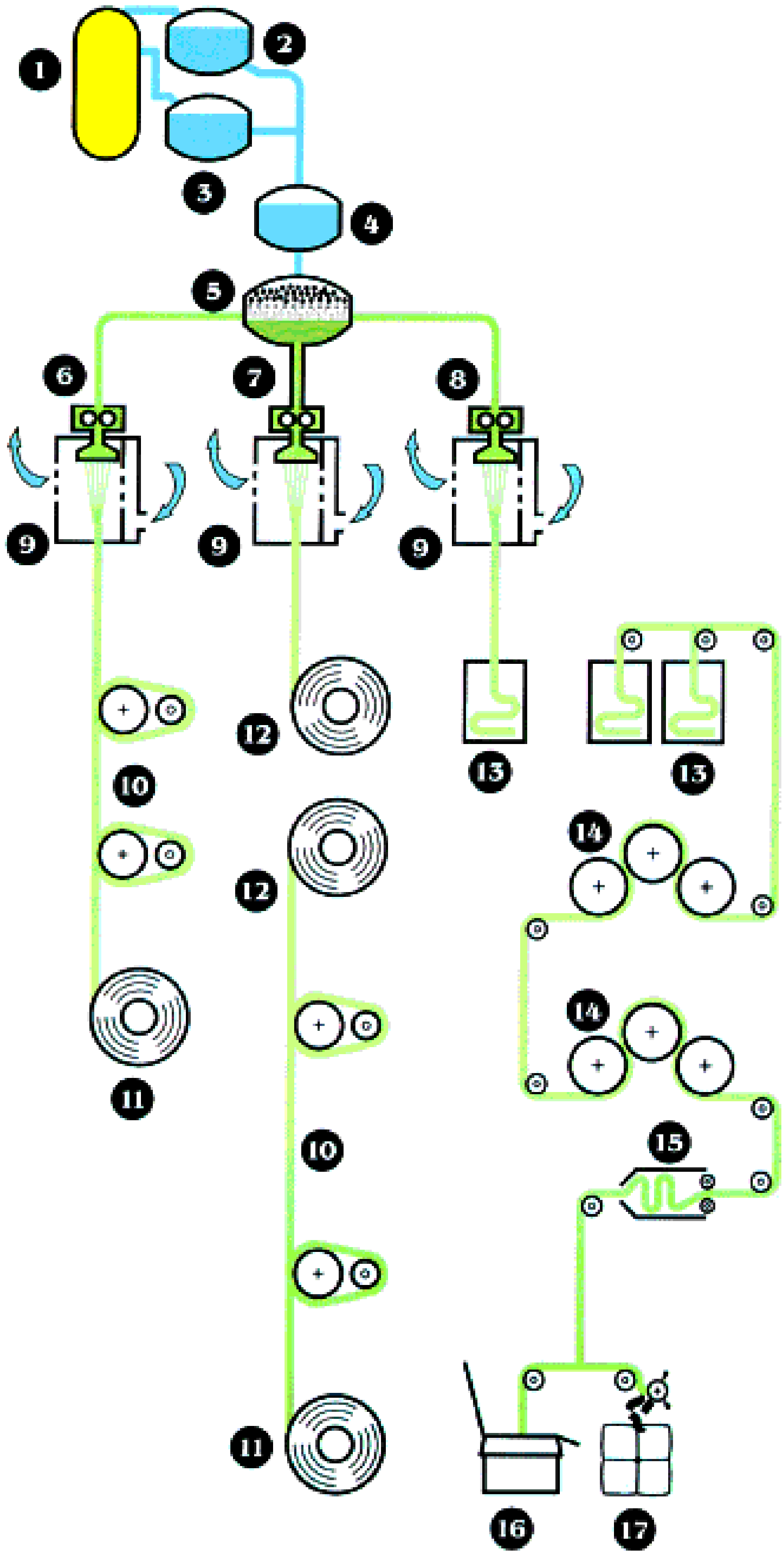


THE MELT SPINNING PROCESS

This process is employed for meltable fibre raw materials. Upon being heated, a melt is formed which is pressed through the spinnerets.

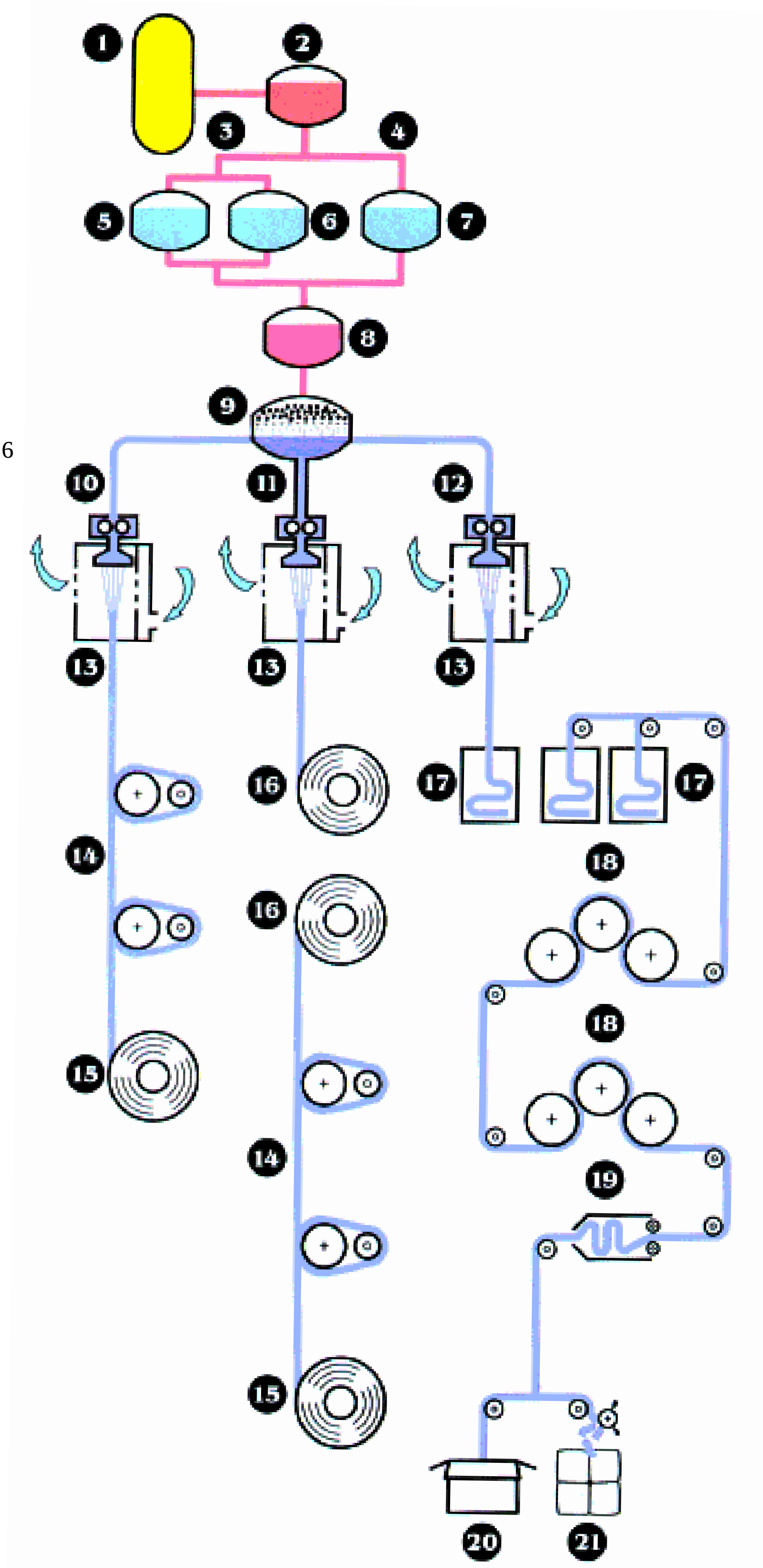


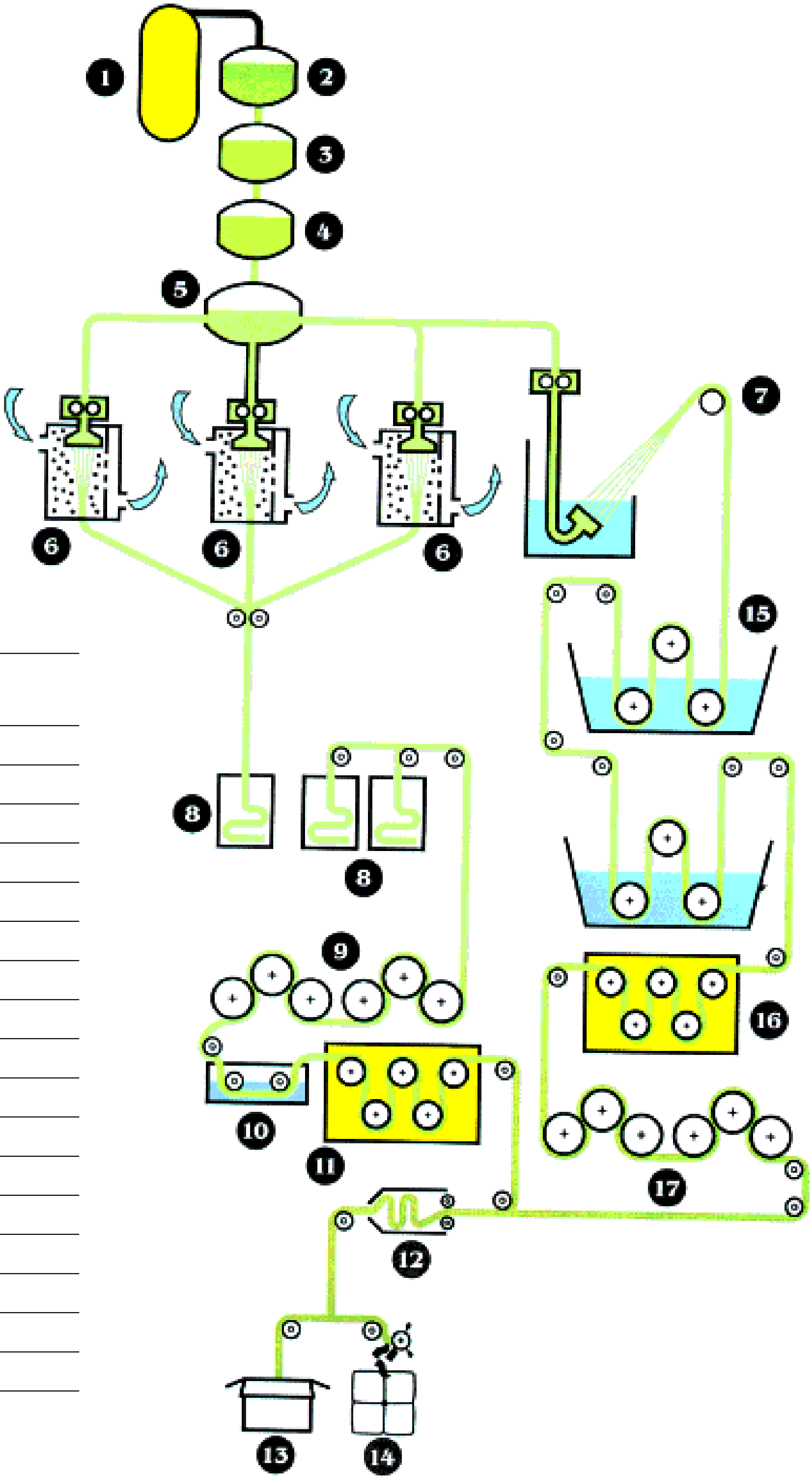
	Polyester
1	crude oil
2	dimethylterephthalate/ terephthalonic acid
3	glycol
4	polyethylene terephthalate
5	melt
6	production of polyester filament yarn, one-step
7	production of polyester filament yarn, multi-step
8	production of polyester staple fibres
9	melt spinning
10	drawing
11	flat polyester filament yarn
12	spinning bobbin
13	tow
14	drawing
15	crimping
16	polyester tow
17	polyester staple fibres



Polyamide

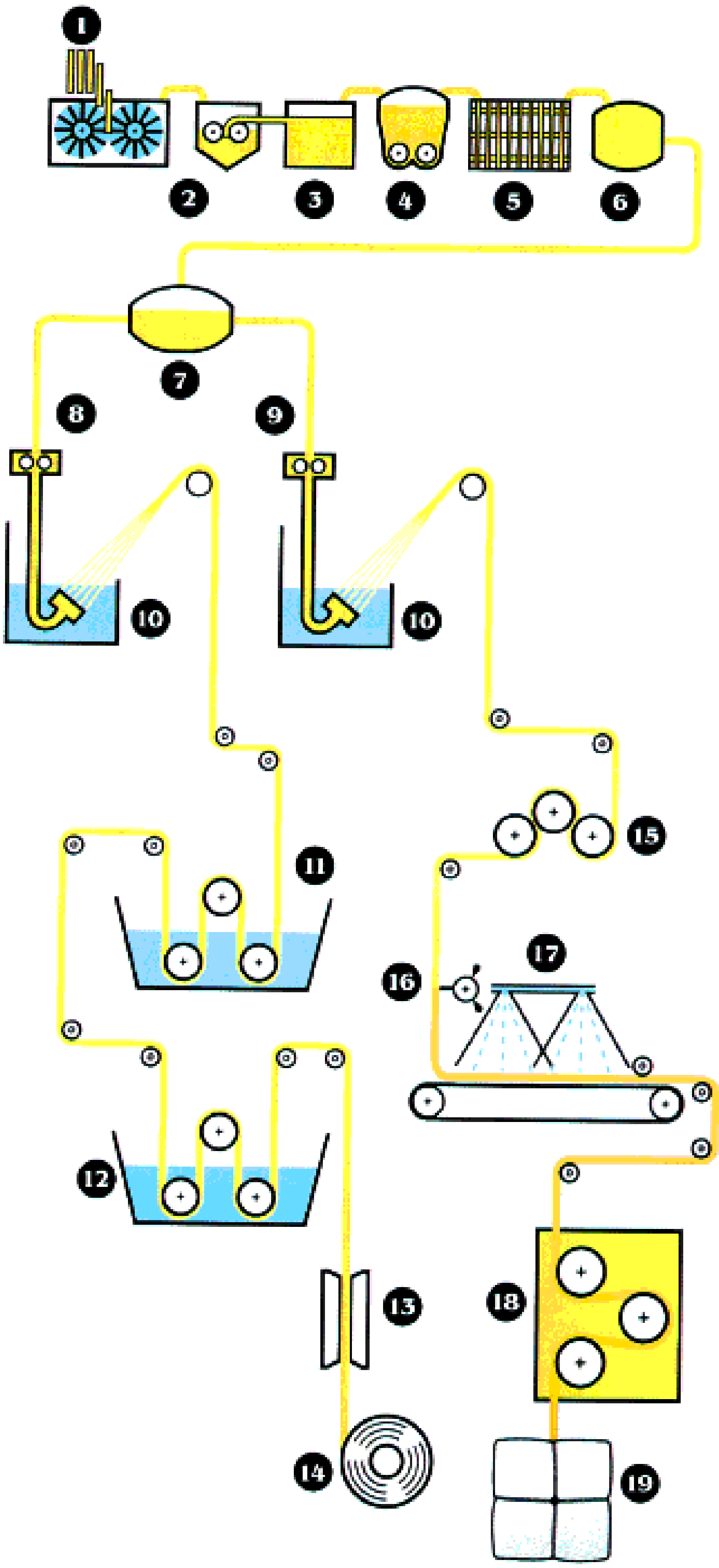
1	crude oil
2	aromatics
3	production of polyamide 6.6
4	production of polyamide 6
5	adipic acid
6	hexamethylene diamine
7	caprolactam
8	polyamide 6 or polyamide 6.6 polymer
9	melt
10	production of polyamide filament yarn, one-step
11	production of polyamide filament yarn, multi-step
12	production of polyamide staple fibres
13	melt spinning
14	drawing
15	flat polyamide filament yarn
16	spinning bobbin
17	tow
18	drawing
19	crimping
20	polyamide tow
21	polyamide staple fibres





	Acrylic
1	crude oil
2	propylene
3	acrylonitrile
4	polyacrylonitrile
5	spinning solution
6	dry spinning
7	wet spinning
8	acrylic tow
9	drawing
10	washing
11	drying
12	crimping
13	acrylic tow
14	acrylic staple fibres
15	washing
16	drying
17	drawing

	Viscose
1	cellulose extracted from wood → cellulose
2	alkalise chopping immerse press
3	preripening
4	dissolve
5	filter
6	ripening
7	spinning solution
8	production of viscose filament yarn
9	production of viscose staple fibres
10	wet spinning
11	wash/desulphurization
12	bleach/brighten
13	dry
14	viscose filament yarn
15	drawing
16	cutting
17	washing/after-treatment
18	drying
19	viscose staple fibres



Drawing man-made fibres

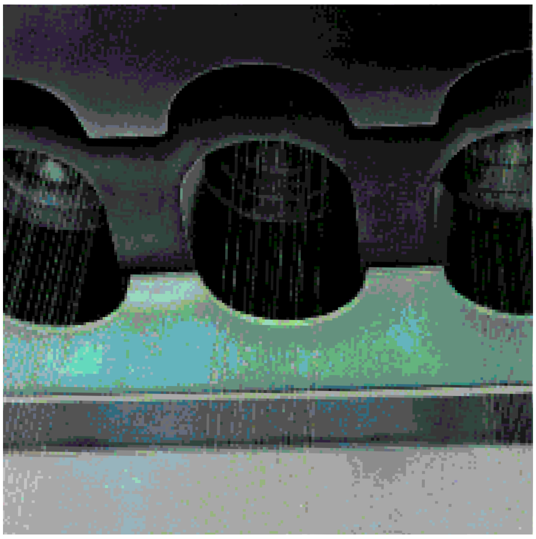
After spinning the man-made fibres, the parallel alignment of the molecules is not yet optimal. Man-made fibres have to be drawn in order to acquire ultimate properties for the yarns.

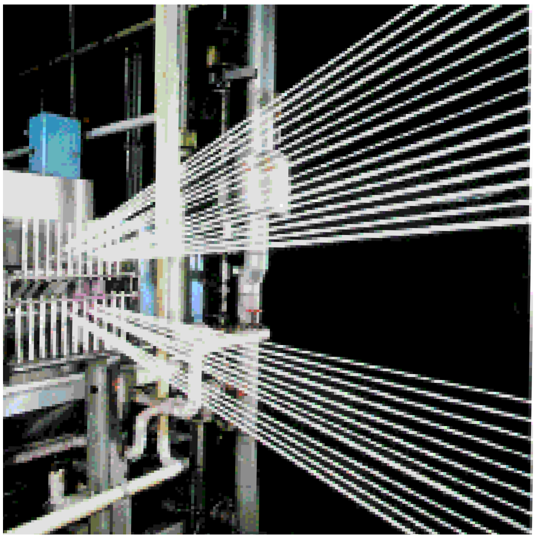
The intended use determines the degree of drawing

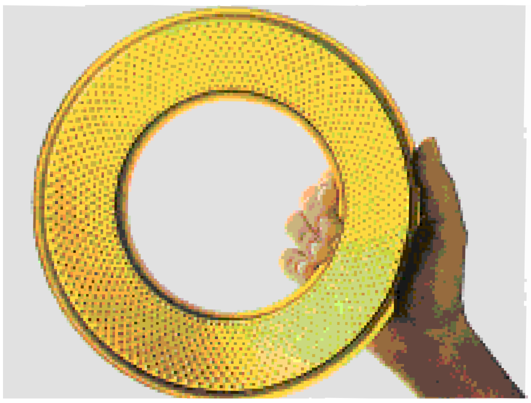
Upon being drawn, a crucial event takes place inside the filaments: the chain molecules align themselves in the longitudinal direction of the filament. The chains align themselves parallel to each other. The cross-forces between the chains improve the tenacity. The filaments become stronger. The extent to which they are drawn depends on their intended use.

The spinneret

The spin mass is pressed through the so-called spinnerets. Depending on the number of holes in the spinneret or strainer, the corresponding number of filaments is produced. If the spinneret has only one hole, one mono-filament is spun. Spinnerets with many openings produce multifilament yarns endlessly. Joining a large number of filaments (several ten thousand) produces a tow.

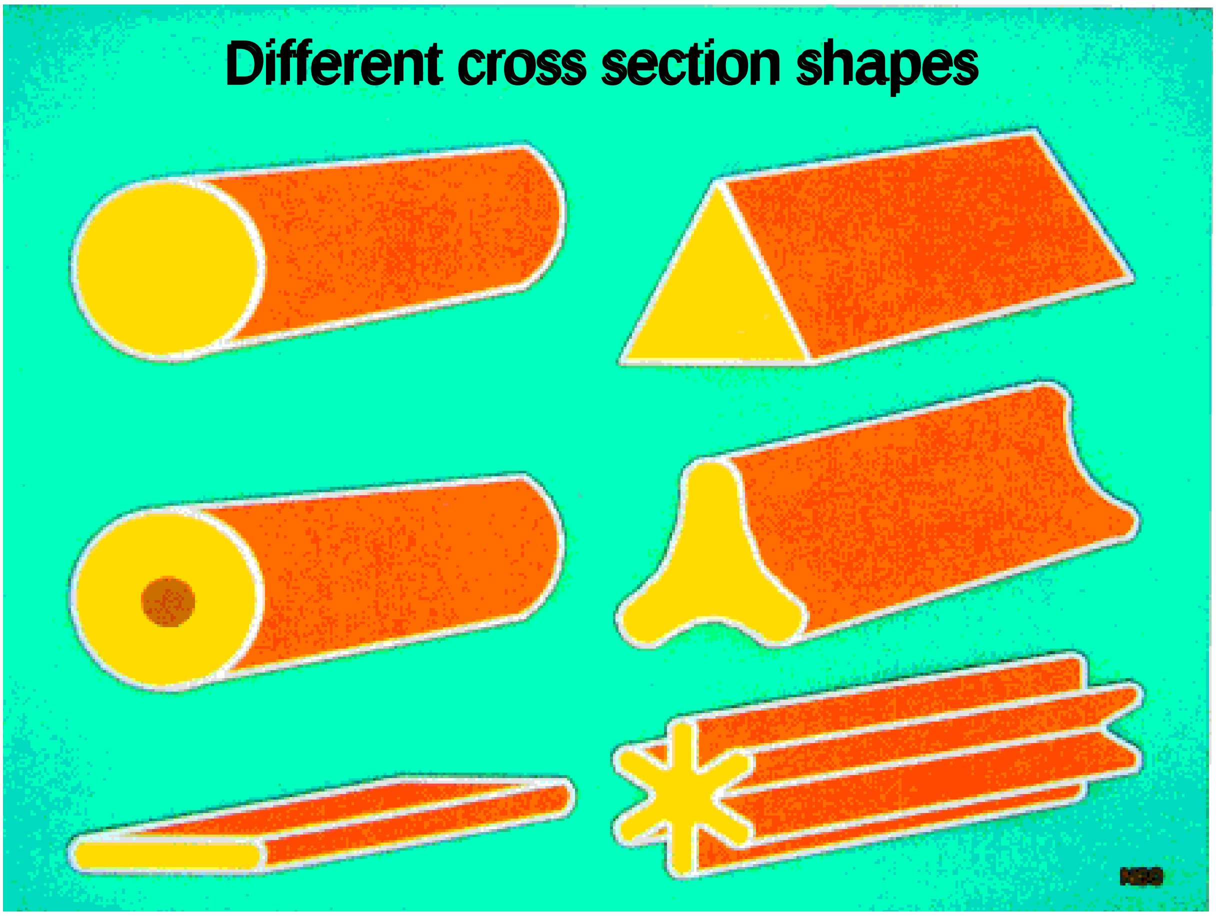






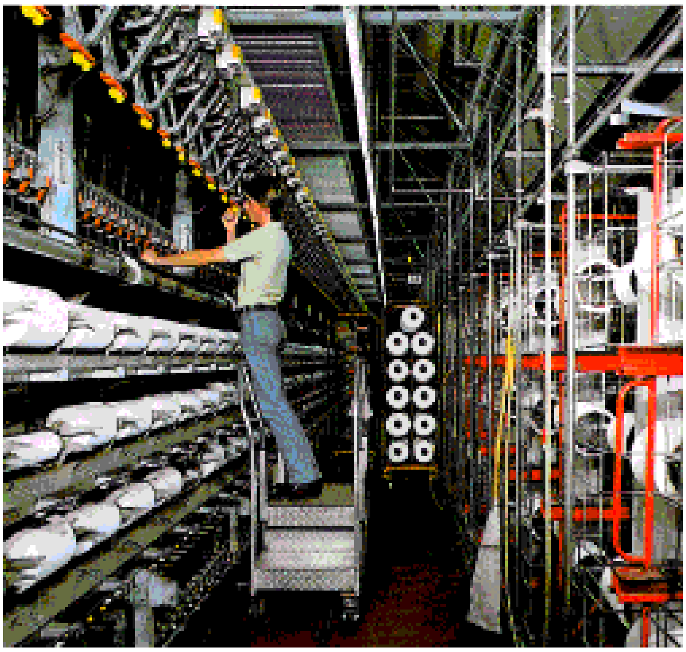
Cross sections

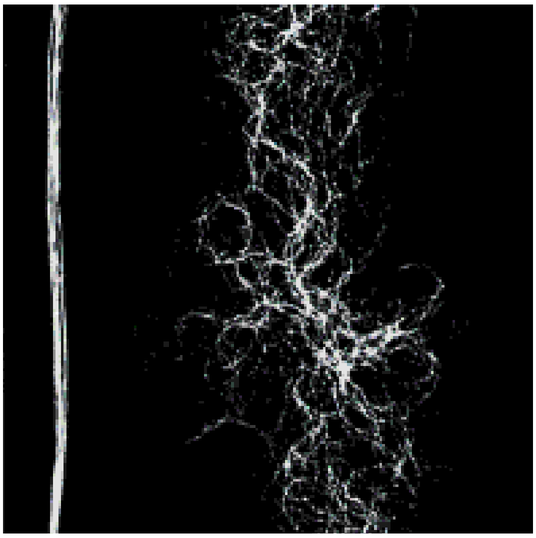
Depending on the shape of the spinneret holes, different cross section shapes are obtained in the melt spun man-made fibres.
The spectrum ranges from round to multi-lobed, triangular and star-shaped to ribbon-shaped. The different cross section shapes of the fibres exert a decisive influence on the properties of the textiles produced from them. For example, the texture of the textile varies, becoming grained or softer, or the textile changes in appearance, taking on a different sheen or none at all.



The procedure

Texturing is a procedure used to increase the volume and the elasticity of a filament yarn. When textured, flat filaments acquire volume and bulk. The texturing process can be carried out separately subsequent to the drawing process. Sometimes, however, the drawing process is carried out in a single step together with texturing on the texturing machine (draw-texturing).



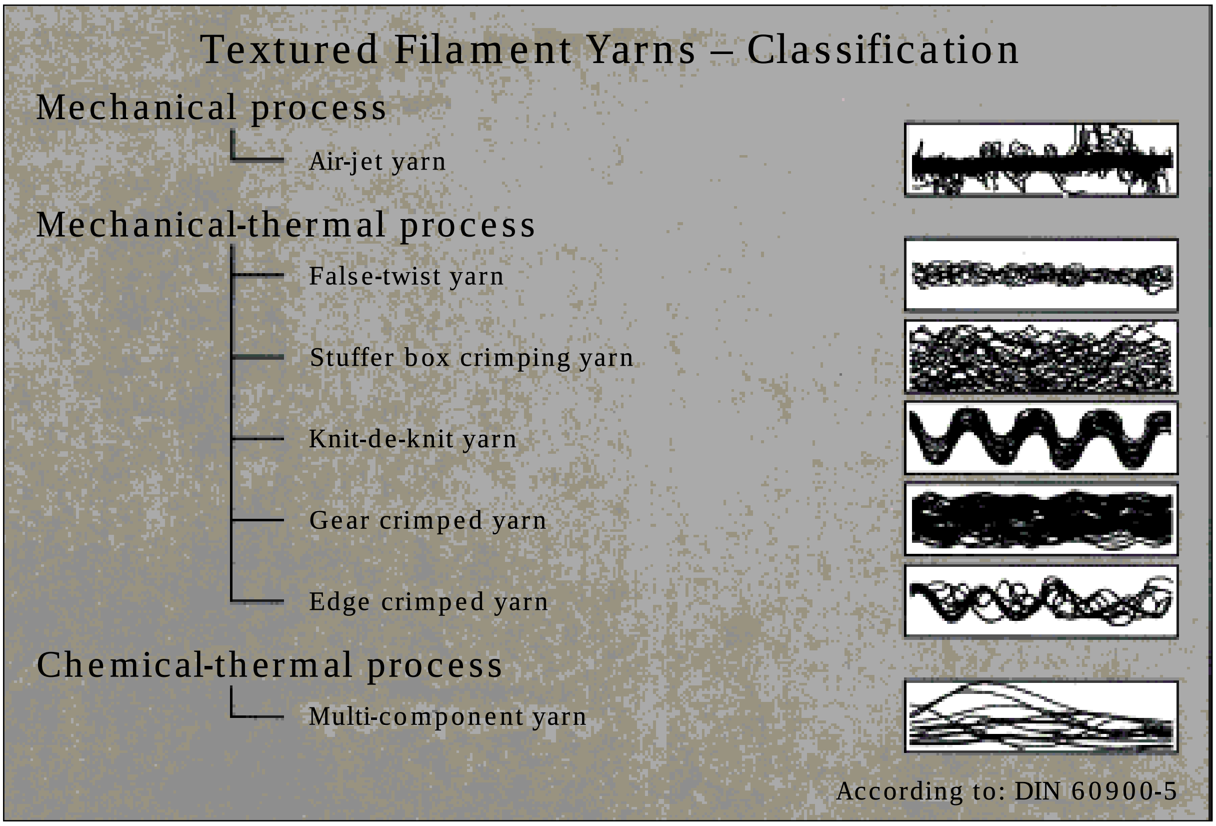


The advantages

Texturing flat filament yarns changes their structure permanently and makes them even more like textiles.
The essential properties of textured yarns and the products made from them are softness, fullness, a high degree of elasticity, thermal insulation and moisture-transporting properties.

The process

All yarns which can be shaped by heat are suitable for texturing. These are predominantly polyamide and polyester yarns.
The most important texturing processes are FALSE-TWIST TEXTURING, STUFFER-BOX TEXTURING and AIR-JET TEXTURING.

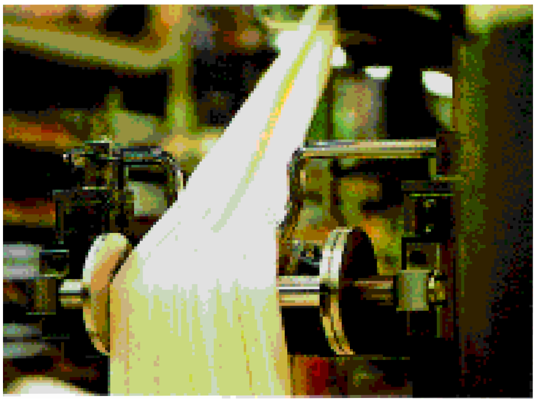


The principle

In all spinning processes, filaments are formed from the spin mass by the spinnerets. If the production of staple fibres is desired, i. e. short fibre sections for the spinning mill, thousands of filaments are combined to form tow and cut into staple fibres.

The tow

While during the production of filament yarns each single filament bundle exiting the spinnerets is wound onto a spool, in the production of staple fibres numerous filament bundles are first combined to form a thick filament tow which can be crimped and cut into staple fibres.

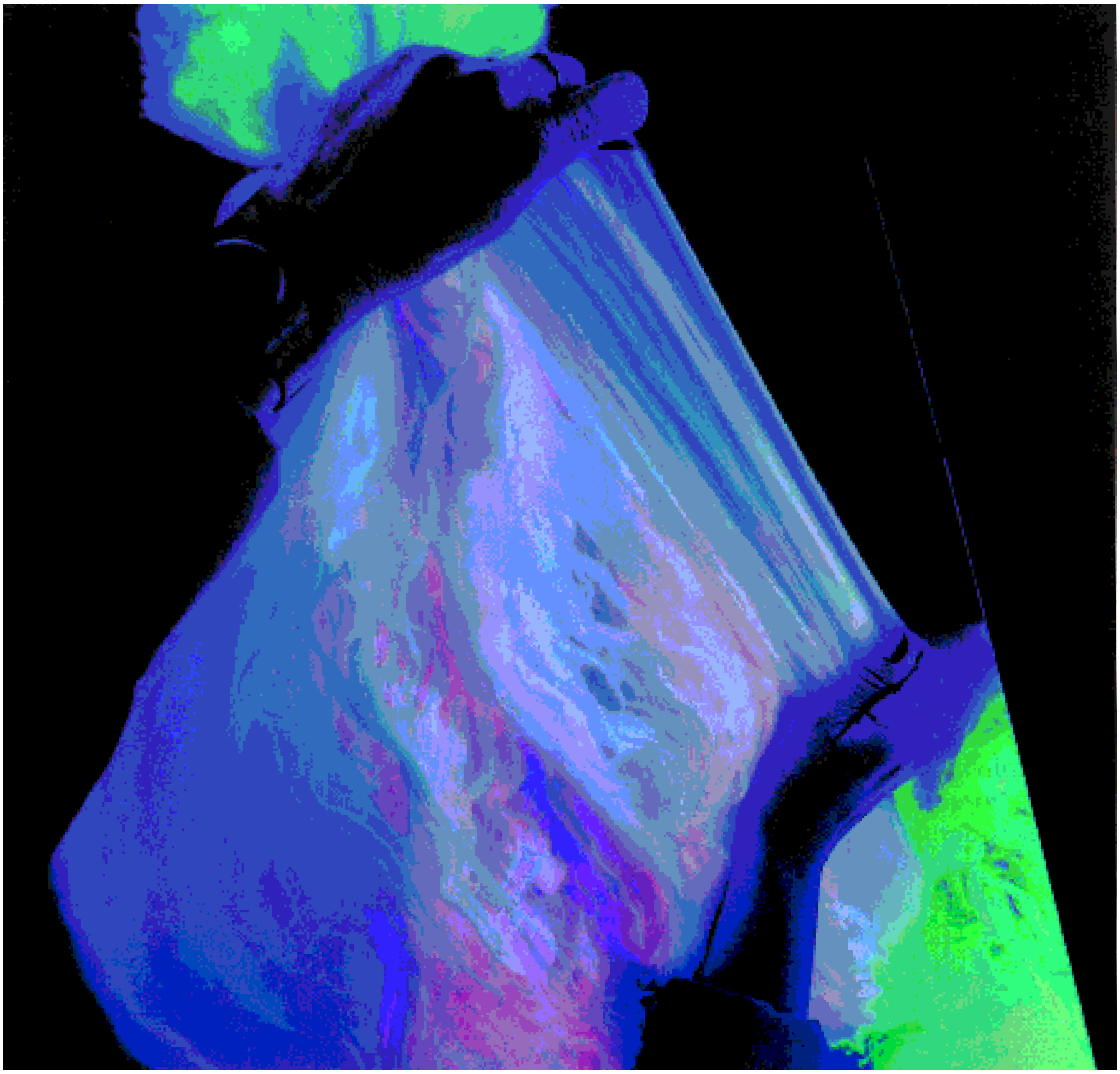


The cutting process

By cutting the tow, staple fibres are obtained which can be compared, for example, with wool or cotton in length. Depending on the process used, the tow is either cut directly by the manufacturer and pressed into bales for delivery, or cut or torn into staple fibres using a so-called converter at a later stage by a downstream manufacturer.

The versatility of man-made fibres

The chemists and technicians who specialise in man-made fibres today are capable of manufacturing customised fibres or developing completely new substances which match the demands posed by the different applications to a very high extent.
Customised fibres can be created specifically for use in apparel, for home furnishings or for industrial uses.

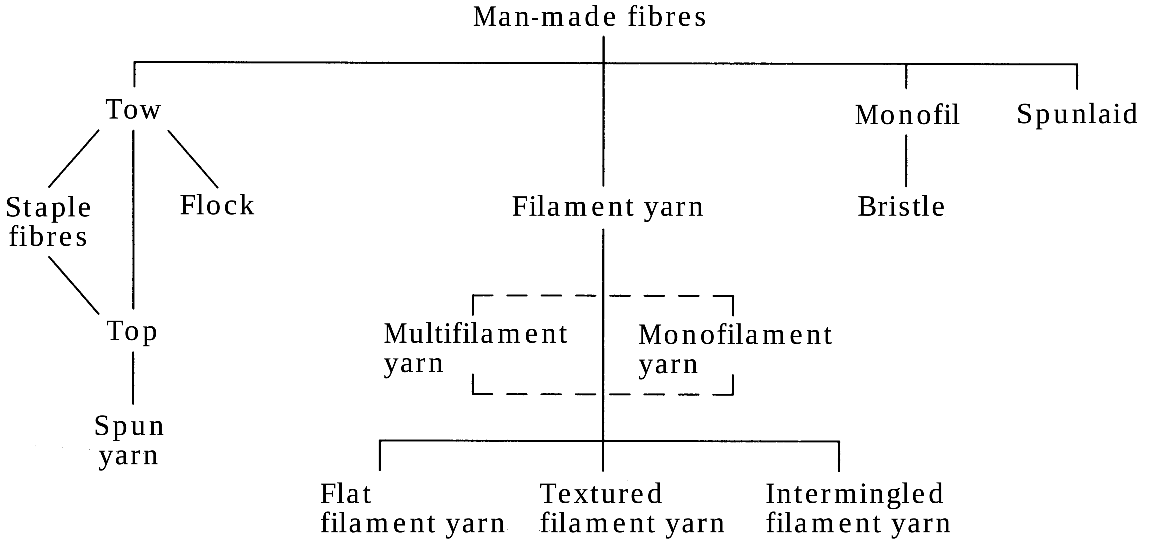


The variety of possibilities

The manufacturers of man-made fibres today are able, for example, to:

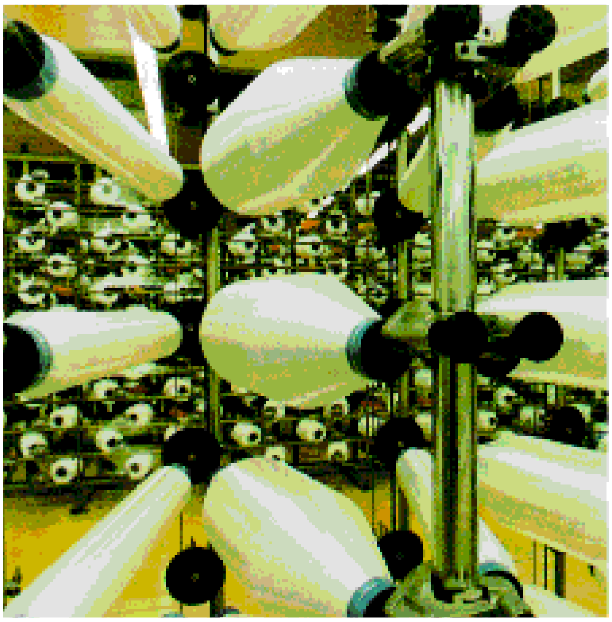
- Vary the fineness of filament yarns, the number of filaments and staple fibres;
- Determine the length of fibres depending on the application and mixture;
- Produce anything from a brilliant sheen to an ultra-dull look;
- Produce the cross-sections of the filaments in a round shape, in three, six, eight-sided or any other form;
- Alter the affinity for dyes of various classes;
- Determine the structure of yarns, be they flat, or textured or bulked yarns produced in various manufacturing processes.

Man-made Fibre Shapes



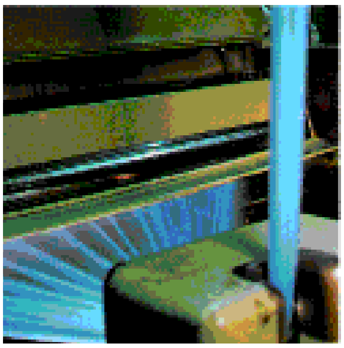
According to:
DIN 60001-2
DIN 60900-1
DIN 61210

The technical advantages



The use of man-made fibres gives numerous advantages to the manufacturing industry:

- Spinning mills, twister and texturizer appreciate the good running properties,
- Weavers and knitters take advantage of the good processing qualities, evenness and yarn strength,
- As a result of the various degrees of colourability and heat fixation, dyers and finishers attain colourful, near to crease-free products which keep their shape while employing environment-friendly finishing technology.



The advantages for the consumer

Consumers particularly appreciate the following properties of man-made fibres:

– Fashion oriented variety
– Durability
– For washable items the ability to keep their shape
– Colour-fastness
– Fastness to light
– Easy care
– Thermal insulation
– Elasticity
– Long life of technical products due to high-tenacity yarns.

Titre designations

In addition to the type of material (viscose, polyester, polyamide, etc.) a yarn is defined by its fineness. For this reason it is given a titre. A titre is the unit of measurement for the fineness of yarns.

In the case of filament yarn, the DEClTEX is the unit of measurement still employed today, just as manufacturers and processors of staple fibres express the titre by using the metric number Nm.

The titre expressed in dtex corresponds to the mass of a yarn in grams at a length of 10,000 metres.

The titre in metric numbers (Nm) indicates the length of the yarn in meters per gram.

The designation of the titre using the international TEX unit is only slowly gaining acceptance. The titre in TEX corresponds to the mass of the yarn in grams at a length of 1000 m. For tow the unit KILOTEX is used (weight in grams per meter).

Titre Designations

Tex system = tex = g/1000 m
dtex = g/10,000 m

For spun yarn there is also the Nm system = m/1 g

Examples:

Filament yarn

44 dtex f10
- f10: Number of filaments in the yarn = 10
- 44 dtex: 10,000 meters weigh 44 g

Staple fibres

1.7 dtex/40
- /40: Lenght of cut = 40 mm
- 1.7 dtex: 10,000 m weigh 1.7 g

The process

In the yarn, the molecules are more or less aligned in the direction of the yarn axis.
Upon weaving and knitting, the straight yarn is mechanically forced into an arched form.
The chain molecules, however, want to bend back into a straight line, i.e. the stitches or folds are unstable.
If the yarns are heated, the macro-molecules can enter into new anchoring and retain this shape upon cooling.

The advantages

During heat-setting, weaved and knitted materials manufactured from synthetic fibres become form-stable. They do not shrink and do not change in shape even upon washing.

The fabrics

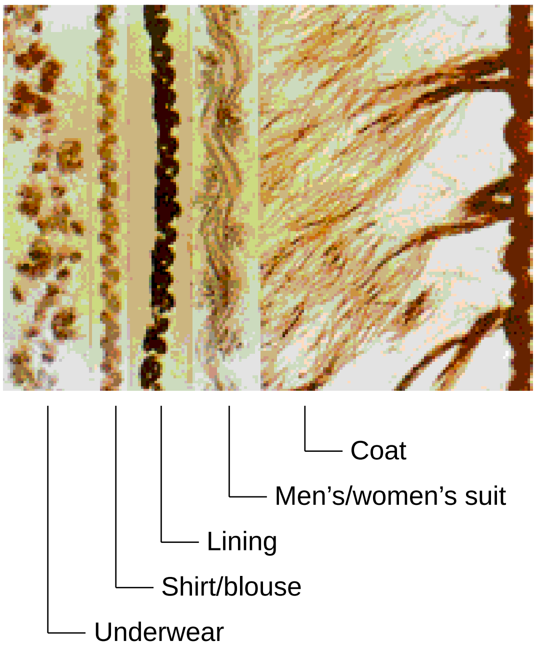
When processed into apparel fabrics, the man-made fibres fulfil all desires and demands on textile fabrics: in all colours, in all patterns and structures, as ornamentation, as a symbol of status or way of life, soft and fluffy, fine and delicate, coarse and tough, for staying cool or keeping warm.

The functions

Many factors determine the value of modern apparel fabrics. They must protect our body from adverse weather and environmental influences, both day and night, in cold and in warm climates, inside and outside buildings, at low exertion levels as well as during strenuous physical efforts.

The system

Our clothing consists of a system of different layers of fabric, each with its own tasks of supporting the life functions of the human organism. On the one hand, the body is to be shielded from external influences and on the other hand, natural perspiration absorbed and transported to the external surface. Dampness can best be channelled away from the body when the yarns of a fabric do not lie flat on the skin. In this way, a fine cushion of air is created to ensure ventilation. In the case of spun yarn, this effect is achieved by the ends of the yarns standing out from their surface. The same effect is achieved for textured yarns by the crimped arches of the yarns.



The layers of clothing

Handling of textiles

Textiles manufactured from man-made fibres reduce efforts made in cleaning and care. They are labour-saving, energy-saving and save on laundry-detergent.
The large selection of modern fabrics manufactured from man-made fibres and their combinations with natural fibres must, however, be handled properly.

The care symbols for textiles

Before washing or cleaning one should be sure to check the care label and proceed according to the instructions given.

The properties of textiles

Utility textiles can be divided into two groups according to their properties:
Group One: For this group, dry cleaning is absolutely necessary. Men's and women's suits and coats made of wool and some wool-man-made fibre mixtures belong to this category.
Group Two: This group does not require dry cleaning. Washable items belong to this category. For the most part they can be cared for at home and are usually made of man-made fibres or other fibres which have been chemically treated.

Wash cycle	95	95	60	60	40	40	40	30		
	Normal wash cycle	Gentle wash cycle	Normal wash cycle	Gentle wash cycle	Normal wash cycle	Gentle wash cycle	Special gentle wash cycle	Gentle wash cycle	Hand wash	Do not wash
	The figures in the wash basin are the maximum washing temperatures, which may not be exceeded. The bar under the wash basin indicates a (mechanical) milder treatment, for example, a gentle wash cycle. It indicates wash cycles suitable, for example, for easy-care and mechanically sensitive articles.									

Bleaching (triangle)	Cl	
	Chlorine bleach possible	Chlorine bleach not possible

Ironing (iron)				
	Iron hot	Iron medium hot	Do not iron hot	Do not iron
	The dots indicate the temperature range for ironing.			

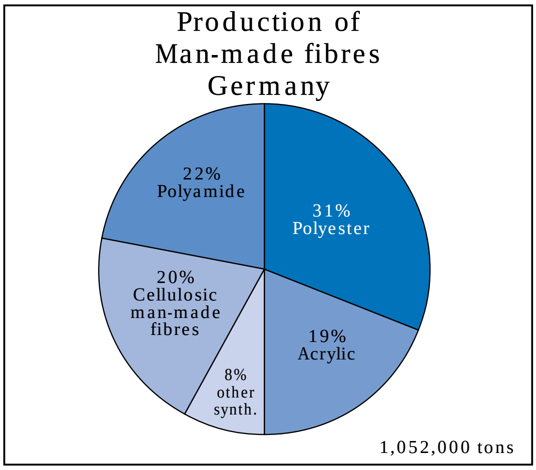
Dry cleaning (Cleaning drum)	A	P	P	F	F	
						No dry cleaning possible
	The letters are for dry cleaning. They indicate which solvents may be used. The bars underneath the circles indicate a limitation of the mechanical stress, addition of moisture and the temperature when dry cleaning.					

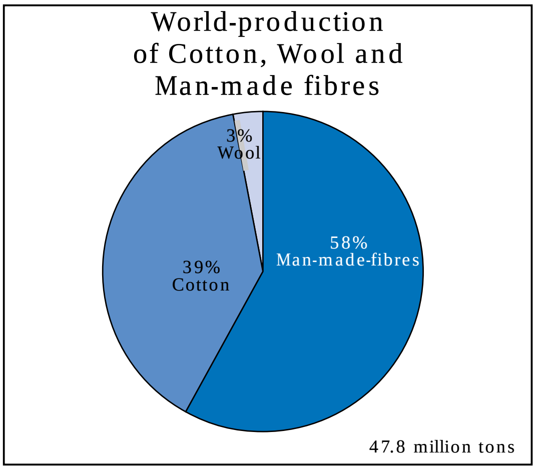
Tumble drying (dryer drum)			
	Dry at normal heat	Dry at reduced heat	Do not tumble dry
	The dots indicate the dryer setting of the tumble dryer.		

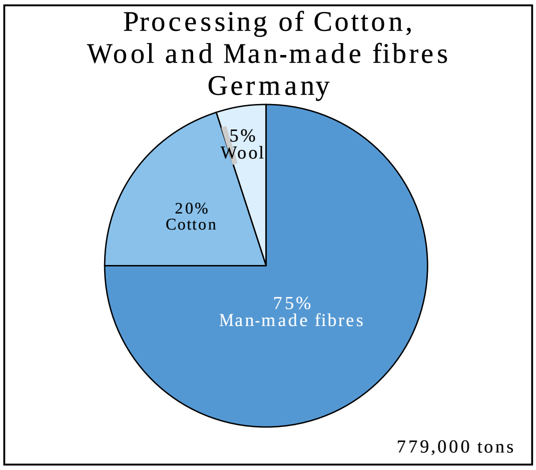
The Significance of Man-made Fibres for the Textile Market

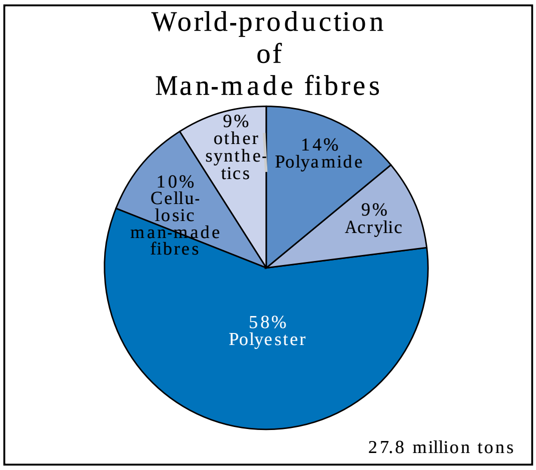
The development

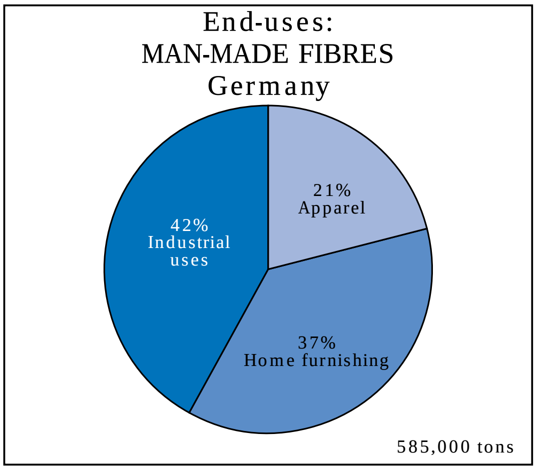
In this century man-made fibres have brought about an almost revolutionary development in all parts of the textile industry. In Germany just as in the other industrialised countries of the world, man-made fibres have become the most significant textile raw materials by far.









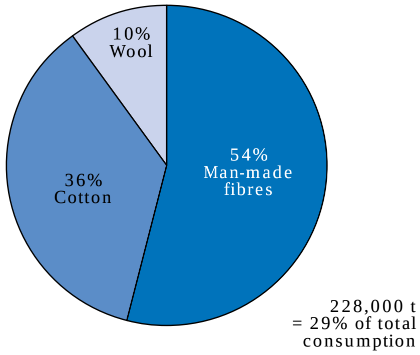


The Significance of Man-made Fibres for the Textile Market

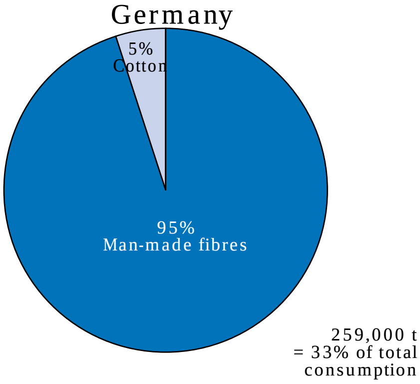
Man-made fibres
in Germany

	1990	1998
Production in 1,000 t	990	1.052
of which:		
Polyamide	220	235
Polyester	333	323
Acrylic	187	201
Other synthetic man-made fibres	70	85
Cellulosic man-made fibres	180	208
Turnover in Billion DM	6.4	6.0
Employees	29,400	19,700

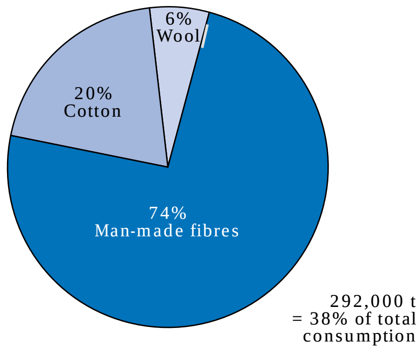
End-uses:
APPAREL
Germany



End-uses:
INDUSTRIAL USES
Germany



End-uses:
HOME FURNISHING
Germany



The future

The large market share of man-made fibres underscores the advantages of man-made fibres in processing and usage. The textile market is no longer thinkable without man-made fibres.

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