The Rieter Manual of Spinning
Volume 7

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Volume 7 – Processing of Man-Made Fibres

Prof. Dr. Thomas Weide

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Volume 7 – Processing of Man-Made Fibres

Prof. Dr. Thomas Weide

THE RIETER MANUAL OF SPINNING

Volume 1 – Technology of Short-staple Spinning

This deals with basic, generally valid, technological relationships in short-staple spinning. Subsequent volumes are organised according to machines or machine groups. This separates generally valid basic principles from ongoing developments in machine design and construction.

Volume 2 – Blowroom & Carding

In-depth information is provided on opening, cleaning, blending and carding and additional aspects are covered such as acclimatisation of raw materials, anticipated waste from various grades of fibre, selection and setting of cleaning and blending machinery, waste recycling, transport and the functions of the various card components as well as selection and maintenance of card clothing and autolevelling systems.

Volume 3 – Spinning Preparation

Here the technical and technological aspects of the yarn production process between carding and ring spinning are covered, that means draw frame, combing section (including combing preparation) and roving frame. This is an important process stage, because the yarn quality largely depends on the quality of the intermediate products from which it is made.

Volume 4 – Ring Spinning

Technical and technological aspects of ring spinning are covered. This is the final process in yarn production. The ring spinning machine greatly influences the yarn and its quality. Ring-spun yarns still represent the standard for comparison when evaluating yarns produced by other spinning processes.

Volume 5 – Rotor Spinning

This process resulted from research into alternative spinning systems. This volume contains in-depth information on the rotor spinning process and its properties. Continual improvements in spinning elements and conditions make it now possible to spin a rotor yarn optically similar to a ring-spun yarn.

Volume 6 – Alternative Spinning Systems

To take full advantage of alternative spinning systems, a thorough understanding of them is therefore essential. This volume contributes towards reaching this goal by describing the most important alternative spinning systems in detail. One of them is the well known air-jet spinning technology.

Volume 7 – Processing of Man-Made Fibres

Ever since the introduction of man-made fibres on a commercial scale, the market share of synthetic fibres has shown an impressive growth rate. In this important field, the variety of man-made fibres with different properties is continuously increasing. For numerous applications today, fibres that are practically “tailor-made” are available. Spinners must therefore have detailed understanding of the fibre properties and the specific characteristics that affect their processing.

EDITORIAL

With Volumes 1-7 of the „Rieter Manual of Spinning“, Rieter makes available comprehensive knowledge of the whole short-staple spinning process. The development of the current process technology has been dominated from its very beginnings to well into the last millennium by cotton.

The story of „man-made fibres“ goes far back into the 17th century and in this volume is also briefly revisited. The original drive for the development of man-made fibres was to replace cotton and thus the complicated process from the fibre to the yarn. An artificial endless thread, initially following the example of silk, was the dream. If the current diversity of products and applications with which synthetic filaments can be produced is traced back, then this dream has been largely realised and furthermore leaves a great many options open. In 2013, a fibre consumption of approx. 83 million tons, excluding non-wovens, was recorded. Filaments with approx. 38 million tons achieved a share of almost 45 % of the global fibre consumption.

Nonetheless, this stormy development of filaments with their innovations could not displace cotton and the short-staple spinning process. In 2013, around 24 million tons of cotton were still processed – far more than half the processed staple fibres of approx. 44 million tons. Cotton is therefore still a very important raw material and this not only for the textile industry but also for the social and industrial development of numerous countries.

Already in the last century, the cotton harvest was insufficient to meet demand. This is the foundation for the equally dynamic development of the synthetic staple fibre production with focus on polyester and viscose fibres. These fibres have partially given staple fibres access to new areas of application and also completely replaced earlier cotton applications. In addition, and that is today by far the greatest component, blends of cotton with synthetic fibres and blends between synthetic fibres allow yarn characteristics to change. These yarn developments aim to achieve better wearing properties, easier care properties, a change in the final fabric in relation to structure or appearance or an increase of the economic suitability.

The blending of raw materials presents new challenges to the short-staple spinning process. The processing of blends is often more difficult than the pure raw material alone. For this reason, this volume specifically deals with these raw materials and their processing. In particular, when the raw material is selected not as a replacement for something but as a tool for something new, it opens exciting possibilities to the spinning industry. To discover these is what I wish readers of this volume.

Our special thanks also go to Dr. Thomas Weide who essentially contributed to this volume based on his wide experience in the field of processing man-made fibres.

Edda Walraf, Vice President Marketing, Rieter Spun Yarn Systems

CONTENTS

1. INTRODUCTION

Since the first production of an artificial fibre in 1855 the man-made fibre technology has been a great success story. Global man-made fibre production (filaments and staple fibres) increased constantly and reached an annual consumption of 55 million tons in 2011, representing more than 65 % of total fibre consumption worldwide (see Fig. 1). Approximately 44 % of the produced man-made fibres are converted to staple fibres. Today it is not possible to ensure an adequate supply of textiles for mankind without the exploitation of man-made fibres.

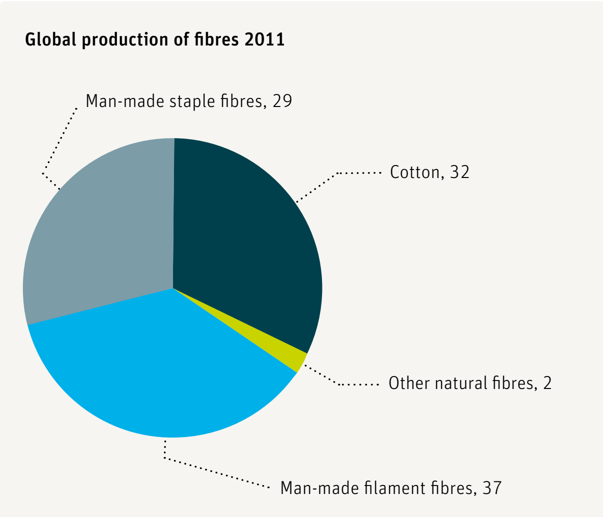


Fig. 1 – Global production of fibres in 2011 [1]

It is expected that worldwide man-made fibre consumption will still increase significantly. Fig. 2 shows the development of the world population and the worldwide fibre consumption per head from 1950 to 2011. It can be clearly seen that these two values increased dramatically over the years. In the future, both world population and absolute fibre consumption per head are expected to rise further, but production of natural fibres can be expanded only slowly (see Fig. 3). The expected substantial rise in the demand for fibres throughout the world during the coming decades must therefore be satisfied by increased use of man-made fibres. The fibres themselves, and hence the know-how involved in processing them, are therefore steadily acquiring greater significance.

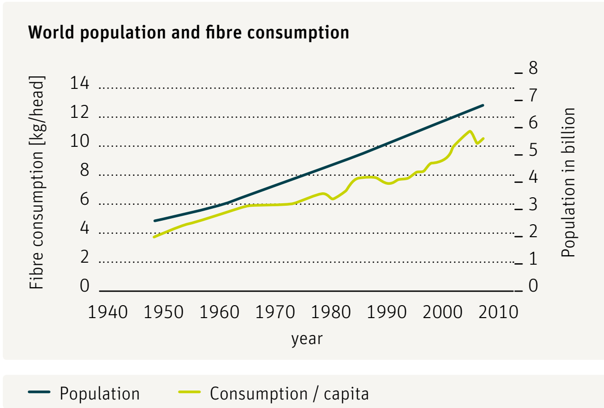


Fig. 2 – World population and fibre consumption over the years [2]

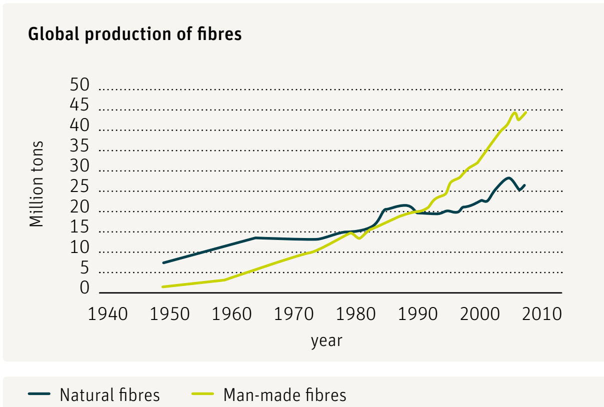


Fig. 3 – Global fibre production over the years [2]

2. OVERVIEW OF MAN-MADE FIBRES

2.1. History

The first patent about man-made fibre production traces back to 1855 when the Swiss chemist George Audemars invented a way to produce artificial silk. He dipped needles into a liquid mulberry bark pulp and gummy rubber and drew threads out of that solution. Though the method was too slow for practical use it was the beginning of a very successful new industry.
The first industrial production of a man-made fibre was realized by the Frenchman Hilaire de Chardonnet. His artificial silk was a cellulose-based fibre known as Chardonnay silk. He started 1891 to produce these fibres in Besancon (France) with a production of 50 kg per day.
In the same year a new way to dissolve cellulose and to spin a viscose yarn was invented by Charles F. Cross, Edward J. Bevan and Clayton Beadle in England. Later this yarn was also called rayon. Though it took a few years before this new method came into industrial and economical production it is still used today and known as the classical viscose spinning method (see chapter 3.2.2.1.).
The first patent for the production of a synthetic fibre was filed by Fritz Klatte in 1913 relating to spinning of polyvinylchloride fibres. However, mass production was not used until 1939 for various reasons.
In 1930 Wallace H. Carothers from DuPont found the first polyester out of which it was possible to draw fibres. But due to the low melting point of that material he focused on making polyamide fibres. He succeeded in 1935 with spinning polyamide 6.6 fibres which were introduced to the market in 1940 and are known as nylon.
To circumvent the DuPont polyamide fibre patents, the German Paul Schlack found a way to produce fibres out of polyamide 6 in 1938. Mass production of the so-called perlon fibres only started in 1950 because of the war.
In 1941 J. R. Whinfield and J. T. Dickson invented in England a melt spinning process for polyester fibres by polycondensation (see chapter 3.2.1.) which went into mass production after the war. Polyester became soon the most important man-made fibre type in the fibre industry.
After finding an appropriate solvent, polyacrylonitrile fibres were first spun in 1942 by Robert Hein (only two months later DuPont made the same invention).

2.2. Man-made fibre types

There is a huge variety of man-fibres that can be produced today. The whole group of man-made fibres can be divided into three major categories:
- natural polymers
- synthetic polymers
- inorganic materials.

In Fig. 4 a further subdivision of these major categories with examples for each group can be seen [2].

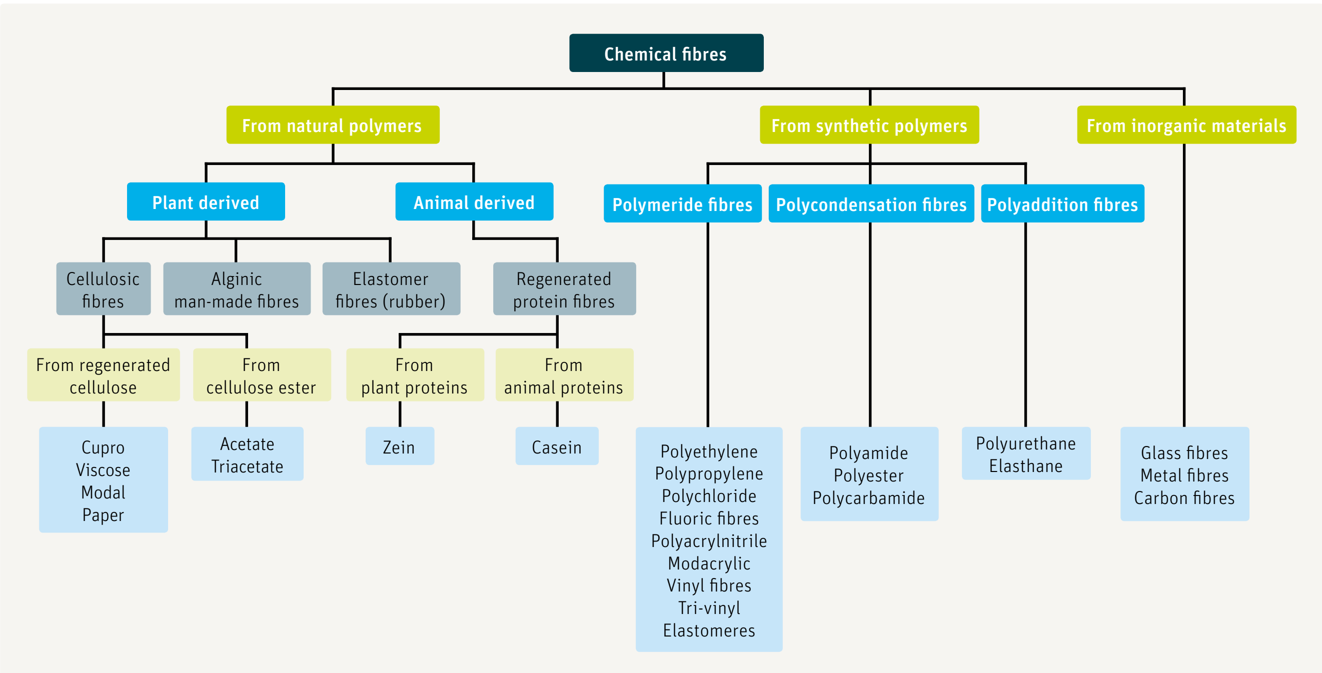


Fig. 4 – Categorization of chemical fibres [3]

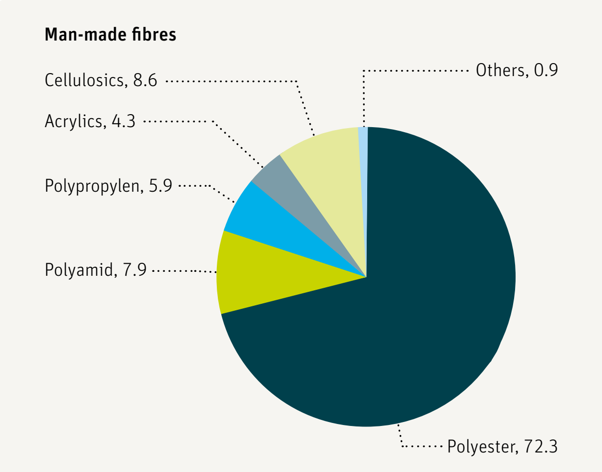


Fig. 5 – Percentage distribution of worldwide produced man-made fibres in 2011 [1]

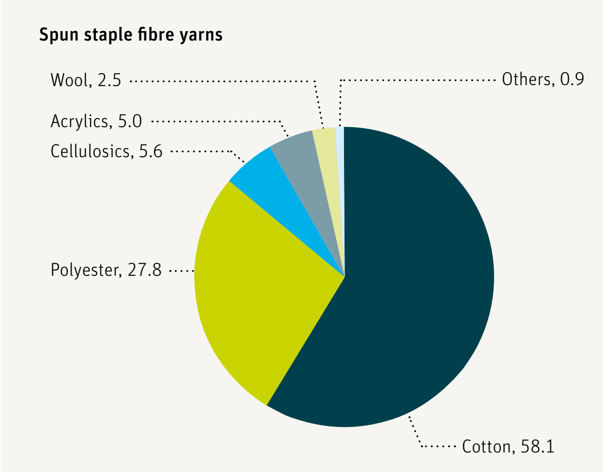


Fig. 6 – Percentage distribution of fibre materials used in spun staple fibre yarns in 2009 [2]

Despite the huge variety of man-made fibres only a few types have a significant market share of the worldwide produced man-made fibres (filament and staple fibres) which can be seen in Fig. 5. Polyester is by far the most important man-made fibre with a market share of more than 70 %. The remaining share is mostly taken by fibres made out of cellulosics, polyamides, polypropylenes and acrylics.

Focusing on the application of spun staple fibre yarns (short and long staple) the variety of used man-made fibres has further decreased. Fig. 6 shows the percentage of all (natural and man-made) fibre materials in staple fibre spinning. In this graph short staple fibres which are with a share of approx. 90 % the dominant group and long staple fibres are considered. In the short-staple spinning mill, beside the use of the natural cotton fibres almost exclusively polyester, cellulosic and polyacrylonitrile fibres are used. Accordingly, the following description will concentrate mainly upon these three raw materials.

2.3. Classifications and definitions

Designation	Definition
Man-made fibre	Generic name for filament yarn, staple fibre, monofilaments, etc.
Filament	Man-made fibre of very great length, e.g. several kilometers
Filament yarn	Man-made-fibre yarn comprising one or more filaments
Monofilament yarn	Filament yarn consisting of one filament with a thickness of up to 0.1 mm (above 0.1 mm = Monofilament)
Monofilament	Single filament with a thickness of more than 0.1 mm (up to 0.1 mm = Monofilament yarn)
Multifilament yarn	Filament yarn comprising many filaments up to 30 000 dtex (above 30 000 dtex = Tow)
Tow	Above 30 000 dtex (below 30 000 dtex = Multifilament yarn)
Staple fibre	Fibres of limited length
Short-cut fibre	Used for (e.g.) pile coatings, and production of nonwoven by the wet process
Web	Textile structure of filament or staple fibre held together by inherent adherence
Non-woven	Web or wadding strengthened by mechanical and/or chemical means
Sliver	Continuous strand of predominantly longitudinally oriented fibres without twist
Roving	Draftable fibre strand with protective twist
Staple-fibre yarn	Spun yarn of staple fibre
Texturized filament	Filament yarn treated mechanically or thermally to impart volume and/or elasticity
Assembled yarn	Multiple yarn of two or more filament or staple-fibre yarns (single or plied) wound together
Plied yarn (twist)	Multiple yarn of two or more filament or staple-fibre yarns (single or plied) twisted together

Table 1 – Classifications and definitions (according to ISO Standard)

3. MANUFACTURE OF MAN-MADE STAPLE FIBRES

In the first part of this chapter the general steps of the production of man-made fibres are theoretically introduced. In the second part the production of the man-made fibres which are mostly used in short staple spinning is described.

3.1. General production steps

3.1.1. Polymer

All man-made fibres have one feature in common – in the first phase of their manufacture, long-chain molecules are formed by a sequence of predominantly chemical process stages. Each long-chain molecule consists of a large number of identical individual molecules bound together in a row. Depending upon the raw material, a chain of this type can be made up of dozens, hundreds, or even thousands of individual molecules. The resulting substance is called a polymer. The polymer-manufacturing process is the determining factor for many basic characteristics, such as density, ability to absorb moisture, melting point, behavior in relation to dye and burning temperature. Additives can also be incorporated into the polymer to adjust the character of the textile raw material. Thus, delustring agents (titanium dioxide), dyes, and lustring agents can influence the appearance of a raw material, while other additives can be used to raise the ignition temperature or to alter behavior in response to selected dye groups.

3.1.2. Spinning

The prepared polymer, in the form of a viscous fluid, is forced through the multiple holes of a spinning nozzle so that a correspondingly large number of streams is created, as in a shower. These so-called filaments are then strengthened. These process steps can be realized by three different spinning principles as follows.

3.1.2.1. Melt spinning

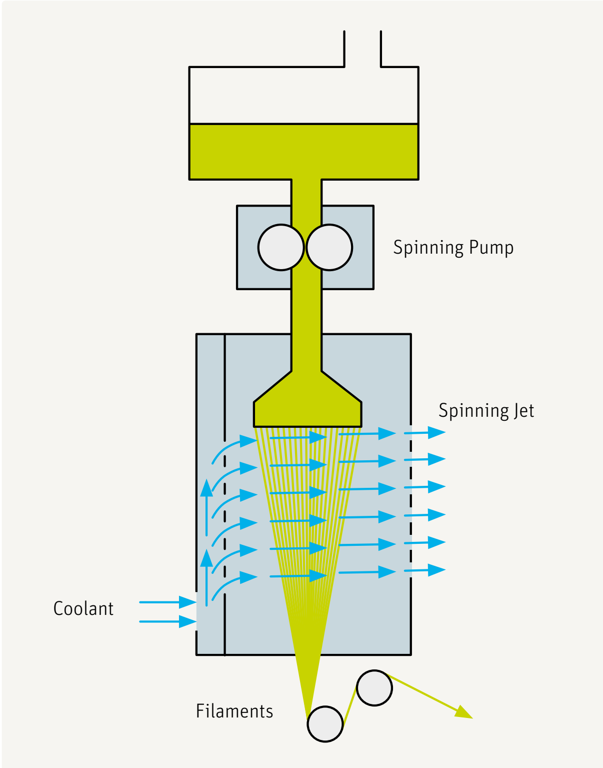


Fig. 7 – Melt spinning

The polymer is fed to the spinning nozzle as a hot molten material. The extruded filaments are cooled by an air stream in the cooling duct so that they can be coiled in carts without sticking together as a bundle (Fig. 7).
This process is used for spinning polyester, polyamide, polyolefin, and glass fibres (amongst others). It is a feature of melt spinning that filaments with all possible cross-sections can be produced by suitable choice of the hole section in the spinning nozzle (e.g. round, triangular, star-shaped, etc.). The other spinning principles, now to be described, enable this to only a limited extent.

3.1.2.2. Dry spinning

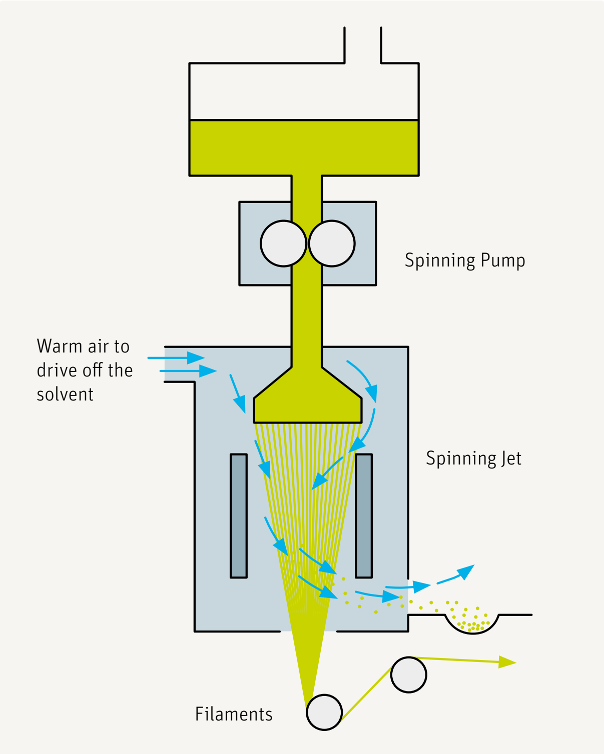


Fig. 8 – Dry spinning

In dry spinning, the polymer is first dissolved in a solvent which is vaporized in the spinning duct by means of hot air leaving the polymer in the form of solidified filaments (Fig. 8).

3.1.2.3. Wet spinning

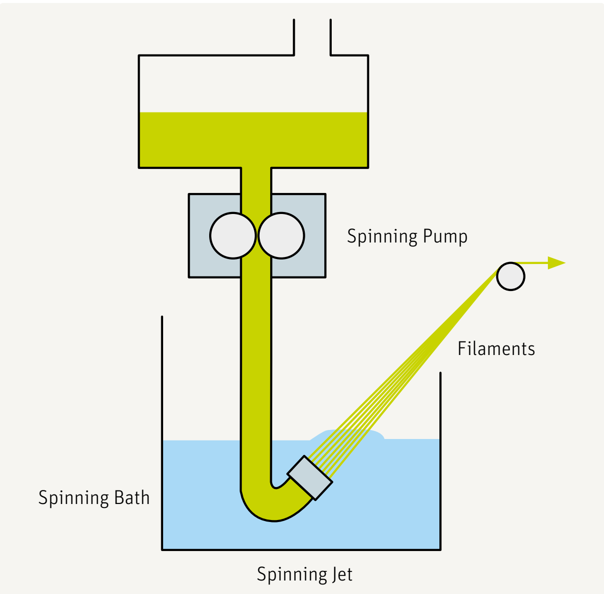


Fig. 9 – Wet spinning

The polymer is also spun in the form of a solution in this process. However, the filaments are strengthened by extraction of the solvent instead of the vaporization step used in dry spinning. The solvent can be extracted either by simply washing it out or by a chemical reaction between the polymer solution and a reagent in the spinning bath. Wet spinning is used to make viscose, aromatic polyamide, and some polyacrylonitrile fibres (Fig. 9).

3.1.3. Drawing

After the consolidation of the spun fibres the chain molecules are more or less randomly oriented. To acquire the definitive stress-strain characteristics, these chain molecules have to be parallelized and aligned in the longitudinal direction by the drawing process. In this process the filaments are extended many times their original length by the use of two or more godet pairs (see Fig. 10); each downstream godet pair runs faster than the godet pair before.

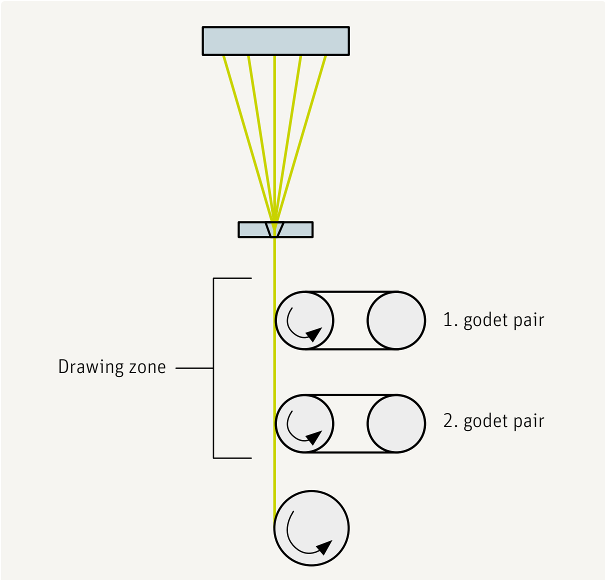


Fig. 10 – Drawing process

The drawing process can be done in a single process step to a fully oriented yarn (FOY) directly after spinning (as it is shown in Fig. 10) or in two process steps. In the latter case the fibres are only partly drawn to a partially oriented yarn (POY) and the final drawing process to fully oriented yarn (FOY) is done at the next process step (e.g. texturizing). Depending on the degree of orientation filament yarns have different names:

- LOY low oriented yarn
- MOY medium oriented yarn
- POY pre (partially) oriented yarn
- HOY high oriented yarn
- FOY fully oriented yarn.

3.1.4. Setting

Temperature treatment (steam or hot air) is used to achieve the desired residual shrinkage behavior. Setting can be carried out before or after imparting crimp and the stability of the crimp can be influenced in this way. Setting of viscose by heat treatment is possible only to a limited degree because this raw material responds less to temperature than to moisture. Accordingly, in this case, the severed tufts are allowed to shrink in hot water and in a tension-free condition; spin-bath residues are washed out simultaneously.

3.1.5. Finishing

Man-made fibres necessarily need a thin surface coating, the so-called spin finish, like the grease coating on wool and wax coating on cotton. Spin finish optimizes the fibre/fibre and fibre/foreign body (e.g. metal, ceramics) friction and acts as a lubricant. In addition the spin finish can affect such important characteristics as:
- anti-static behavior
- thread connections
- openability
- protection of the material.

In contrast to the described positive effects of the spin finish, it also causes problems in the downstream processes which will be explained in chapter 5.1.1.. The optimal spin finish composition represents the most favorable compromise between the previously mentioned positive, desired characteristics and the negative flow-on properties.

3.1.6. Crimping

The originally smooth fibres must be crimped for spinning to ensure better blending properties in combination with other fibre materials, and also in part to achieve a certain feel or volume in the end products. The operation is usually performed by means of a stuffing chamber in which the filament tow receives an irregular, two-dimensional, zigzag crimp. However, this principle is not suitable for treatment of viscose fibre which cannot be plastically deformed so easily. Accordingly, in this case, inherent shrinkage differences within the fibres are exploited; during the washing step (see Setting in chapter 3.1.4.), these differences give a slight three-dimensional crimp. Certain measures can be taken to reinforce the local shrinkage differences within the fibre and thus to achieve a more intensive crimp effect.

3.1.7. Drying

Heating of the filament tow, required for drawing and crimping, is often performed by means of hot water or steam. Spin finish is also often applied as a dispersion in water. Hence the drawn, lubricated, and crimped tow must be dried which is usually done in perforated-belt or drum dryers.

3.1.8. Cutting

Tow is often delivered directly to the worsted spinning mill, but the short-staple mill needs staple fibres cut to predetermined lengths. Filament tow is fed to a cutting device while being held under a defined tension; the resulting tufts are transported to the bale press and packed. In the case of viscose fibres, cutting is carried out straight after drawing, so that lubrication, crimping, shrinking, and drying are performed on tufts, not tow.

3.1.9. Pressing

The tufts are compressed in box-like presses to rectangular bales (sometimes cubes). A bale with a volume of between 0.5 and 1 m^3 contains between 200 and 400 kg of tufts. The trend is towards heavier bales for reasons of economy; limits to this tendency are set by floor loading in transport and storage and by the maximum permissible height of bales that can be presented to automatic bale openers.

3.2. Manufacturing of man-made fibres

As mentioned in chapter 2.2. there are only three man-made fibre types with a significant market share in the short fibre industry: the synthetic fibres polyester and polyacrylonitrile and the cellulosic fibres with viscose still representing the dominant fibre type in that category but also lyocell and modal fibres. The production methods of these fibre types will be explained shortly in the following chapters.
In general, a comparison of the production method of polyester (Fig. 11), polyacrylonitrile (Fig. 12) and viscose (Fig. 13) will reveal a basic difference between polyester on the one hand (two-stage process) and acrylic / viscose fibres (single step process) on the other.
Each of these processing types has advantages and disadvantages inherent in its operating principle. The two-stage operation in melt spinning gives the advantage of a lower number of spinning positions or nozzle jets. Furthermore, the separate downstream-process equipment

can be stopped for maintenance or minor repairs without causing problems, because the step of coiling material in cans serves as a material buffer. The associated disadvantage is that of a greater requirement for floor space to support cans and enable can transport. The disadvantages and advantages of wet spinning can be derived from the same considerations. Both these considerations also apply for other fibres that require separate downstream treatment because they are made by melt or dry spinning processes (e.g. polyamide, polyolefin, and dry-spun polyacrylonitrile fibres).

3.2.1. Manufacturing of synthetic fibres
3.2.1.1. Polyester (PES)

Polyester is made from ethylene glycol and terephthalic acid by splitting out water molecules, so it is a typical example for polycondensation where molecules are split out when the monomers join together.

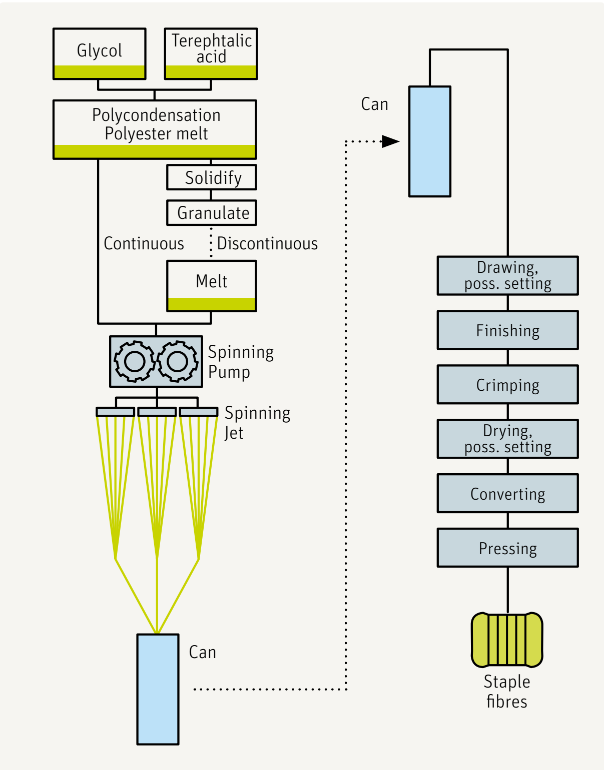


Fig. 11 – Manufacturing of polyester staple fibres

Fig. 11 shows the production of polyester-staple fibres. It can be seen that operations after the polycondensation stage can be performed continuously or discontinuously. In the first case, the polyester melt is fed directly to the jet by way of the spin pump while in the second case, a granulate is formed by allowing the material to solidify and then breaking it into pieces. The granulate can be transported and stored easily so that any desired number of spinning machines, in the same plant or elsewhere, can be supplied from a central granulate-production installation. In general, the more economic continuous process will be selected for large-scale production; for specialties, e.g. spun-dyed fibres, there are advantages in using the granulate route. The melt spinning process is separated from downstream processing. The intermediate product is spun at high speed (over 1 000 m/min) and coiled in cans. Large numbers of these cans are then presented as feedstock to the subsequent processing stage in which drawing, setting, finishing, crimping, drying and cutting (converting) takes place. The delivery speed of the second processing stage is not high enough to cope with the delivery speed of the first processing stage and therefore the two stages have to be separated.

3.2.1.2. Polyacrylonotrile

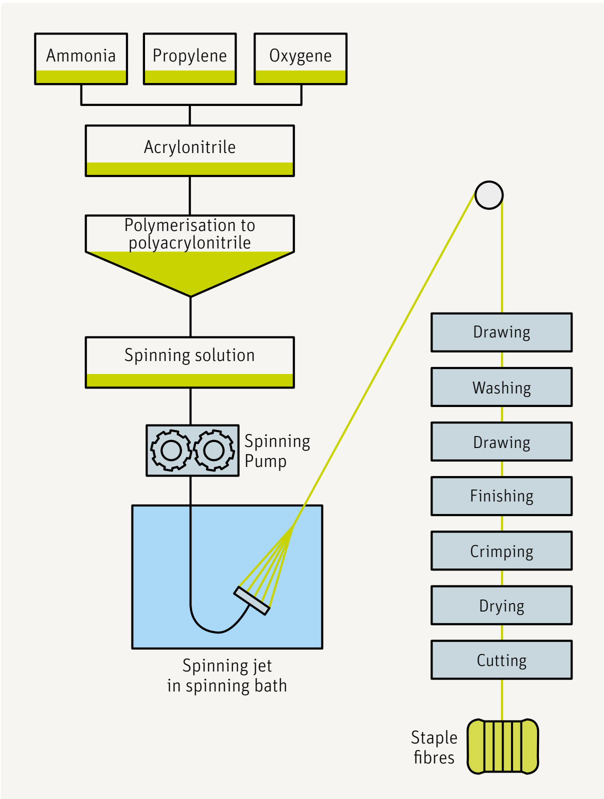


Fig. 12 – Manufacturing of polyacrylonitrile staple fibres

Polyacrylonitrile is manufactured by radical polymerization out of acrylonitrile which is made out of ammonia, propylene and oxygen. The spinning solution is then wet spun. Downstream processing is continuous with spinning. Wet spinning is performed at much lower speeds (about 100 m/min or less), so that the spun filaments can be treated directly (Fig. 12).

3.2.2. Manufacturing of cellulosic fibres

3.2.2.1. Viscose

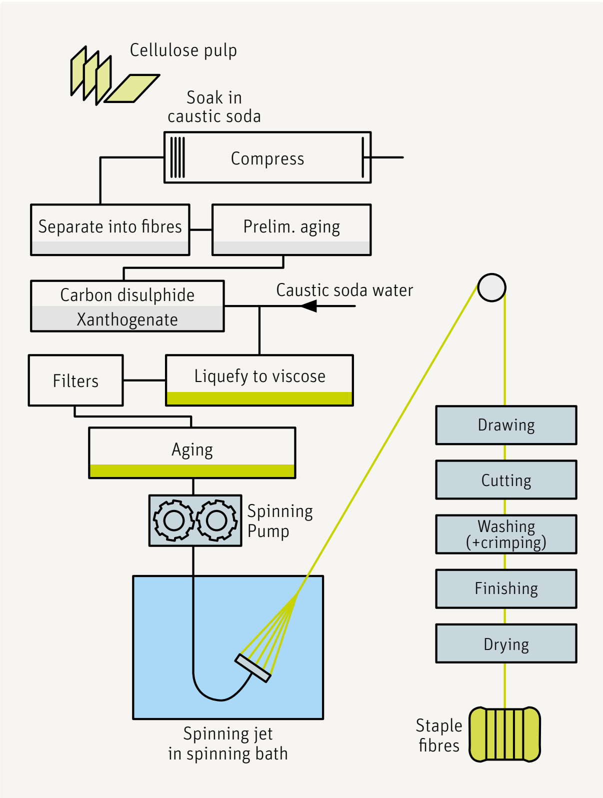


Fig. 13 – Manufacturing of viscose staple fibres

To manufacture a viscose fibre, cellulose pulp which is a natural polymer is dissolved in caustic soda, separated into fibres and allowed to age. The preliminary aged pulp is then treated with carbon disulphide to form a yellow-colored cellulose xanthogenate which is dissolved in caustic soda again to start the viscose formation. After filtering and aging it is wet spun to filament fibres.
Like the manufacturing of polyacrylonitrile fibres the downstream processing is continuous with spinning (Fig. 13).

3.2.2.2. Modal

Modal is a cellulosic fibre manufactured by a modified viscose spinning process with a higher degree of polymerization and a modified spinning bath. In comparison to viscose which is made out of wood pulp of different trees modal is made only out of beech wood.
As a result of the modified process modal fibres have improved fibre properties such as higher dry and wet strength.

3.2.2.3. Lyocell

In comparison to the manufacturing process of conventional viscose fibres lyocell is manufactured by a solvent-spinning process. The cellulose is directly dissolved in the solvent N-methyl-morpholine-N-oxide (NMMO) containing just the right amount of water. The solution is then filtered and wet spun to filament fibres. Because of the fact that in this spinning process the NMMO solvent is recovered and re-used the lyocell manufacturing process is very environmentally friendly.

4. PROPERTIES OF MAN-MADE STAPLE FIBRES AND THEIR EFFECTS ON SPINNING

The properties of man-made fibres are determined by three largely independent types of influence:

- **basic polymer**
  establishes certain basic properties such as density, moisture absorption, resistance to liquids, electrical conductivity (and hence the behavior in response to electrostatic charge), dyeability, flammability, and resistance to light and weather;
- **additives**
  the above-mentioned basic properties can be adjusted within certain limits by incorporating small quantities of other substances. This is done especially to modify behavior in relation to dyes, and flammability;
- **subsequent treatment**
  in this stage of the manufacturing process, some technological properties can be influenced to a very large extent, especially stress-strain behavior and shrinkage characteristics.

These wide-ranging possibilities of influencing the product, together with quality and price stability, represent the major advantages of man-made fibres. In many cases, it is possible to achieve optimal processing and use characteristics by selective application of specially developed fibres.

4.1. Structural properties
4.1.1. Fibre fineness
4.1.1.1. Significance

Fineness of man-made fibres can be selected within a wide range and adapted to the intended application. Nowadays, distinctions are drawn in accordance with the following scale:

• Super finest fibres	below 0.1 dtex
• Finest fibres (micro fibres)	up to 1 dtex
• Fine fibres	up to 2.5 dtex
• Medium-fine fibres	up to 7 dtex
• Coarse fibres	up to 70 dtex
• Coarsest fibres	above 70 dtex.

The short-staple spinning mill processes almost exclusively fine fibres between about 0.8 and 3.3 dtex. Though there is an increase in using microfibres below 1 dtex they are still not commodity fibre products for the staple fibre spinning process.

Finest and superfine fibres are used for the manufacture of synthetic leather, for very fine velour and velvets where an extremely soft feel is required, for filters and lining materials, etc.
As was described in The Rieter Manual of Spinning – Volume 1 the fibre fineness is one of the most important fibre characteristics and it affects virtually every yarn property. All properties improve with increasing fineness because with finer fibres more individual fibres can be packed into a yarn of a given section.

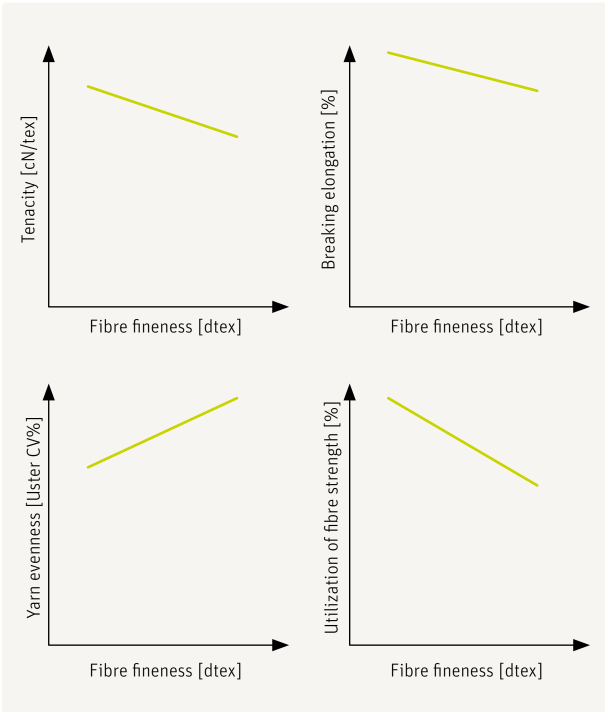


Fig. 14 – The influence of fibre fineness on yarn characteristics

The influence of fibre fineness on, for example, yarn strength, evenness and elongation is therefore very high and can be seen in Fig. 14 [4].
The number of thread breaks also declines with the use of fine fibres. Higher efficiency is then achieved in the weaving room. However, fine fibres are more expensive than coarse fibres, and finest fibres are notably more expensive. Furthermore, finer fibres always give rise to greater processing problems in the blowroom and the carding room. So the production rate has to be reduced significantly.

4.1.1.2. Numbers of fibres in cross-section in blended yarns

The number of fibres in the yarn cross-section n_F can be calculated approximately by (see The Rieter Manual of Spinning – Volume 1 for further details):

$$n_F = \frac{tex_{yarn}}{tex_{fibre}} = \frac{Nm_{fibre}}{Nm_{yarn}}$$

The average fineness of fibres in a blend can be derived from the relation:

$$tex_{fibre} = \frac{(P_x \times tex_x + P_y \times tex_y)}{100}$$

where P represents the proportion of fibres as a percentage and the index x represents one component and the index y the other.
Micronaire values can be converted into dtex in accordance with the formula:
dtex = micronaire x 0.394.

Examples for a cotton/man-made-fibre blend:

cotton:	4.5 micronaire
man-made fibre:	1.7 dtex
yarn fineness:	Nm 50; Ne 30; 20 tex (200 dtex)
blend ratio:	PES/CO:67/33

dtex cotton = 4.5 x 0.394 = 1.773

$$tex_{fibre} = \frac{(67 \times 1.7 \text{ dtex} + 33 \times 1.773 \text{ dtex})}{100} = 1.724 \text{ dtex}$$

Numbers of fibres in the cross-section:

$$n_F = \frac{200}{1.724} = 116$$

4.1.1.3. Spinning limits

As was described in the Rieter Manual of Spinning – Volume 1, the numbers of fibres in the yarn cross-section is an important parameter. Depending on the used spinning technology and on the fibre properties, as for example fibre length and fibre/fibre friction, a minimum number of fibres in the yarn cross-section, the so called spinning limit, is required.
Spinning limits according to different spinning technologies are indicated in the appropriate chapters.

4.1.2. Fibre length

As with natural fibres, most yarn characteristics improve with increasing length of fibres. Since man-made fibres are produced in endless form, and are subsequently converted to staple fibres in a manner enabling any desired fibre length to be selected, it may at first appear that the ideal has been achieved in this respect. However, this first appearance turns out to be misleading, because production processes used to make staple fibre yarn do not permit spinning fibres of any length – there are limits to the possible range of lengths:
- yarns made of overlong fibres tend to lose their textile character and can be used only for specific fields of application
- the various spinning processes are designed for predetermined maximum fibre lengths
- man-made fibres are used extensively in blends, where the length of the man-made fibre has to be matched to that of the natural fibre
- the slenderness ratio of the fibre has to be borne in mind.

The term "slenderness ratio" refers to the relationship of the fibre length to the fibre diameter (see The Rieter Manual of Spinning – Volume 1). In relation to man-made fibres, the ratio can be derived as follows:

Slenderness ratio = length (mm) x 100/dtex

To avoid problems, polyester fibres for use in the short-staple spinning mill should have slenderness ratios between 2 700 and 3 600.

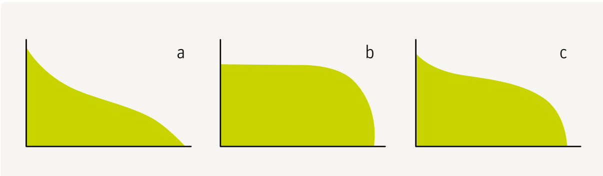


Fig. 15 – Shapes of staple diagrams:
(a) triangular; (b) rectangular; (c) trapezoidal

If the fibre is too short in relation to its diameter, it is stiff and cannot be bound into the fibre strand. On the other hand, if it is too long, it has no springiness or resilience to enable it to turn back to shape. Processing of this type of fibre leads to nep formation and fibre damage. If such fibres are bent or rolled up, they cannot be re-straightened. In spite of these limitations, the ability to choose fibre length remains one of the great advantages of man-made fibres.

An approximately rectangular staple (Fig. 15 (b)) is obtained after the cutting stage in the manufacturing process of man-made fibres. The lack of length variations leads to problems for example in the drawing processes (see Rieter Manual of Spinning – Volume 1). But the length evenness cannot be maintained because of the shortening of the fibres in the initial process stages, especially in the card. However, even in this case, the proportion of short fibres remains small which is an advantage because this fraction can generate many disturbances in spinning. The effect on the resulting properties is significant.
A relatively new technology is to cut man-made fibres in a way that the staple diagram is similar to that of cotton (trapezoidal, Fig. 15 (c)), especially for use in blends with cotton. The advantages of these materials are the easy processability in the spinning mill and a better yarn quality (except the slightly lower tenacity) [5].
It should nevertheless be kept in mind that short fibres generally enable higher carding efficiencies to be achieved than longer fibres.

4.1.3. Fibre cross-section

Natural fibres are usually curled, angular, have scales and are crimped; they seldom have a smooth round section. This gives them a typical textile character and feel. Man-made fibres must also exhibit a textile character if they are to be used in the textile field. They are therefore often formed with non-round sections such as indented, star-shaped, triangular, polygonal, etc. (Fig. 16). They can also be made hollow-formed.

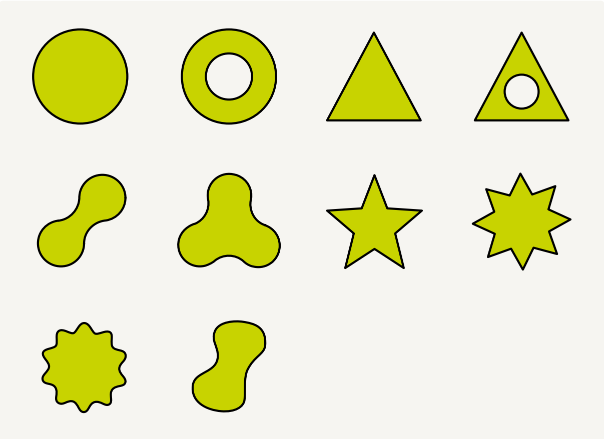


Fig. 16 – Some types of man-made-fibre cross-sections

The fibre section mainly influences the yarn volume, feel, insulating ability, luster, and working performance in processing.

4.1.4. Crimp

Natural fibres are mostly more or less strongly crimped or looped. Usually, man-made fibres must also be crimped. The crimp can be permanent or temporary, i.e. set, partially set, or onset. Set crimp is selected in order to achieve certain characteristics in the end product, such as:

- a full, bulked, soft feel, and
- high insulating capacity.

Partly set and upset crimp, selected for most fibres in the short-staple spinning mill, serves almost exclusively to improve the processability of the fibres. This form of crimp enables, for example, the following to be achieved, among other effects:

- better web and sliver formation, because the fibres inter-engage with each other
- easier opening
- an improvement in cardability, and
- reduction in drafting problems by avoidance of the glass sheet effect.

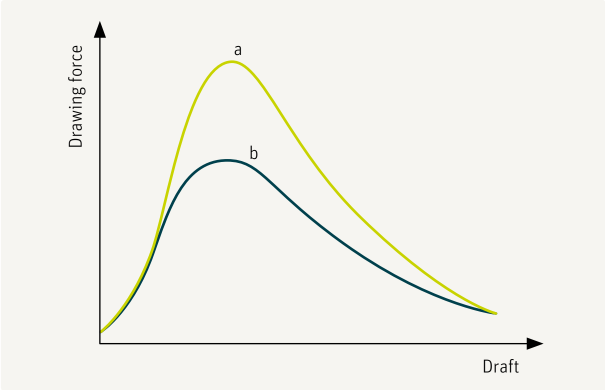


Fig. 17 – Drawing force for uncrimped (a) and crimped (b) fibres

However, if the crimp is too high, drawing problems increase because the required drawing force rises with increasing crimp (Fig. 17, 18).
Moreover, a high degree of crimp causes problems in processing the fibres in the normal type of rotor-spinning machine, or even makes such processing impossible. After the last draw frame passage, at the latest, crimp must be removed from fibres which are to be spun on the rotor spinning machine.
When considering the effects of crimp, it is important to bear spin finish in mind because it reinforces the effect of the crimp. There is interplay between these two factors. Many problems that appear to arise from spin finish actually have their origin in the crimp level, and vice versa.

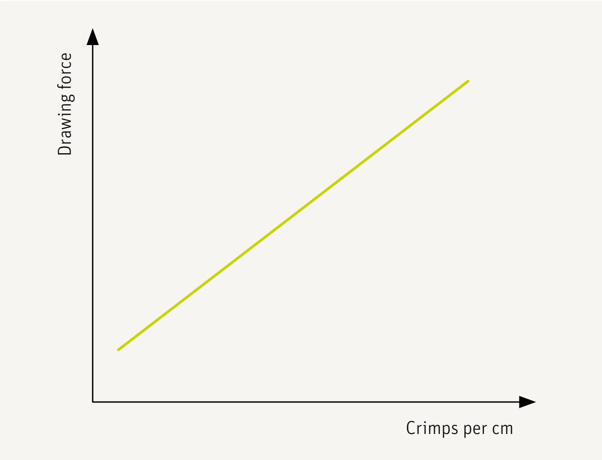
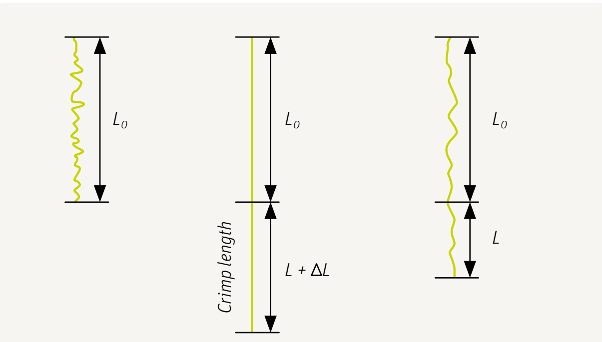


Fig. 18 – Drawing force versus intensity of crimp

The fibre crimp is usually reduced by carding and drawing forces in the spinning mill. The crimp itself and the change of the crimp can be measured by the parameters removing crimp, recovering crimp and crimp stability (see Fig. 19).



$$\text{Removing crimp} = \frac{L + \Delta L}{L_0 + L + \Delta L} \times 100\,\%$$

$$\text{Recovering crimp} = \frac{\Delta L}{L_0 + L + \Delta L} \times 100\,\%$$

$$\text{Crimp stability} = \frac{\text{recovering crimp}}{\text{removing crimp}} \times 100\,\% = \frac{\Delta L}{L + \Delta L}$$

Fig. 19 – Recovering crimp and crimp stability

The removing crimp can be seen as an indicator for fibre stress and parallelization work. It should be decreased continuously through all the process steps in a spinning mill. An abrupt drop of the removing crimp in a process step indicates that the fibre stress and the process settings should be optimized, accordingly are too high (Fig. 20).

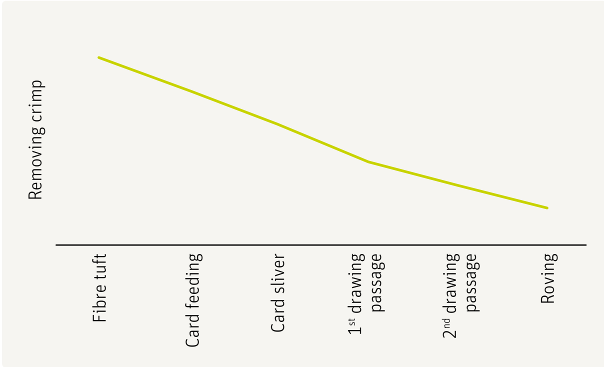


Fig. 20 – Change of removing crimp through the process steps

4.1.5. Fibre surface area

The surface area of the fibre is mainly dependent upon the form of the section. A round section gives a smooth fibre with high luster. If an indented, star-shaped, or polygonal form is chosen, the fibres lose smoothness and luster. If luster and smoothness are to be suppressed in round fibres, it can only be done chemically. In this case a delustrant (or roughening agent) is applied to the fibre.
Titanium dioxide (TiO_2) is used for this purpose. Unfortunately, delustred fibres of this kind have a highly abrasive character. In processing such fibres, wear on machine components will be very high. (Fibres dyed by pigments display the same effect.)
The degrees of delustring in Table 2 are commonly distinguished.

Level	Quantity of titanium dioxide applied (%)
Bright	0 – 0.05
Semi-matt	0.06 – 0.4
Matt	0.41 – 1.0
Strong matt	1.01 -2.1
Superstrong matt	Above 2.1

Table 2 – Degree of delustring

4.2. Physical properties
4.2.1. Fibre strength and elongation

Strength and elongation are connected by a cause/effect relationship and cannot be considered separately because when loaded in tension the fibre is simultaneously stretched. These two properties are therefore often quoted in combination as stress/ strain behavior, in the form of a stress/strain characteristic in the stress/strain diagram. Each fibre type exhibits a characteristic typical of itself.

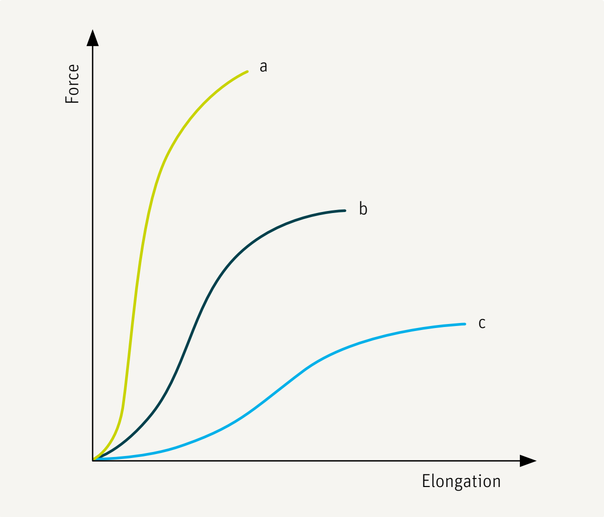


Fig. 21 – Strength / elongation diagram;
a) high tenacity; b) normal tenacity; c) low tenacity (high elongation)

In the case of man-made fibres, the stress/strain characteristic can be influenced within clearly defined limits, i.e. by drawing the fibre after spinning of the thread. A higher degree of extension gives higher strength together with lower elongation (high modulus, Fig. 21 (a); a lower degree of extension gives lower strength with somewhat higher elongation (low modulus, Fig. 21 (c)).
Akzo gives the fibre strengths of polyester fibres as follows:

- high modulus 40 - 60 cN / tex
- medium modulus 20 - 40 cN / tex
- low modulus 10 - 20 cN / tex.

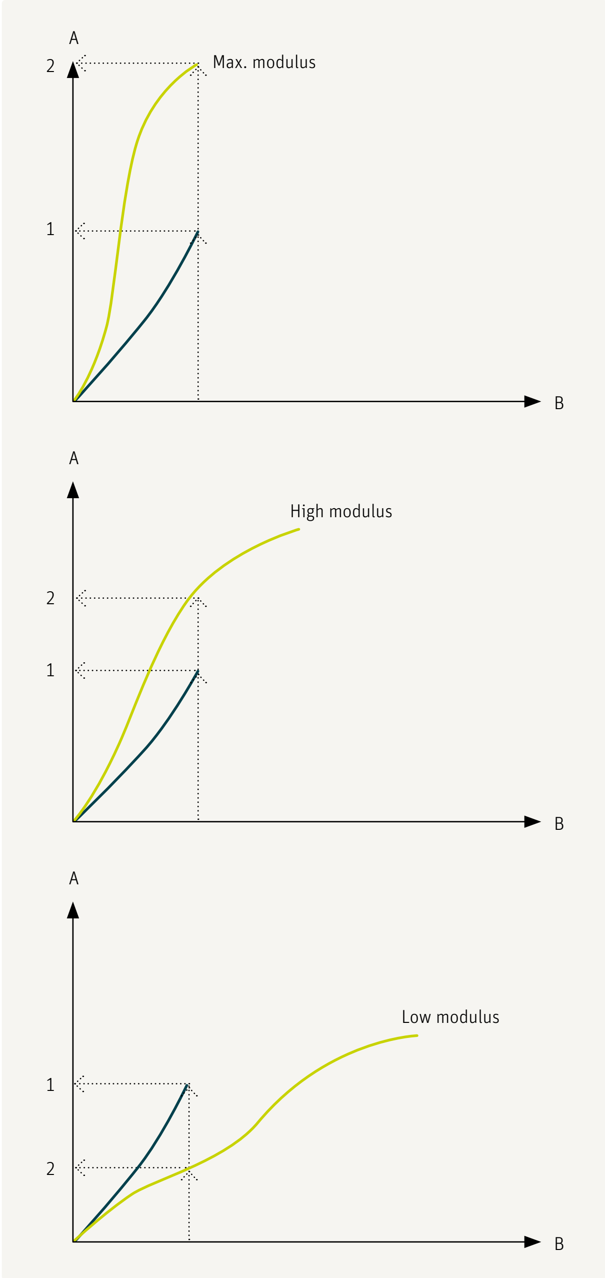


Fig. 22 – Cotton (1) / polyester-fibre (2 blend with maximum-modulus, high-modulus and low-modulus polyester-fibre)
A: tenacity B: elongation

In a blend, the stress/strain characteristic of man-made fibres should be adapted in a form approximating to that of the natural fibres because differences have strongly marked effects. This becomes plain from an explanation given by S. Kleinheins (Akzo) in relation to a polyester-fibre cotton blend and published in Melliand TextiIberichte (Fig. 22) (1: cotton; 2: PES) [6].

4.2.2. Lateral strength [6]

In the end product, fibres are stressed not only in the longitudinal direction but also laterally. This is typical in bending, as in yarn loops and knots; extremes can be reached, e.g. where yarn is used for sewing (loops) and in net (knots).
There are fibre materials that behave like a razor blade: very high longitudinal strength, very low bending strength. Glass fibres in particular belong to this category. For example, glass-fibre yarns cannot be joined together by knotting because, as the knot is drawn tight, the transverse load on the fibres leads to yarn breaks. Moreover, many regenerated-cellulose (polynosic) fibres are very brittle. Polyamide fibres are at the other end of the scale: they are extremely supple and have excellent lateral strength.

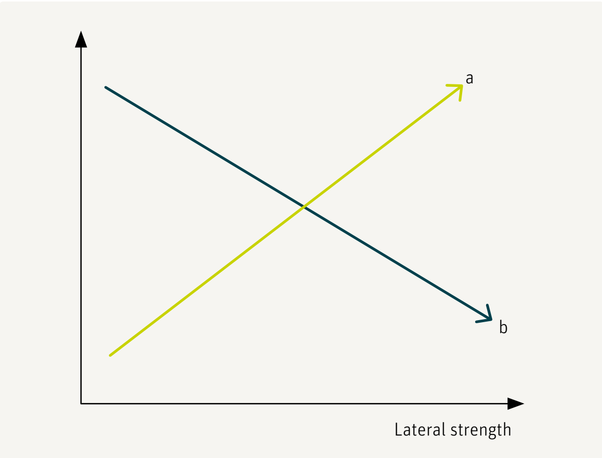


Fig. 23 – Effect of the lateral strength; a durability, b pilling resistance

A high lateral strength can be an advantage or a disadvantage depending upon the field of use (see Fig. 23). In general, high lateral strength gives good durability to the finished articles; this is very important in technical applications, in working clothes and uniform fabrics and also in floor coverings. However, the pilling tendency also increases so that in the civilian clothing sector only limited use is made of fibres with high lateral strength. This applies especially in relation to knitted goods, where the individual fibres are not so strongly anchored; for example, polyester fibre must be deliberately made brittle for use in knitted products to avoid pilling (anti-pilling types).
The expression “pilling” refers to the formation of fibre balls on the surface of a textile fabric. Such balls do not form where fibres with low lateral strength are used (wool, anti-pilling synthetic fibres), as such fibres can be very easily scrubbed off when they project from the surface; this is not true for fibres with a high lateral strength. In the latter case, the projecting fibres are not rubbed away but remain on the surface and spoil the appearance. Unfortunately it has to be said that pilling resistance and durability are inversely related to each other. Also, low lateral strength reduces carding performance and raises the tendency to fibre damage.
The following test methods are used to determine lateral strength:
• loop strength
• bending strength
• buckling rubbing strength
• torsional strength.

4.2.3. Shrinkage behavior [6]

In the course of processing, fibres do not always retain the length they had before processing started. Fibres can be shortened by various influencing factors during processing and use. This is referred to as “shrinkage”. Every fibre shrinkage leads automatically to a corresponding shrinkage in the yarn and /or in the fabric.
Usually, it is a heating, wetting, or wet-heating process that leads to shrinkage. Depending upon raw material, a fibre reacts more strongly to heat, moisture or moist heat. Thus, cellulose fibres (cotton, viscose) react to simple wetting and driving with noticeable shrinkage, while polyester fibre exhibits no change of length under the same circumstances. On the other hand, polyester fibre shrinks markedly under dry heat and still more under wet heat, while polyamide fibre reacts only to wet heat.

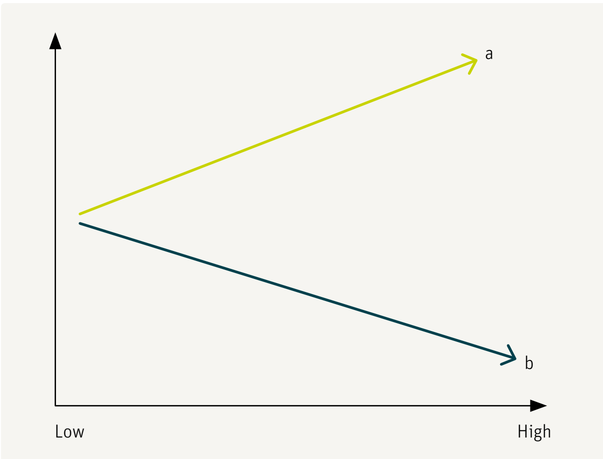


Fig. 24 – Effect of the shrinkage characteristics (low/high): (a) piece-dyeing behavior, dye-fastness, efficiency in weaving, fabric appearance; (b) crimp tendency, lateral run in knitted fabric, tendency to pilling, yarn dyeing behavior

The shrinkage characteristics of synthetic fibres can be selected within a wide range (from low to high shrinkage) by adjusting stretching and relaxing and by use of varying temperatures in the production stage. Admittedly, however, as Fig. 24 shows, there are certain interrelationships between the various characteristics.
For example, where the yarn is to be dyed in the package, a certain degree of shrinkage should not be exceeded because otherwise it is not possible to ensure problem-free penetration of the package by the dye liquor. On the other hand, high shrinkage can be an advantage as regards the feel and visual impression of the resulting product. High-shrink fibres permit a reduction in weft and warp density giving low ends-down levels and a high efficiency.
In the production of blends, the use of PES fibres with raised shrinkage can give notable improvements in feel and wearing behavior because the shrinking PES fibres migrate into the core of the yarn while the natural fibres stay on the surface. If man-made fibres are subjected to wet-hot processing, it is essential to know the shrinkage behavior in advance.

4.3. Behavior against environment [6] [7]
4.3.1. Moisture

Almost all fibre material contains a certain quantity of water. The magnitude of this water proportion depends upon the raw material and the environmental conditions. Distinctions are drawn, for example, between the following criteria:
- moisture take-up from the air
- water-retention capability after soaking and centrifuging
- water take-up after soaking and drip-draining.

Moisture take-up and water-retention capacity are dependent practically only upon the raw material, while in relation to water take-up the design of the textile also plays a major role in determining the result.

	Water from the air (65 % rh) %	Water after soaking and centrifuging %	Relative wet strength %
PES	0.5	2 - 5	100
PAC	1 - 2	7 - 10	90 - 95
PA	4 - 5	10 - 15	85 - 95
Viscose	12 - 14	60 - 110	45 - 75
Cotton	7 - 8	45 - 50	100 - 110
Wool	14 - 15	40 - 45	70 - 90

Table 3 – Behavior in relation to water

In the case of man-made fibres, there is a clear relationship between the ability of the raw materials to take up water and their strength in the wet condition. The more water a fibre can hold, the greater is the difference between wet and dry strength. The relative wet strength is generally given as the measure of this effect, and is expressed as a percentage of the dry strength.
Depending upon their field of use, fibres with a higher or lower moisture take-up will be required, e.g. high – hand towels, underclothing; low - bathing costumes.
In relation to clothing, however, it is not only the moisture take-up that is important but also the ability to transport moisture and wettability. Both properties have a strong influence on wearability. They depend upon fibre surface area and the capillary effect on the fabric. Thus, although PES has a low moisture take-up, good moisture transport can be reached by means of appropriate apparel design (Table 3).

4.3.2. Temperature

Textiles react to heat in the most varied ways, depending upon the raw material and temperature. The reaction can vary from simple shrinkage through change of color, softening and/or becoming sticky to melting, decomposition, or carbonization.
Unfortunately, the frequently raised question regarding temperature resistance of individual raw materials cannot be answered by quoting a single figure, or even a sequence of figures. The number of influencing factors is too large to enable a comprehensive answer to be given to an issue of this magnitude. Thus, heat resistance is affected by the following influences (amongst others):
- medium
- temperature
- time of subjection to heat
- structure of the sample
- associated substances
- evaluation parameter (quantity).

Polyamide and polyester are melt-spun fibres. This means that they have a clearly defined melting point. When a certain temperature is reached, they liquefy almost without any intermediate phase. In the region just below melting, however, there is increasing softening and stickiness, so that in use it is not advisable to come within 20 - 30°C of the melting point for even short periods. Otherwise, permanently adhered locations are created which will alter completely the character of the textile.

Below the softening region lies the broad zone in which setting is possible. Here, heating and cooling with the material in a given form can result in the establishment of this form as the normal condition of the material to which the fibres always tend to return. Pressing-in of a crease belongs to these procedures, as does setting of crimp or removal of unwanted creases by ironing.
The other fibres are practically non-settable under heat. They do not react to increasing temperature by becoming soft and melting but by increasing degrees of decomposition and brittleness; this is usually accompanied by noticeable change of color and can extend to genuine carbonization.
All normal textiles burn when exposed to an open flame. Only special fibres are inflammable; they have such grave disadvantages in other areas that they are used only where inflammability is the decisive criterion.
Once again, clear differences can be observed in the behavior of different fibres in burning.
Cellulose burns very easily and quickly but leaves only a weak, harmless ash skeleton. Acrylic fibre cannot be ignited so easily but will burn very intensively once the ignition phase has been passed.
Polyamide and polyester fibres are relatively difficult to ignite. Nevertheless, they have the serious disadvantage that the fibre substance melts and drips; in some circumstances, the result of this behavior can be far more serious for humans and the environment than in the case of cellulose.
Of all normal fibres, wool has the most favorable burning characteristics. It is fairly difficult to ignite, and, after burning, it leaves a brittle, rapidly cooling residue that does not adhere to adjoining surfaces.

4.3.3. Light and weather

It is generally known that exposure to light can affect many dyes more or less strongly; however, it is often overlooked that light also causes genuine damage to the substance of textiles.
Basically, all fibre materials suffer a loss of strength when illuminated. As in the case of heat, the magnitude of the reduction in strength depends upon many factors of which the following are worth a mention:
- light spectrum
- intensity
- lighting rhythm
- temperature of the sample
- moisture content of the sample
- thickness of the sample
- composition of the surrounding air.

The ultraviolet component of the light and the moisture content of the sample are of special significance. In this connection, it is important that a large part of the very aggressive UV components is absorbed by normal window glass. That is why curtains degrade much more slowly than textiles left outside (e.g. awnings or tarpaulins).
As regards the fibre itself, it is interesting to note that matt fibres are more strongly damaged than bright ones. Titanium dioxide works as a catalyst and accelerates the decomposition. Under the microscope, it becomes apparent that individual particles of the delustrant act as the core of a steadily expanding spherical zone of decomposition.
Furthermore, it should be noted that the depth of penetration of light rays is very shallow. Accordingly, a reduction of damage is observed with increase in titer.
Comparative tests of various raw materials reveal that PAC is strongly resistant to light while PA and natural silk have very poor resistance. Admittedly, however, a significant improvement in resistance of man-made fibres to light can be obtained by incorporating appropriate stabilizers.
Resistance to weather depends upon a still greater number of influencing factors. Apart from the influence of light, climatic effects have to be considered and especially variation in those effects: dry/ wet, warm/cold, light/dark.
The composition of the air also plays an important role, e.g. as regards pollution by industrial waste gases.
Completely satisfactory resistance to weather can be achieved for practically all fibre materials by coating with weather-resistant plastics material, primarily PVC.

4.4. Fibre properties in the end product

A diagrammatic illustration of the important fibre characteristics will serve as a supplement and as an aid to comprehension. Modal fibres have been inserted into this diagram along with the normal viscose fibre; the modal variety is a viscose fibre produced under modified process conditions to give properties which differ from those of normal viscose, particularly in respect of stress/strain behavior (dry/wet). Modal is more similar to cotton fibre and is therefore finding increasing application in the short-staple spinning mill.
The selected mode of evaluation:
- high / favorable
- medium / normal
- low / unfavorable.

is to be interpreted on the understanding that most characteristics can be assumed as high/medium/low, but wash

ability and behavior in response to dyes defy this form of assessment. In relation to several characteristics, it must also be borne in mind that a higher (lower) value may be either favorable or unfavorable depending upon the intended field of use. This can be demonstrated by reference to moisture absorption: high absorption of water is a very favorable characteristic in a towel but unfavorable in tent cloth.
Finally, a dosing comment must be made in relation to the production and properties of man-made fibres (Table 4).

	PES	CV	MODAL	PAC
Strength, dry	High / favorable	Low / unfavorable	Medium / normal	Medium / normal
Strength, wet	High / favorable	Low / unfavorable	Medium / normal	Medium / normal
Elongation	Medium / normal	Medium / normal	Low / unfavorable	Medium / normal
Form stability	High / favorable	Low / unfavorable	Low / unfavorable	Medium / normal
Crease resistance	High / favorable	Low / unfavorable	Low / unfavorable	Medium / normal
Pilling resistance	Low / unfavorable	High / favorable	High / favorable	Medium / normal
Resistance to rubbing	Medium / normal	Low / unfavorable	Low / unfavorable	Low / unfavorable
Thermal set ability (pleating)	High / favorable	Low / unfavorable	Low / unfavorable	Medium / normal
Water absorption	Low / unfavorable	High / favorable	High / favorable	Low / unfavorable
Wash ability	High / favorable	Low / unfavorable	Low / unfavorable	Low / unfavorable
Dyeing behavior	Medium / normal	High / favorable	High / favorable	Medium / normal
Light and weather resistance	Medium / normal	Low / unfavorable	Low / unfavorable	High / favorable
Resistance to rotting	High / favorable	Low / unfavorable	Low / unfavorable	High / favorable

High / favorable   Medium / normal   Low / unfavorable

Table 4 – Some properties of man-made fibres such as: polyester (PES), viscose (CV), viscose-modal (modal) and acrylic fibres (PAC)

Staple man-made fibres now provide about one-third of all textile raw materials. They are made in many varieties with a broad range of properties for practically all fields of application. Further development will bring still more new fibre types, but it is already clear that completely new polymers are becoming ever more rare while modification of known polymers for specific purposes is increasing. For the short-staple spinning mill, this means that no basically new requirements are likely to be raised from the side of man-made fibres. However, it is unavoidable that many special modifications of man-made fibres already available will necessitate minor changes in processing conditions and these will have effects on spinning plans, settings, and speeds. In this field, close and reciprocal co-operation between spinner, machine manufacturer and fibre producer is especially important.

4.5. Modifications of fibre properties

Since man-made fibres represent a manufactured raw material, many of their properties can be adapted to the special needs of specific end-uses. In addition to those already mentioned, the following modifications, amongst others, are common in practice (depending upon the requirements):
- antistatic
- anti-soiling (dirt-repellent)
- anti-ignition easy-care
- hydrophilic.

4.6. Summary of most important fibre properties

As mentioned at the beginning of this chapter the major advantages of man-made fibres are the wide-ranging possibilities of influencing the fibre properties by choosing the right polymer together with the right additives and subsequent treatments.
On the other hand, it is difficult to present a comprehensive and meaningful summary of the properties of man-made fibres in the framework of a condensed work of this kind. In relation to many properties, the range of possibilities is simply too wide to permit a rational short presentation. Accordingly, we are forced to compromise and give only figures for typical basic properties and guidelines for stress-strain and shrinkage behavior of those man-made fibres most important for the short-staple spinning mill, namely, polyester (PES), viscose (CV), and polyacrylonitrile (PAN) (Table 5).

		Polyester fibre	Viscose	Acrylic fibre
Density	g/cm^3	1.38	1.52	1.24-1.18
Moisture absorption capacity at 20°C / 65 % rh	%	0.4-0.6	11-14	1-2
Water-retention capacity after immersing and centrifuging	%	3-5	65-120	5-12
Melting point	°C	250-260	-	-
Decomposition temperature	°C	-	175-205	250
Tenacity (dry)	cN/tex	30-60	20-45	20-35
Relative loop strength (dry)	%	50-95	20-60	30-70
Wet strength	%	95-100	40-70	80-95
Elongation to break (dry)		15-40	12-30	15-40
Elongation to break (wet)	%	15-40	15-35	15-45
Boiling shrinkage	%	2-8	1-8	1-5
Shape in section	%	Round (possibly profiled)	Round to folded	Round to dumb-Bell shaped

Table 5 – Typical basic fibre properties

5. PROCESSING OF MAN-MADE STAPLE FIBRES IN SPINNING MILL

5.1. General problems

5.1.1. Spin finish

Several problems that can arise for the spinner in the use of finishes have already been mentioned. The main additional prejudicial factors are as follows:

- The spin finish combines with dust to form a hard coat on machine parts. These deposits can result in great disturbance in processing – most strongly in card clothings (especially on the licker-in), in the sliver-guide passages of the card and draw frame, in the flyer on the roving frame and on the opening roller and rotor of the rotor spinning machine. Often, additional costs arise because these parts have to be cleaned periodically.
- Inadequate distribution of the spin finish can cause fibre flaking and lead to increases in ends down and accumulation of electrostatic charge. In such cases, we talk of macro-distribution of spin finish because finish content can be established only by taking samples of many millions of fibres. Development of models regarding the distribution of spin finish on individual fibres therefore remains a branch of purely academic science. It is important for the spinner to know that the spin-finish concentration can only be exactly established gravimetrically in the light of precise knowledge of the spin-finish composition.
- If spin finish can penetrate components such as rollers and aprons when the machine is not running, it can cause swelling or cracking with corresponding prejudice to the drafting operation.
- Fibres treated with titanium dioxide as a delustrant exhibit lower drafting resistance (lower dynamic friction) but simultaneously higher wear (higher static friction) on fibre-guide elements. In this case, an optimized spin finish recipe has to be used. Besides titanium dioxide, other spin-finish components can increase wear on fibre-guide elements, especially when corrosive properties also exert an effect. Cationic substances are especially suspect in this connection. Wear, leading to spinning problems and degrading of yarn characteristics, occurs on travelers and on opening rollers of rotor spinning machines.

For the sake of objectivity, it should also be mentioned that processing problems arising in practice are sometimes alleged without justification to be due to spin finish. Several examples taken from practical experience are:

- where opened bales are left standing in the spinning room without allowing adequate acclimatization, moisture can condense on the fibre surface (especially in winter) and lead to considerable carding problems
- in the processing of blends of polyester fibres with cotton where room temperature and humidity are too high, cotton wax can smear and lead to lap formation
- superannuated rubber top rollers and notches on teeth and opening rollers are also sources of processing and quality problems
- fibre crimp is actually just as important as spin finish in its influence on processing; crimp is steadily reduced in the passage of the fibre from opening through to the spinning machine; the spinner here exerts a significant influence on his own processing conditions.

5.1.2. Inadequacies of fibre material

5.1.2.1. Cut packets (cut groups)

In the severing of filaments to form staple fibres, occasionally whole bundles of fibres are squashed together. These form a coherent fibre packet that can generate significant problems in processing. The effect is often reinforced if crimp setting is performed after cutting, because then setting of the bundle also arises. Fibre packets of this kind cannot then be separated from the strand. Application of spin finish can also lead to an increase in adherence within the fibre bundle.
In the ideal case, these fibre packets will be eliminated in the blowroom. However, since this is not fully achieved, the card is required to extract the remainder. After the card, there should no longer be any fibre packets in the strand.

5.1.2.2. Coarse fibres (hairs, bristles)

Staple fibres very rarely contain individual fibres having a fineness markedly different from that of the remainder. There are various causes that can lead to this phenomenon in the man-made-fibre plant.
The largest part of these fibres can be eliminated before the ring spinning machine; the card flats represent the most important eliminating location. If individual bristles nevertheless pass through to the ring spinning machine, they cause ends down. If they pass beyond this machine, they detract from the appearance of the yarn and the end product.
The cleaning position on the rotor spinning machine is advantageous in this connection. In addition to dirt, this also eliminates coarse fibres, fibre packets, and long fibres.

5.1.2.3. Overlong fibres

It does not matter if individual fibres depart only slightly from the set length in the upward direction. It is more serious if, for example, fibres of 60 - 80 mm are found in staple of 40 mm (double-cut length). In this case, processing difficulties are inevitable.
Since most man-made fibres are strong, the overlong fibre will not break in a drafting zone set to a staple length of 40 mm. The delivery-roller pair rips this fibre out of the nip of the feed cylinder in the course of which neighboring fibres are always carried along. The result is thin and thick places.
If the fibres do not slide out of the upstream nip, the overlong fibre will be extended; finally, this gives the same result. The fibre returns to its previous length after leaving the drafting arrangement. This occurs suddenly, and neighboring fibres are again carried along. Webs or rovings then exhibit wave formations; thin and thick places appear it the yarn at the ring-spinning machine.

5.1.2.4. Fibre dust

This is cutting and pressing dust, i.e. fibre debris that arises in the course of converting tow. It also causes disturbance in the process mainly due to dust deposits on the machines.

5.1.3. Further disturbances arising from the fibres
5.1.3.1. Anti-pilling types

In the outerwear sector, if singles yarns are used in preference to plied yarns, then anti-pilling fibres are generally chosen for the singles yarn. They have a low buckling break and rubbing strength, and also a low tensile strength.
They therefore tend to give a higher ends-down rate and strong generation of fly. This is especially noticeable in rotor spinning, because here fibres in the yarn are rubbed away at high speeds; the only remedy is a reduction in revolutions.

5.1.3.2. Fibre delustrants

Delustring of fibres is achieved by application of titanium dioxide. This simultaneously imparts an extremely abrasive surface to the fibre. This causes high wear on machine parts, not only soft parts such as roller coverings but even metal components. At the same time, there is a high generation of abraded particles.

5.1.4. Static electricity
5.1.4.1. Generation of static electricity

In an electrically neutral atom, the number of protons is equal to the number of electrons, so that their charges balance out – which is the basis of the neutrality. If now two materials of different chemical composition come into contact with each other, electrons from one material can pass to the other. Electrically charged layers of opposite sign are thus produced at the contacting surfaces. As long as the materials remain in contact, these charges are of no significance. However, if the materials are separated, the charges are also separated - but the positive and negative charges remain on the sides where they were (Fig. 25).

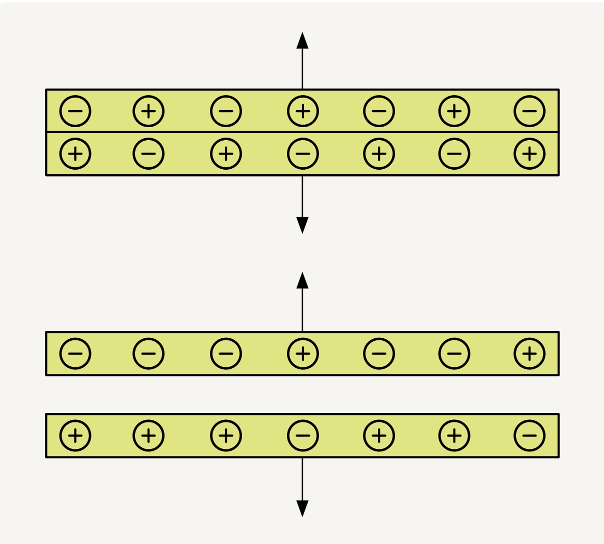


Fig. 25 – Generation of electrically charged layers at the boundary between two raw materials

Static electricity is simply an imbalance in the distribution of electrons, defined as:
"An accumulation of time-invariant charge of positive and / or negative sign on a material (either locally or overall)".
This charge often generates a high voltage associated with low current levels.
Charge accumulates in non-conductors or insulated conductors where there is no possibility of discharge by flow of current – the charge is at rest.
If such a charged material, e.g. the human body, comes into contact with a conductor, discharge will follow in the form of a current pulse lasting only milliseconds. The human being perceives this discharge as a minor electric shock.

5.1.4.2. Influencing factors

Static charge is therefore inherently a contact rather than a friction problem. Friction merely reinforces the effect as it increases the contact surfaces and the surfaces are changed by the thermal and mechanical stress.
The magnitude of the charge is dependent upon several factors, e.g:

- electrical conductivity, which in turn is dependent upon the conductivity of the material itself and the conductivity arising from moisture content
- dielectric constant
- speed of the process generating the charge
- temperature difference between the two materials relative humidity
- Dried out man-made fibres and wool always tend to accumulate charge, as do fibres with a low water-retention capacity (synthetic fibres) if they are not properly treated with an antistatic agent. Accordingly, the problem occurs more often in winter than in summer as heating leads to drying out of fibres in winter.

5.1.4.3. The problems for the spinning mill

Two main groups of problems giving the spinner trouble in connection with static electricity are:

- adherence of fibres to the machine components, and
- falling apart of fibre strands.

Charge accumulations on the fibres and on the machines often have different signs. The machine components therefore tend to attract individual fibres or even whole strands. This leads to formation of laps, catching of fibres, blockages, etc., especially on cylinders, in clothings and in guide ducts.
Falling apart of strands is caused by all fibres in the strand having the same charge and therefore tending to repel each other. In minor cases, this causes spreading out of the edge fibres; in extreme cases, the strand disintegrates.

5.1.5. Environmental conditions
5.1.5.1. General conditions

Raw materials used in spinning mills do not only exhibit different characteristics depending upon their moisture content but also varying running performance (behavior).

		Normal	Hot Countries (Maximum)
	rh%	°C	°C
Viscose:			
Spinning preparation	50 - 55	22 - 25	27
Ring spinning	50 - 55	22 - 25	27
Polyamide fibre:			
Blowroom and carding room	50 - 55	22 - 25	27
Draw frame and roving frame	50 - 55	22 - 25	27
Ring spinning	50 - 55	22 - 25	27
Polyacrylonitrile fibre:			
Blowroom	4 - 55	20 - 24	27
Spinning preparation	5 - 60	20 - 24	27
Ring spinning	50 - 55	22 - 25	27
Polyester fibre:			
Blowroom and carding room	50 - 55	20 - 24	27
Spinning preparation	45 - 50	22 - 25	27
Ring spinning	about 50	22 - 25	27

Table 6 – Good ambient conditions for processing of man-made fibres

This behavior occurs especially with wool and man-made fibres. Since the moisture content of the fibres is primarily dependent upon the moisture content of the atmosphere and the time of exposure to this atmosphere, air conditioning of the mill plays an important role in processing man-made fibres. Unfavorable ambient conditions can make spinning not just difficult but impossible.
At low moisture levels the main problem is static electricity; at high moisture levels, spin finish may smear, favor nep formation and cause drafting difficulties. Low moisture levels may increase static charge which can lead to choking of clothings, blockages in sliver passages and lap-formation at cylinders. High moisture levels lead to an increase in yarn unevenness and imperfections. Experiences have shown the following ambient conditions to be favorable for the spinning mill:

- relative humidity (rh): 50 - 60 %
- temperature: 22 - 24 (-27) °C

In detail, conditions which are listed in Table 6 have proved to be favorable.

In spinning, relative humidity is a very important criterion. However, since spin finish needs a minimum moisture content to have an effect and tends to smear at excessively high levels, the absolute moisture content of the air is also significant. It should be in the following range:
For PES and PES/CO
- in the spinning mill, 8.5 -11 g H_2O/kg dry air
- in the winding room, 10.5 -13 g H_2O /kg dry air

For PES/modal and PES/viscose
- in the spinning mill, 9 - 11 g H_2O/kg dry air
- in the winding room, 10.3 - 13 g H_2O/kg dry air

For acrylic fibre
- in the spinning mill, 9 - 10 g H_2O/kg dry air

It is not enough to consider only average values when assessing an air-conditioning system. It is also important to maintain the set values within narrow tolerance limits as synthetic fibres react strongly to moisture variations. Viscose and cotton fibres are less problematic in this connection.

5.2. Storage of man-made fibres

Actually, storage of man-made fibres ties up less capital than the storage of cotton fibres. On the one hand, this is due to the short distance of the man-made fibre manufacturer from the mill and on the other hand to the short delivery times. However, a disadvantage that should not be underestimated (especially in the colder seasons) is the behavior of synthetic fibres when subjected to temperature and moisture.
If the fibres are stored in a cold room, as is usual, and the bales are opened immediately after transport into the blowroom, condensation will form on the surface of the fibres. This condensation makes normal processing of the fibres impossible, especially in the blowroom and the carding room, and it also affects the spin finish. Synthetic fibres are usually well and hermetically packed by the manufacturer. Such fibres must be left to stand in an unopened condition for at least 24 hours in the blowroom or in another room at the same ambient temperature before the opening process can begin. During this period, the fibres in the bale adapt to the prevailing temperature.

Very long periods of storage should be avoided not only for economic reasons but also because the properties of the spin finish, and hence the processability, can change during storage. However, if a good spin finish has been used, no changes are to be expected for a storage period of one to two years. Processability is also affected by exposure to strong sunlight and should therefore be avoided.

5.3. Blending

As the theory of blending including the evaluation of blends, de-blending and types of blending has already been described in The Rieter Manual of Spinning – Volume 1, the following chapters point out some details about blending of man-made fibres.

5.3.1. Purpose of blending

For certain fields of application neither natural nor man-made fibres are optimally appropriate but a blend of these two fibre types can achieve the required characteristics. In such cases, a blending step is the obvious solution. Another major reason for blending natural fibres with man-made fibres is the relatively high price of natural fibres (e.g. cotton). Due to the increase of fibre consumption and the limited production rates of natural fibres, these high prices will most probably rise even higher in the future. This leads to a continuous increase of the proportion of products made by blended yarns. Furthermore, not only blending of natural fibres with man-made fibres is increasing but also blends of different types of man-made fibres.

5.3.2. Blend proportions

When two fibre components are brought together, each will contribute characteristics that are advantageous and less advantageous for the end purpose. These individual characteristics exert a greater or smaller influence depending upon the blend properties of the components. If both the requirements of the end product and the fibre properties are known, the optimal blending proportions can be approximately determined. This can be illustrated by the examples shown in Fig. 26 by Dr. Albrecht [8].

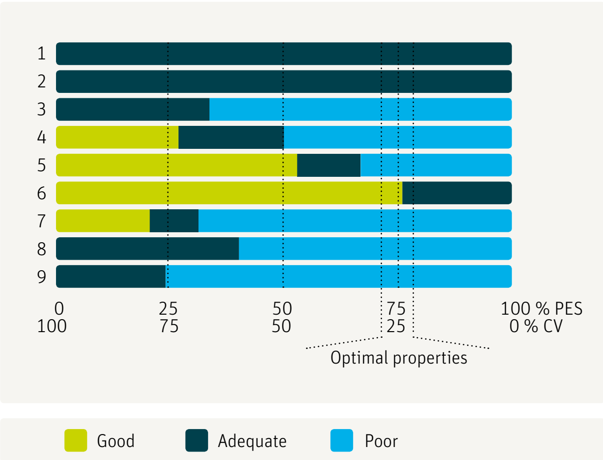


Fig. 26 – Establishing an optimal blend by reference to given end-product characteristic (1 = appearance; 2 = fabric feel; 3 = recovery from creasing (dry); 4 = recovery from creasing (wet); 5 = retention of ironed creases; 6 = resistance to heat; 7 = shrinkage resistance; 8 = tearing strength; 9 = resistance to rubbing)

The following blends are examples for very common blends with man-made staple fibres:

- Polyester/Cotton: (85/15); 65/35; (67/33); 50/50; 45/55
- Polyester/Modal fibres: 65/35
- Polyester/Viscose: 67/33
- Acrylic/Cotton: 85/15; 70/30; 50/50

5.3.3. Blend evenness

As described in The Rieter Manual of Spinning – Volume 1 the blend evenness must always be assessed in two directions: the longitudinal direction and the transverse direction. For the blend evenness in the longitudinal direction there are very stringent requirements. Deviations from predetermined limits lead to uneven fabric appearance, stripes, bars, etc. In Europe, tolerance limits have been established by law. The permitted variation is ±3 %, e.g. for a 50/50 PES/CO blend, the blend proportions can vary in extreme cases between 47/53 and 53/47. However, since the spinner very often does not know the final application of the yarn and the above-mentioned tolerance limits can still influence fabric appearance, tolerance limits should not exceed ±2 % (for difficult blends even as tight as ±1 % and in bi-color blends ± 0.5 %).
For the blend evenness in the transversal direction a homogenous blend is preferable and should be aimed at in most cases.

5.3.4. Types of blending operations

There is a huge variety of possibilities to blend different fibre materials as was listed and described in The Rieter Manual of Spinning – Volume 1, but over the course of time three ways have become established for blending man-made fibres in modern spinning mill installations:

- tuft blending at the start of blowroom process
- tuft blending at the end of blowroom process
- sliver blending.

The typical general process stages for tuft blending and sliver blending of cotton and polyester can be seen in Fig. 27.

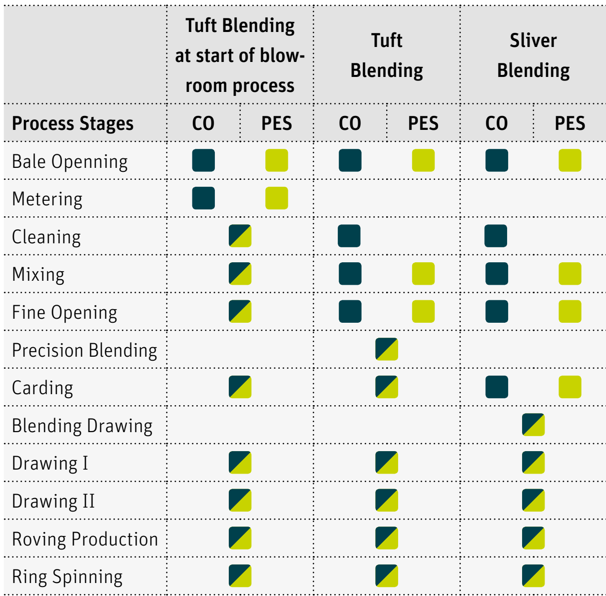


Fig. 27 – Typical process stages for tuft blending and sliver blending of cotton and polyester

Although tuft blending is becoming more important in many countries, sliver blending is still most frequently applied to blend natural and man-made fibres.

5.3.4.1. Tuft blending at the start of blowroom

Tuft blending at the start of the blowroom process is, for example, realized by weighing hopper feeders (see Fig. 28). These are equipped with weighing devices so that the individual components can be delivered in metered quantities. At least two and usually more of such weighing hopper feeders work together, delivering weighed material onto a common transport belt. The latter transfers the delivered material to blending machines that are needed to ensure the actual intermixing.

Fig. 28 – Weighing hopper feeder (Temafa)

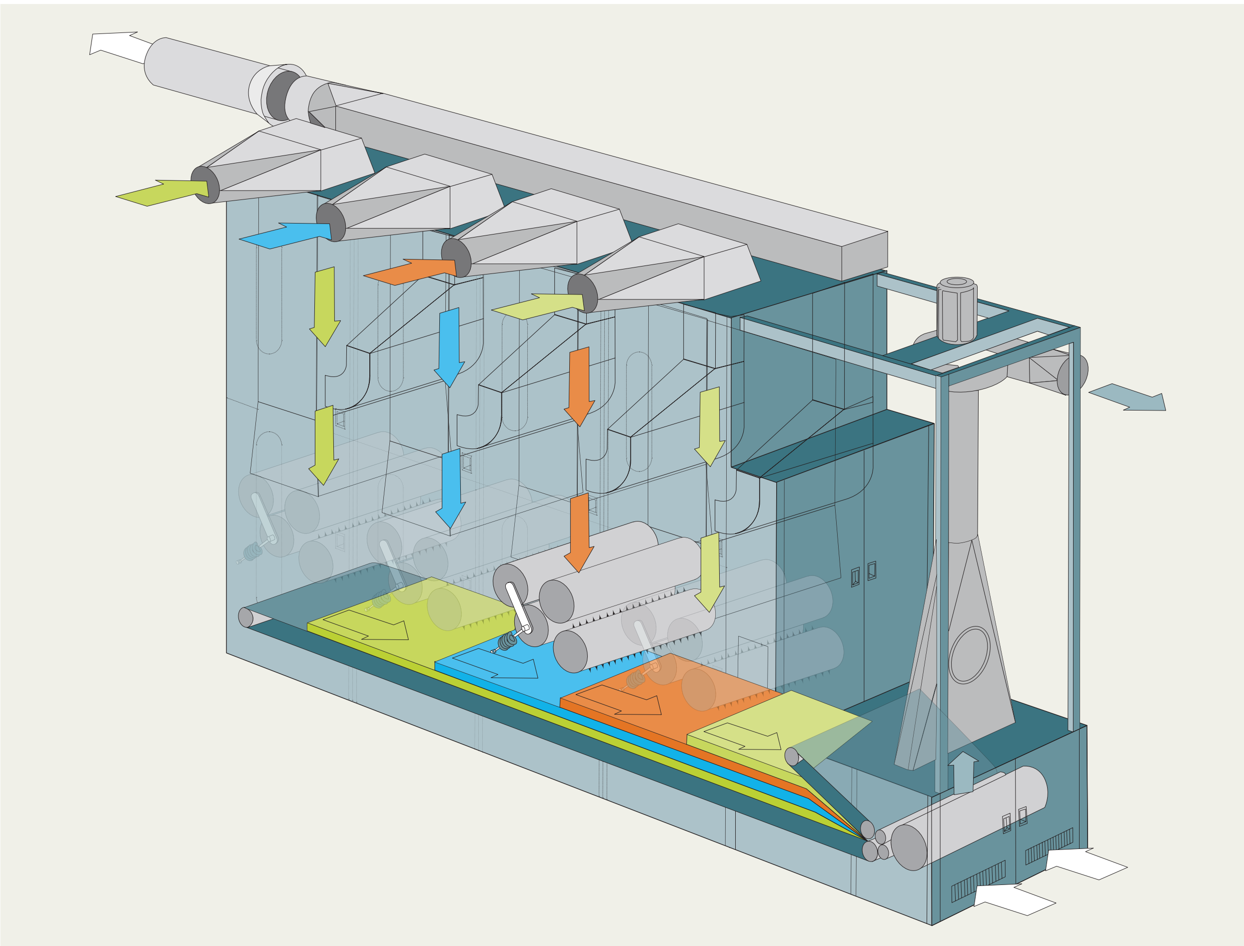


Fig. 29 – Rieter A 81 UNIblend

In processing with weighing hopper feeders, it is important that the individual feeders deliver the material with a degree of opening giving equal volumes of the two or more components. This is essential to achieve an even blend. In tuft blending at the start of the blowroom process, there is always a risk of deblending in the following blowroom process stages because of differences in the fibre parameters and rolling movements.

5.3.4.2. Tuft blending

The risk of de-blending can be eliminated by using tuft blending at the end of the blowroom process. For this technology blending machines like Rieter A 81 UNIblend (Fig. 29) are required. Several chutes, each with its own feeds of different types of material, are arranged side by side. Every chute ends at the bottom with a metering device so each chute drops a precisely measured quantity of material onto a collecting conveyer belt which again transports the accurately metered material to the take-off unit. An example for a complete installation using tuft blending at the end of the blowroom process can be seen in Fig. 31.

Tuft blending gives advantages in blending evenness in the transverse direction. The blending evenness in the longitudinal direction can achieve highest quality standards as well by using modern tuft blending machines like Rieter A 81 UNIblend.

5.3.4.3. Sliver blending

In sliver blending an additional blending passage is inserted preceding the two usual draw frame passages in the cotton spinning mill. It provides the advantages that up to the draw frame each material can be processed separately on the machines best suited to it and that it produces a very high blending evenness along the length of the product (longitudinal direction). The main disadvantage is the poor transverse blending evenness which can produce stripiness in the finished product (see The Rieter Manual of Spinning – Volume 1).

5.3.5. Blending of waste material

Lap stripings, card sliver and draw frame sliver can be mixed in even and metered quantities. They should not be fed in blended where pure man-made fibres are spun or unblended where blends are processed. Grid waste, flats-strips and roving waste should not be blended in.

5.4. Blowroom
5.4.1. Blowroom installations

In contrast to natural fibres, man-made fibres normally contain no impurities. Accordingly cleaning machines are not required when running 100 % man-made fibres and the main tasks for the blowroom are reduced to:
• opening and
• blending (mixing).

Furthermore, opening of man-made fibres is easier than opening of cotton as the fibres are less compressed. Accordingly, the blowroom installation can be limited to the minimum number of machines. These usually consist of:
• automatic bale-opening machine
• blending machine and
• fine opener that also delivers feed-stock into the card-feeding equipment.

In Fig. 30 and Fig. 31 typical blowroom machine installations for spinning 100 % man-made fibres and polyester/cotton blends are shown.

Fig. 30 – Typical blowroom line for 100 % man-made fibres

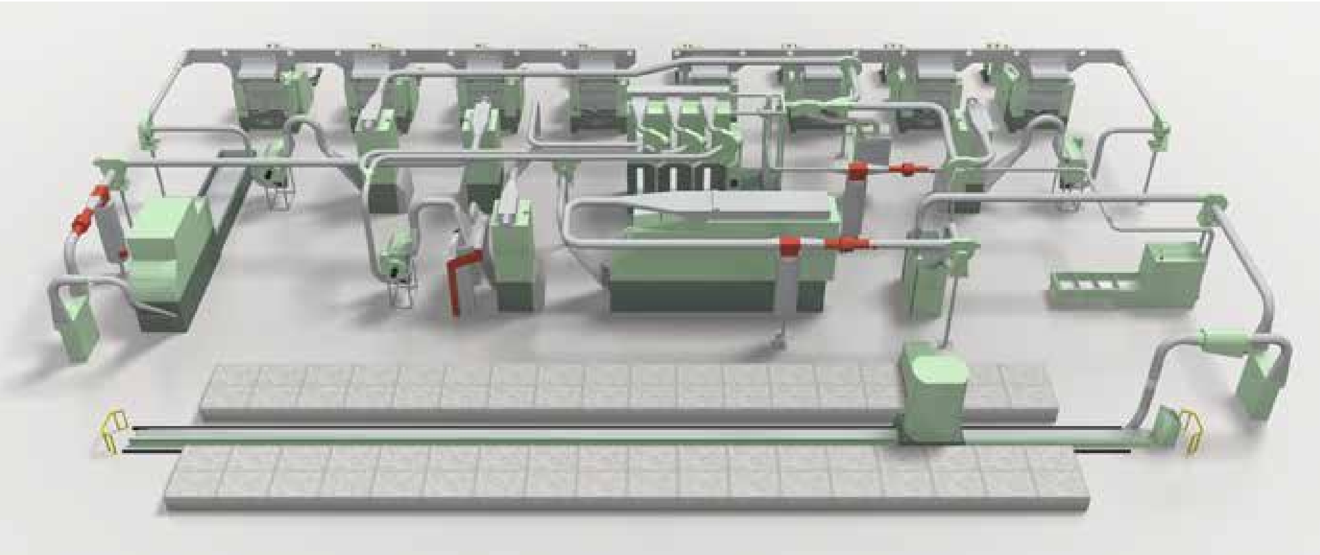


Fig. 31 – Typical blowroom line for polyester/cotton blends

5.4.2. Bale layout

In man-made fibre-producing installations, fibres are produced under conditions that are almost always the same. It would, however, be wrong to conclude that they have always identical properties. Man-made fibres exhibit a lower degree of variability than natural fibres but they are not sufficiently homogeneous to process them individually, one bale after another. Inhomogeneities can, for example, occur in general fibre properties (e.g. length, crimp etc.), in the spin finish application or in the moisture content in different bales.
To compensate these inhomogeneities it is desirable to take fibres from 12 bales at the same time and preferably from 20. Small differences can also appear between different consignments. The short-staple spinning mill does not operate on a batch but on a continuous basis and it is required to produce the same yarn over a long period of time. Accordingly, the 12 bales of a bale laydown should be taken from at least three, preferably four, consignments.

5.4.3. General settings

In general, man-made fibres have to be treated gentler than cotton fibres so the clothings on the rollers should be chosen coarser, the distances between the opening elements wider and the roller speeds lower. As there are no impurities, the grids should be kept more or less closed.

The detailed settings are dependent upon the major fibre characteristics. For example smooth polyester fibres need just a little opening, whereas viscose fibres and dull or polypropylene fibres require more intense opening processes. The following fibre parameters have an influence on the blowroom settings:
- length
- fineness
- bulk
- crimp
- springiness
- spin finish
- delustring agent.

5.4.4. Problems

The main problems arising in the processing of man-made fibres are:
- static electricity (see chapter 5.1.4.)
- deposit of spin finish or marking color on machine components and in interiors of passages
- overlong passages that lead to bundling of tufts and finally to neps
- several bends in passages also lead to bundling of tufts and neps.

Deposits in feed chutes can lead to large variations in the material flow. Especially in card-feed chutes this can give marked quality deterioration. The affected elements should therefore be cleaned periodically, e.g. by washing with soapy water.
When processing acrylic fibres the settings of the feed chutes should be set wide, because of the high volume of these fibres.

5.4.5. Processing environment

In the blowroom it is desirable to work with a moisture content of 9 - 13 g per kg of dry air. This gives the following relative humidity:

Temperature °C	Relative Humidity %
20	60 (- 85)
25	45 - 58
30	(35 -) 48

Table 7 – Good ambient conditions for processing of man-made fibres in the blowroom

5.5. Carding
5.5.1. General

Cards with revolving flats are ideally suited to the processing of man-made fibres with staple lengths of up to 60 mm. However the machine elements and the settings of the card have to be adjusted when processing man-made fibres because of the different fibre properties in comparison to cotton fibres.
As was mentioned in the settings of the blowroom (chapter 5.4.3.), man-made fibres are generally more sensitive to aggressive treatment and therefore have to be treated gentler than cotton fibres.
However, in this case, as for cotton processing, the card causes shortening of fibres. Man-made fibres therefore include a small proportion of short fibres after carding. The shortening occurs more often with
• longer fibres
• finer fibres
• narrower settings
• finer clothings
• higher roller and cylinder revolutions.

As compared with the processing of cotton, therefore, settings are selected rather wider, clothings rather coarser and revolutions rather lower.
Sliver fineness for PES fibre lies in the following ranges (for acrylic fibre usually a bit finer):
• Fine yarn: 4-5 ktex
• Medium to coarse yarn: 4.5 - 6.5 ktex
• Normal: about 5 ktex

Sliver fineness should not fall below 4 ktex for PES fibre and 3.6 ktex for acrylic fibre.
Fibre crimp is an important fibre parameter that influences the production rate. Strong fibre crimp gives the card web better cohesion and web stability and vice versa. To card low crimp fibres the production rates have to be reduced and sometimes the card web weight has to be increased.

5.5.2. Machine elements and general settings
5.5.2.1. Card clothing

The clothing has the greatest influence on the quality and on the productivity in the carding process. As man-made fibres are very sensitive, it is very important to process these fibres on the card with an appropriate clothing to avoid fibre damage and hence loss in yarn quality.
The most important parameters of the clothing have already been described in The Rieter Manual of Spinning – Volume 2. As mentioned, a great many criteria exert an influence on the optimal card clothing, for example:
• type and design of card
• rotation speed of the cylinder
• production rate
• material throughput
• raw material type
• fibre characteristics
• overall quality requirements.

Because of this huge range of criteria it is not possible to give a general and comprehensive list of card clothing recommendations. However in Table 8 card clothing recommendations for carding different types of man-made fibres are given for Rieter C 70 card.

Fibres		C 70 card	
		Man Made > 1.0 dtex	**Man Made < 0.6 dtex**
Licker-in	points	60 - 120	60 - 120
	angle	5 - 20	5 - 10
	rpm	1 000 - 1 400	900 - 1 200
Cylinder	points	600 - 700	700 - 800
	angle	20 - 30	20 - 30
	rpm	650 - 750	650 - 750
Flat	clothing	400 - 500 ppsi	500 - 600 ppsi
Doffer	points	300 - 500	300 - 500
	angle	30 - 40	30 - 40

Table 8 – Recommendations for card clothing and speeds for Rieter C 70 card

Positive teeth of the licker-in have the advantage of better opening of the tufts; negative teeth have a gentler action on the fibres and give better transfer of fibres to the main cylinder because of the lower retention capability. Negative teeth have a lower tendency to choke. When acrylic fibres or very sensitive fibres are to be processed it is advisable to fit the licker-in with negative teeth.
In the early days of microfibre processing (fineness < 1.0 dtex), very fine cylinder clothings have been selected to keep the number of fibres in the tooth gaps as constant as the ones of coarser fibres or even to increase quality with a higher number of points. These fine clothings resulted in excessive carding forces because of the high fibre/metal friction. Additionally the fibres reached the tooth gaps only with difficulties. On the other hand, a too coarse wire tends to overload the clothing due to the high number of fibres between the teeth and obstructs the fibre transfer from the cylinder to the doffer [9].
For blends of cotton and synthetics the type of card clothing can be closer to that of the cotton clothing, but it is still necessary to use a "combination" wire which can be used for blends and 100 % cotton.
The operating life of the clothing is strongly dependent upon the type of fibre, the spin finish and the additives in the finish.
Grinding intervals are also strongly dependent upon spin finish and finish additives. For this reason, no guidelines can be given. As regards the doffer, its clothing should be ground (slightly) regularly to keep the points sharp.

5.5.2.2. Licker-in

As an all-important parameter of the card, the licker-in settings have to be optimized to the special fibre properties when running man-made fibres and their blends.
Because of their sensitiveness, 100 % man-made fibres are usually carded on cards with a single licker-in to ensure gentle fibre opening with reduced removal of good fibres. In this way, fibre features such as length and tenacity are retained most effectively and thus contribute to higher yarn quality.
Recommendations for the clothing of the licker-in have already been listed in Table 8. In general it can be said that licker-ins with low, neutral or even negative front angles of the clothing are best when running 100 % man-made fibres to avoid fibre damage and a good transfer of the fibres to the main cylinder. In some cases, licker-ins with needle or pin rollers also give good results in carding of 100 % man-made fibres.

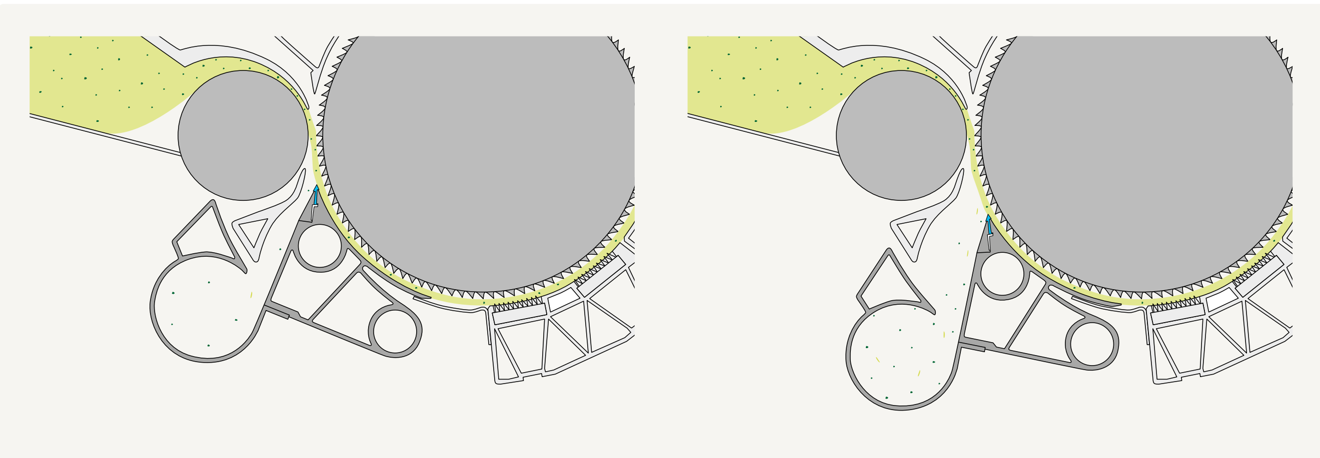


Fig. 32 – Adjustable mote knife on a Rieter C 70 card (left: closed for MMF – right: more open for Cotton applications)

In general man-made fibre material is free from impurities; however, depending on the supplier or process it is possible that fibre packages, melted together fibres can occur. These need to be removed and this can be done at the licker-in with the mote knife. In the Rieter C 70 card, the mote knife can be adjusted during production. Fig. 32 shows the knife almost closed as it would be recommended for man-made fibres (left) in comparison to a very open knife position for a high cleaning efficiency when running 100 % cotton.
The speeds of the licker-in depend on its roller diameter and on the raw material type. They should be set at the lower end of the overall speed range of the card. Typical licker-in speeds for man-made fibres are listed in Table 8.
A general rule for the speed of the licker-in is: the finer the fibres and the higher the production of the card the faster the licker-in speed.
When running blends of man-made fibres with cotton, the setting of the licker-in should be more like the one for cotton fibres which means:

- use of single licker-in roller
- use of clothings with a low positive front angle
- settings of the knife slightly open to ensure removal of impurities, fibre packages and melted together fibres.

5.5.2.3. Pre- and post-carding areas

In modern cards, one or more stationary carding elements are inserted between the licker-in and the flats and between the flats and the doffer. This enables progressive opening of the tufts prior to the main carding area between the main cylinder and the flats or preparation of the fibres for the doffing action. In addition to these stationary carding elements, cleaning elements are often integrated to remove dust, trash, and very short fibres. Because of the lack of impurities when running man-made fibres, knives should be set very close and should be opened a little bit when running blends with cotton. In the Rieter C 70 card, the opening widths of these cleaning elements can be easily changed by replacing inserts without any tools (see Fig. 33).

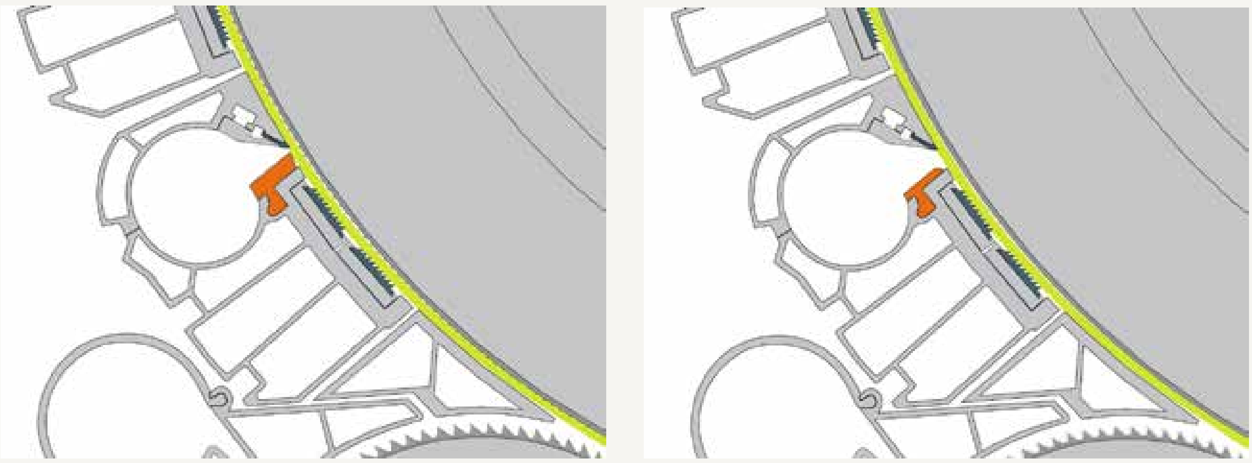


Fig. 33 – Adjustable open width of cleaning elements in a Rieter C 70 card (left: almost closed – right: completely opened)

5.5.2.4. Main carding area

The most important parameters to optimize the carding process in the main carding area between the cylinder and the flats according to the raw material are:
- cylinder clothing
- flat clothing
- cylinder speed
- distances between the cylinder and the flat.

Recommendations for the clothings and the cylinder speed can be found in Table 9.
The distances between the cylinder and the wire should be wider than those used for cotton. For bulky acrylic fibre they should be still wider than for polyester fibre. This is necessary to avoid:
- fibre damage
- strong generation of dust
- high accumulation of static charge.

On the other hand, settings should not be too wide, otherwise they result in:
- poor opening of the tufts
- reduced ability to eliminate and open up neps
- choking of the clothings.

Pos.	Element	Settings [mm] / (100/")
1	Stationary Licker-in	[0.60] (24)
2	Transferzone Licker-in to Cylinder	[0.30] (12)
3	Coverplate Licker-in to Cylinder	[1.00] (40)
4	Precarding Segment 1	[0.65/0.80] (26/32)
5	Precarding Segment 2	[0.55/0.70] (22/28)
6	Precarding Segment 3	[0.45/0.60] (18/24)
7	Revolving Flat Flexbow back	[1.30] (52)
8	Revolving Flat 1st Setting point	[0.40] (16)
9	Revolving Flat 2nd Setting point	[0.375] (15)
10	Revolving Flat 3rd Setting point	[0.35] (14)
11	Revolving Flat 4th Setting point	[0.30] (12)
12	Revolving Flat 5th Setting point	[0.25] (10)
13	Revolving Flat Flexbow front	[1.30] (52)
14	Postcarding Segment 1	[0.45/0.60] (18/24)
15	Postcarding Segment 2	[0.45/0.60] (18/24)
16	Transferzone Cylinder to Doffer	[0.25] (10)

Table 9 – Card distance recommendations for man-made fibres

Typical settings in the main carding area and at the rest of the card can be found in Table 9.

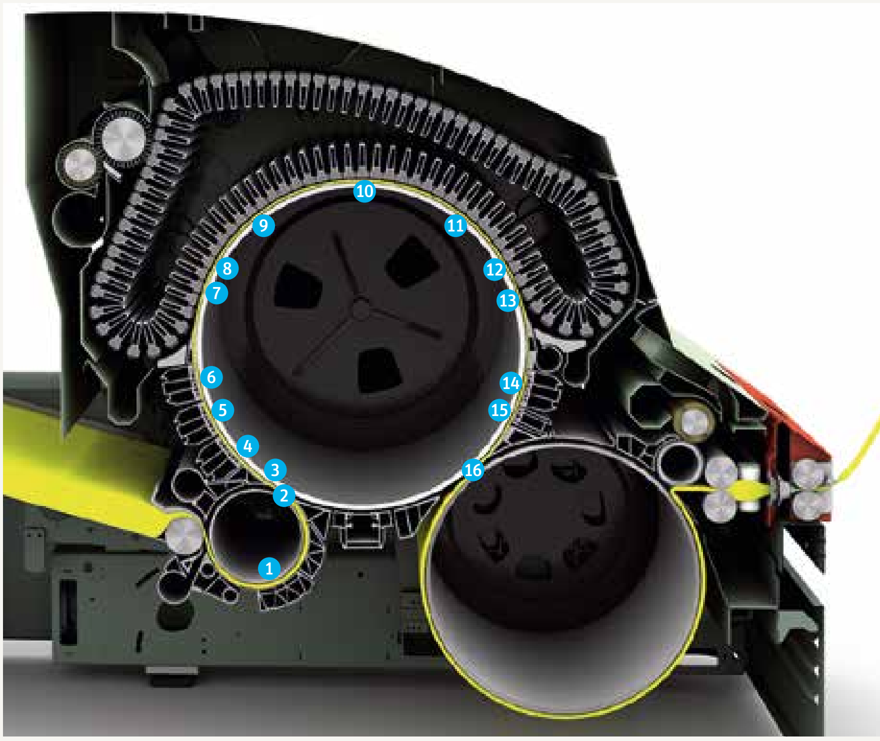


Fig. 34 – Settings of distances at the card

5.5.2.5. Doffer

The web is formed on the doffer by its considerably lower surface speed in comparison to the speed of the cylinder. The doffer clothing (see recommendations in Table 8) has a limited filling capacity which depends on the fibre fineness. When the filling approaches or exceeds a maximum loading, the extra fibres tend to be entangled and produce a cloudy and weak web which is difficult to control. Especially when processing fine man-made fibres, this overloading of the doffer should be avoided as it leads to an excessive number of neps that can be produced during the drawing process.

5.5.3. Problems

The wrong spin finish can lead to neps, smearing and choking of the clothings and also to electrostatic charging of the fibres. Running of the card causes warming of the card parts (and the fibres) which in turn leads to drying out in the processing region. Accordingly, within every card there is a micro-environment of a special kind. If processing is carried out while the environment is too arid, the fibres become dry and static charge accumulates.
In some cases, choking of the clothing can be avoided by increasing revolutions as the resulting higher centrifugal force improves the lift of fibres off the main cylinder and transfer to the doffer. Moreover, choking can often be prevented by occasional grinding of the doffer clothing and wider setting of the flats. Furthermore, clothings should be periodically freed from spin-finish deposits.
Higher roller and cylinder revolutions usually give a cleaner web but also lead to greater shortening of the fibres and possibly also to thermal damage. In addition, too aggressive settings of the licker-in result in more short fibres in the sliver. If the fibres show bad running behavior, a reduction in points/in² may help to overcome the trouble.

5.5.4. Process environment

The humidity in the card room should be sufficient enough to control static build up and maintaining of fibre strength, but not too high to accentuate sticky characteristics of the fibres. In addition, the clothing will choke if humidity is too high.
It is also necessary to card synthetic fibres in cooler environment. Table 10 shows a recommended condition to run man-made fibres and blends in the card room.

Water content	Temperature	Humidity
9 - 12 g/kg	22 - 28 °C	48 - 60 % rh

Table 10 – Good ambient conditions for processing of man-made fibres in the carding room

5.6. Combing

It is not currently normal practice to comb man-made fibres as there is still no particular reason to do so. However, in the production of blended yarns, combing could prove of value in the production of high-quality yarns and difficult dye shades. In this so-called comb-blending process, blending of the two fibre components is performed on a blending draw frame between the card and the comber. All further process stages, such as combing, drawing (mostly only one passage is required), roving frame and ring frame, do not process separate fibre components but fibre blends. This gives the best blends in longitudinal and transverse directions. Furthermore, the comber eliminates the shortened man-made fibres which otherwise exert a strongly disturbing effect, noticeably affecting the yarn values.
Because of the additional machines needed in the combing room the processing machines required are certainly more expensive. On the other hand, this process gives more flexibility: if there is no market for blended yarns, one could easily switch to combed cotton yarns which would not be possible when other processes had been selected.

5.7. Drawing
5.7.1. Number of draw frame passages

The number of the draw frame passages that is required in a spinning mill depends not only on the raw material and on the required yarn quality but also on the used yarn spinning technology. In Fig. 35 typical examples for different raw materials and different spinning technologies are shown.
When spinning sliver-blended polyester/cotton blends with ring spinning machines, a total of three drawing passages including the blending draw frame is needed to fulfill the highest quality standards. In contrast, when spinning the same material by rotor spinning technology two drawing passages are enough. In rotor spinning the fed sliver is completely opened to single fibres which ensure fibre/fibre mixing and additionally a lower number of draw frame passages is required.

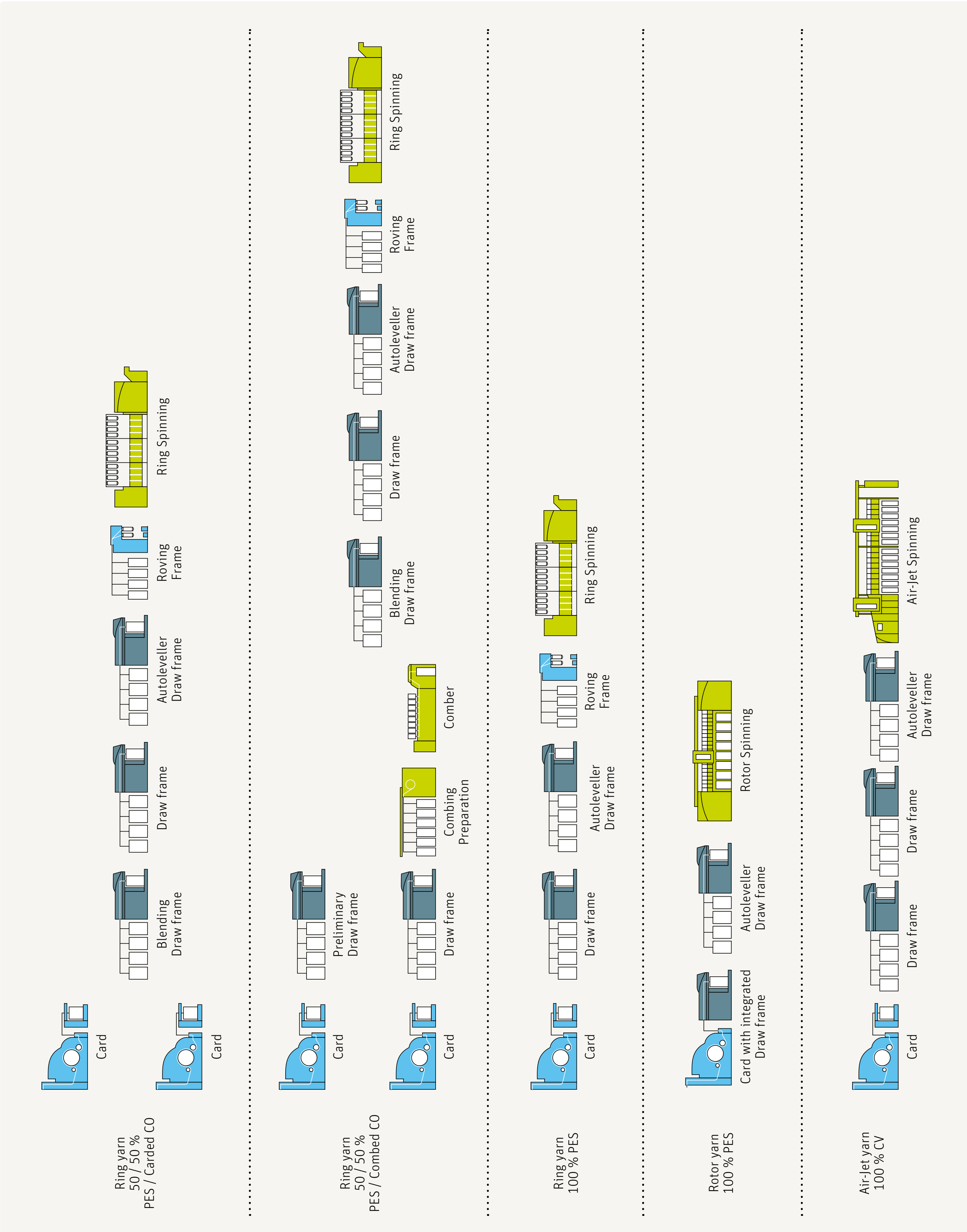


Fig. 35 – Examples for different numbers of draw frame passages

If the synthetic material is sliver blended with combed cotton, an additional preliminary drafting stage for the synthetic fibre component is advantageous. Usually the fibres of the combed cotton sliver presented to the blending draw frame have a high degree of parallelization; the polyester fibres, coming straight from the card, are more or less randomly oriented and slightly interlaced in the sliver. But a preliminary draw frame means little extra costs and enables an equivalent arrangement of the fibres in the feedstock slivers of both components.
A major difference in longitudinal orientation of both components also leads to a difference in drafting resistance.
If two such different slivers are fed simultaneously into a drafting arrangement, the result will be packet-wise movement of the fibres. This cause sliver and blend unevenness and results in increased yarn unevenness, a higher number of thin places and Classimat defects.
When spinning 100 % synthetic fibres with ring spinning technology, two draw frame passages are needed to eliminate the leading and trailing hooks of the card sliver which is necessary prior to the high draft drawing system of the ring spinning machine. Thus, the use of two draw frame passages in the spinning preparation is the optimum solution regarding production costs and yarn quality and is therefore used in most cases.
The rotor spinning technology is less sensitive to the existence of fibre hooks, so when spinning 100 % synthetic fibres with this technology the numbers of draw frame passages can be adjusted depending on the required yarn quality. The following list gives alternatives where the yarn quality increases stepwise from the first to the last point:

- card with integrated autoleveler draw frame
- card + autoleveler draw frame
- card with integrated draw frame + autoleveler draw frame
- card + draw frame + autoleveler draw frame.

The most sensitive spinning technology for the number of draw frame passages is air-jet spinning. To avoid problems in the high speed drafting system of the air-jet spinning machine, three drawing passages are necessary.

5.7.2. General settings

Processing of blends on the draw frame itself causes hardly any additional difficulties when compared with that of cotton. Some adaptations and know-how are needed in connection only with the drafting of pure synthetic fibres.

5.7.2.1. Roller setting

The roller settings (distances between the roller pairs of a draft zone) have to be adjusted according to the fibre lengths of the raw material. Settings which are too narrow cause fibre damage while too wide settings increase the number of floating fibres and result in higher unevenness of the sliver.

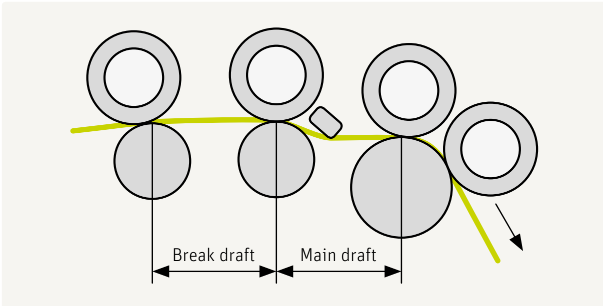


Fig. 36 – Roller settings in 4 over 3 drafting system

For polyester and polyamide fibres the following roller settings can be recommended (see Fig. 36):

- break draft field: fibre cut length +20 %
- main draft field: fibre cut length +5 to 10 %.

Rather wider settings become necessary with:

- processing of low-pill fibres
- processing of high-strength fibres
- processing of fine fibres
- processing of fibres with considerable crimp
- processing of fibres with poor spin finish
- use of low break drafts.

In the case of acrylic fibre, too narrow settings in the main drafting field can lead to cold draw setting and thus to a higher shrinkage level in the end product. If fibres longer than 40 mm are to be processed, it is advisable to remove all fibre-guiding elements, e.g. the pressure bars, from the drafting arrangement. Examples of roller settings on a 4 over 3 roller drawing frame depending on different raw materials are given in Table 11. These settings should only be used as a start-up recommendation while optimum settings always have to be found out by experiment.
General settings for standard fibres (regarding pilling behavior, strength, crimp etc.) can be found on the 5 over 3 roller drafting system in Fig. 37.

For special fibre types the settings have to be adjusted.

Material	Break draft roller setting [mm]	Main draft roller setting [mm]
50 % cotton combed 50 % polyester 1.7 dtex / 40 mm	48	43
50 % cotton carded 50 % modal 1.3 dtex / 38 mm	46	42
100 % viscose 1.3 dtex / 40 mm	48	44
100 % polyacrylic 1.3 dtex / 40 mm crimped	50	44
100 % polyester 1.9 dtex / 36 mm crimped	50	43
100 % polyester sewing thread 1.3 dtex / 38 mm	50	44
100 % polyacrylic 3.3 dtex / 60 mm crimped, dyed	65	58

Table 11 – Examples for Roller settings with different materials (4 over 3 roller)

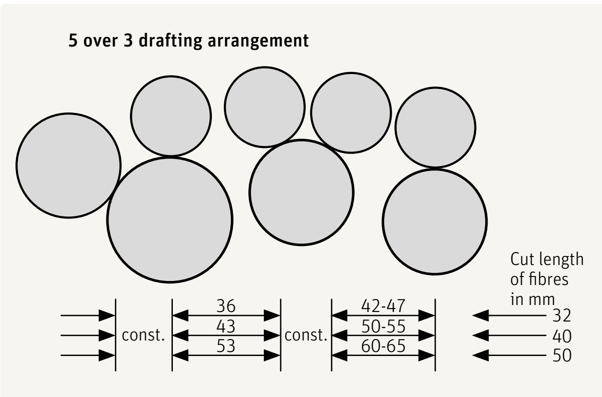


Fig. 37 – 5-over-3 roller drafting system

5.7.2.2. Top roller pressure

The task of the top roller pressure is to ensure the clamping of the fibres which is needed for an optimal drafting process. The roller loading of older draw frames must be set rather higher than for processing cotton. Modern draw frames already use high pressures for all fibres so usually no change of the pressure is required when different materials are used. Only if high drafting forces occur, higher top roller pressures are required. This can be the case, for example, when heavy sliver weights or fibres with high drafting resistance are drawn.
In Fig. 38 and Table 12 examples for regular and high top roller settings on Rieter draw frames are given.
In the case of high top roller settings an increased effective nip zone has to be taken into account and the roller settings (see chapter 5.7.2.1.) have to be increased by 1-2 mm.

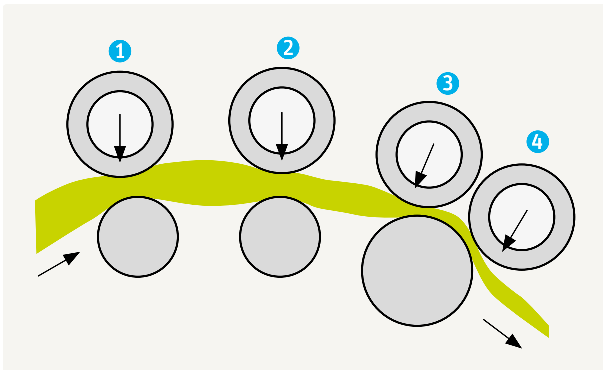


Fig. 38 – Top roller pressures on a 4-over-3 roller drafting system

	Roller 1	Roller 2	Roller 3	Roller 4
Regular setting	320 N	320 N	320 N	200 N
Settings for high drafting forces	440 N	440 N	320 N	200 N

Table 12 – Examples of top roller pressure settings on a 4-over-3-roller drafting system

5.7.2.3. Draft distribution

The total draft on a drawing frame is performed in two steps: the break draft and the main draft (see Fig. 36). The task of the break draft is to prepare the fibres for the main draft by introducing pretension into the sliver and by removing the fibre crimp. Usually the break draft is between 1.28 and 1.7 and depends on several influencing factors. In general it can be said that higher break drafts are needed with:
- earlier draw frame passages
- finer fibres
- longer fibres
- pill-free fibres
- high strength fibres.

In any case stick-slip motion has to be avoided (see Rieter Manual of Spinning – Volume 1).
Since the break draft depends on the material and the total draft is usually set by the processing system, the main draft is given and has to be calculated by total draft divided by break draft. For high quality products the main draft should however be limited to the following values:
- cotton/man-made fibre blends: 3.8
- viscose: 6.3
- acrylic (crimped): 5.2
- polyester (crimped): 6.0
- polyester (sewing thread): 3.7
- polypropylene: 6.1

Examples of draft arrangements for different materials and for draw frames of the first and second draw frame passage are given in Table 13.

5.7.2.4. Speed

The maximum speeds possible for a draw frame depend on the fibre material and are limited by:
- an increase of top roller laps
- a top roller temperature that is too high for sensitive man-made fibres
- an increase of machine stops and reduced efficiency
- a deterioration of the sliver quality
- a reduction of cot lifetime.

In general it can be said that the maximum possible speeds are lower with the use of:
- fine fibres
- low-pill fibres
- high-strength fibres
- fibres with high crimp
- fibres with poor spin finish
- fibres with low melting point.

In Fig. 39 examples of standard and maximum draw frame speeds are given for different fibre materials. It is advisory to set delivery speed not to maximum rates because of the low influence of the drawing processes on the total spinning costs and the influence of the speed on the sliver quality.

Material	1. Draw frame passage		2. Draw frame passage	
	break draft	total draft	break draft	total draft
50 % cotton combed 50 % polyester 1.7 dtex / 40 mm	1.41	8	1.28	8
50 % cotton carded 50 % modal 1.3 dtex / 38 mm	1.41	8	1.28	8
100 % viscose 1.3 dtex / 40 mm	1.41	9	1.28	8.3
100 % polyacrylic 1.3 dtex / 40 mm crimped	1.7	6.8	1.28	6.7
100% polyester 1.9dtex / 36 mm crimped	1.41	8.4	1.28	8
100 % polyester sewing thread 1.3 dtex / 38 mm	1.7	6.4	1.7	6.4
100 % polyacrylic 3.3 dtex / 60 mm crimped, dyed	1.7	6	1.41	8

Table 13 – Examples of draft distributions with different materials

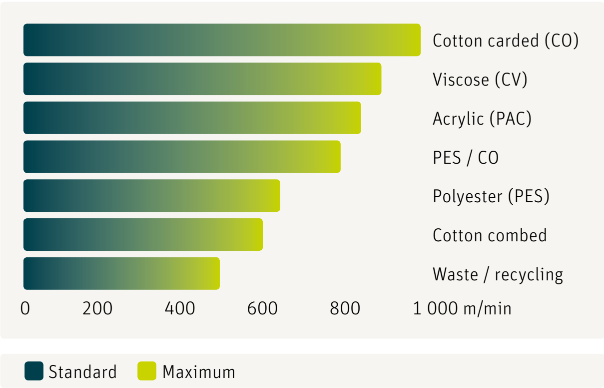


Fig. 39 – Standard and maximum draw frame delivery speeds for different materials

5.7.2.5. Web condensing

When the fibres are delivered by the delivery rollers the fibre strand has to be condensed and guided to the calendar rollers. This is done with by a web funnel and a trumpet (condenser). The hole diameter of these elements has to be adjusted according to the sliver weight and bulkiness of the fibre material.
The tension draft between the delivery roller and the calendar roller also needs to be set according to the fibre material, in order to gather the web and pull the sliver through the trumpet and to ensure good evenness values. The following tension drafts can be used as a general recommendation:
- cotton: 1.00 to 1.02
- polyester/cotton: 0.99 to 1.00
- man-made fibres: 0.98 to 1.00

5.7.3. Problems

The running behavior at the draw frame is influenced by the following factors:
- fibre parameters (e.g. fineness, crimp, length, etc.)
- spin finish
- moisture content of air
- condition of machine components contacted by the fibres
- settings.

The main problems, which almost exclusively arise in the processing of 100 % man-made fibres, are:
- laps on the machine parts
- splitting-out of fibres from fleece and sliver edges blocking of sliver-guide passages
- drafting problems and drafting disturbances
- thermal deterioration of the fibres and spin finish.

A lap can occur if the remaining crimp, and hence the spreading ability of the fibres, is too low. In addition fine fibres have a stronger tendency to form laps than coarse ones. Thus, the delivery speed must often be reduced in the processing of fine fibres.
Other reasons for lap formations on machine parts, mainly on the drafting cylinders, are:
- accumulation of static charge (when the air is too dry)
- smearing of spin finish (poor finish or excessive moisture content)
- splitting out of edge fibres.

However, laps are very often caused by poor or badly maintained top rollers. To avoid laps, the following instructions are advisable:
- cots treatment with anti-static
- (75) - 83° Shore hardness (tendency to form laps higher with softer cots)
- avoidance of damage to the cots
- periodic washing of the cots.

Surface treatment of the coatings is also very advantageous, though lacquering is not particularly useful. Better results are obtained by the smoothing of the coatings by an acid treatment or UV-light irradiation (Berkolising).
Splitting-out of edge fibres from the fleeces and the sliver leads to laps, blockage in guide passages and interlacing of fibres, and hence to sliver breaks and increased hairiness of the slivers. This arises especially from:
- poor spin finish (too little fibre adherence)
- static charge
- bad feeding of slivers in sliver blending.

In sliver blending, those slivers with the lowest tendency to splitting-out fibres should always be fed on the outside, for example in blends with combed cotton, the cotton slivers should not be located at the edge.
Blockages of guide passages are caused partly by static charge, but mainly through deposits of spin finish. This tendency may be due to the finish itself or to excessive moisture content of the air. This problem can only be avoided by periodic cleaning.
Drafting difficulties arise in connection with:
- incorrect spin finish (excessive fibre/fibre adherence)
- incorrect matching of the staple lengths of the cotton and man-made fibre components in blends
- high fibre crimp
- too narrow draft settings (mainly break-draft distances)
- wrong break draft
- excessive fibre mass in the drafting arrangement (use lower doubling or finer-feedstock slivers).

Thermal damage is caused by heating of the top rollers. Even at speeds of 400 m/min, top-roller temperatures can reach 80 °C. With a normal flow of fibres through the drafting arrangement, there will be no fibre damage because the contact time is too short. However, damage arises when the draw frame is stopped and the heat is applied to the fibres under pressure. For example, polyester begins to change its structure at temperatures of 80 °C (polyolefin much earlier) and this primarily affects dyeing behavior. Even if the influence in the sliver is restricted to a length of 1 - 2 cm, it will affect 5 - 50 m of yarn. This defect becomes visible only after dyeing.
The heat affects not only the fibre itself but also the spin finish; this effect can arise at temperatures of only 50°C. Mainly the viscosity changes and, as a result, several processing parameters (e.g. the friction force) are radically affected.

5.7.4. Process environment

Material	rh%	Temperature		g. water / kg air
		Deg C	Deg F	
Polyester	50 - 52	24 - 26	75 - 79	10 - 11
Viscose / Polyester	48 - 54	24 - 26	75 - 79	10 - 12
Cotton / Polyester blends	45 - 50	24 - 26	75 - 79	9 - 11

Table 14 – Good ambient conditions for processing of man-made fibres at the draw frame

5.8. Roving production
5.8.1. General settings
5.8.1.1. Roller setting

Like the roller settings in the draw frame, the roller settings at the roving frame have to be adjusted according to the fibre length. Settings which are too narrow cause fibre damage, while settings which are too wide increase the number of floating fibres and result in higher unevenness of the roving. The break draft distance is an important parameter for the roving quality. The optimum setting is not only influenced by the fibre length but also by the drafting resistance of the fibre material. The higher the drafting resistance the higher the break draft roller setting has to be used.
Examples for roller settings on a Rieter roving frame can be found in Figure 40 / Table 15. The values in that table can be used as a startup setting for further optimizing.

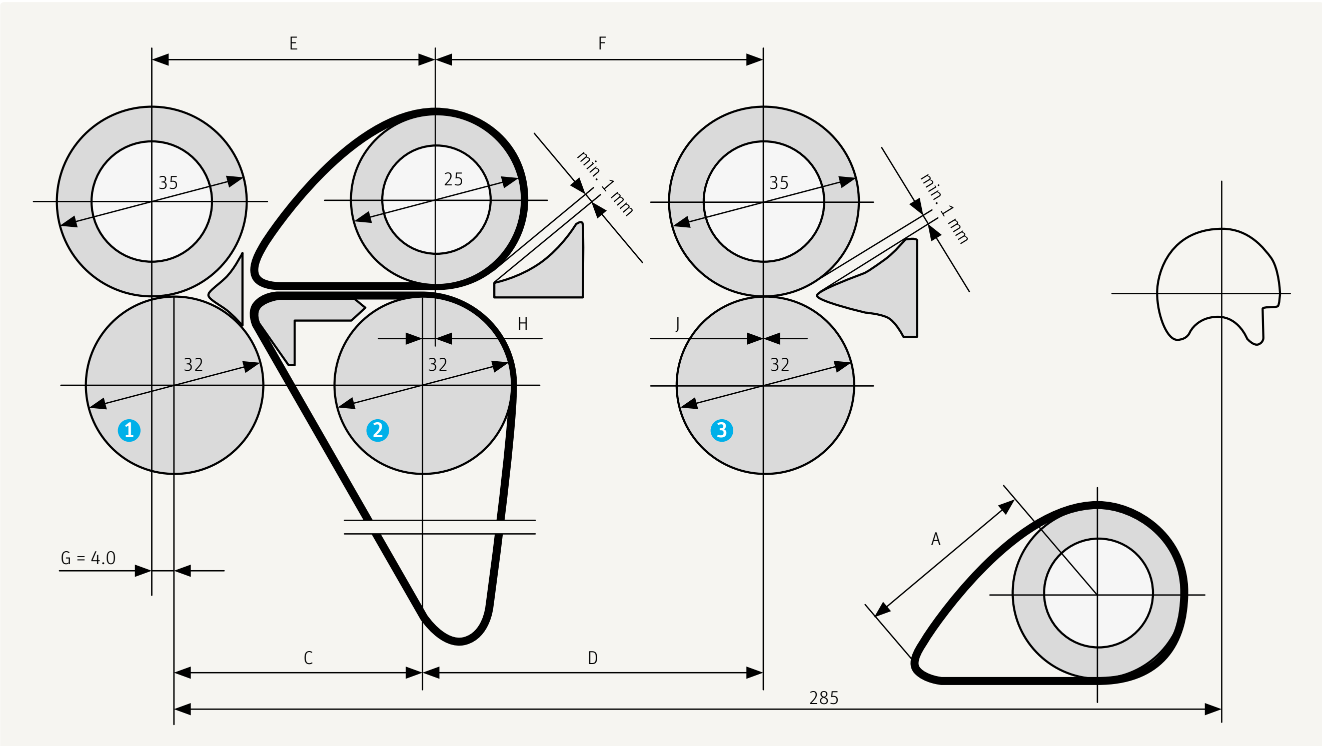


Fig. 40 – Roller settings at the drawing system in a roving frame

Setting	1	2	3
Raw material	**For cotton, synthetics and blends up to 40 mm**	**For cotton, synthetics and blends up to 50 mm**	**For synthetics and blends up to 60 mm**
A = Cradle length	34.5 mm	45.0 mm	60.5 mm
B = Guide bar	24.0 mm	33.0 mm	48.0 mm
C = Main draft distance bottom rolls	49.0 mm	69.0 mm	76.0 mm
D = Break draft distance bottom rolls	min. 60.0 mm	min. 60.0 mm	min. 70.0
E = Main draft distance top rolls	55.0 mm	66.0 mm	82.0 mm
F = Break draft distance top rolls	min. 59.0 mm	min. 59.0 mm	min. 70.0 mm
G = Forward offset 1st top roll	4.0 mm	4.0 mm	4.0 mm
H = Backward offset 2nd top roll	2.0 mm	2.0 mm	2.0 mm
J = Backward offset 3rd top roll	0.0 mm	0.0 mm	0.0 mm

Table 15 – Examples of standard roller settings according to the fibre length on a Rieter roving frame

5.8.1.2. Draft distribution

The task and the influencing factors of the break draft on the roving frame are very similar to the same on the drawing frame (see 5.7.2.2.). Optimum setting depends on the fibre material and should be set high enough to get pretension onto the fibres and to remove the crimp and low enough to avoid stick-slip motion (see Rieter Manual of Spinning – Volume 1). Usually setting of the break draft is between 1.1 and 1.4. For fibres with high draft resistance, the setting of the break draft has to be reduced to avoid vibrations in the feed and middle roller, in some cases to values even lower than 1.1.
The total draft depends of course on the output fineness, which is influenced by the fineness of the required yarn fineness. In general, when processing synthetic fibres or blends, the total draft on the roving frame should be above than 7.5. In Table 16 recommendations for the total draft settings can be found for cotton/man-made fibre blends or for pure man-made fibres.

Recommended total draft range		
Fibre type	**Preferred draft**	**Possible range**
Blends of cotton / synthetics and man made fibres	7.5 to 12.5	7 to 13
100 % synthetic fibres (polyester, viscose, acrylic and nylon) up to 60 mm length	8 to 14	7.5 to 17

Table 16 – Recommended total draft ranges

5.8.1.3. Condensers

Condensers (see Fig. 41) guide the fibres through the drafting system and compact the fibre strand slightly, which reduces hairs and fibre fly. The openings of the condensers should be selected according to the fineness of the fed sliver but have to be adapted to the higher bulkiness of man-made fibres.

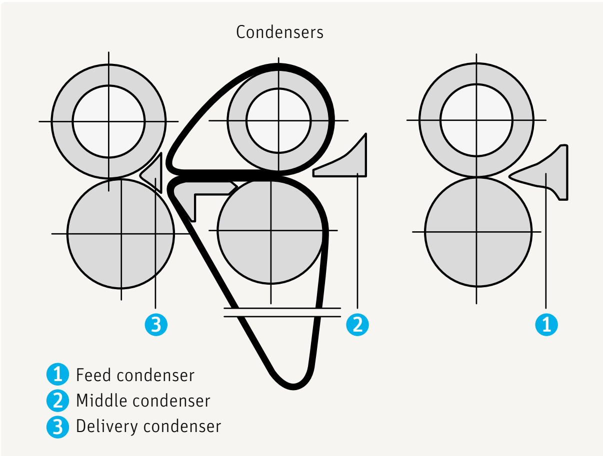


Fig. 41 – Condensers in the drawing system of a roving frame

5.8.1.4. Roving twist level

Because of longer fibres and higher fibre-fibre friction, the twist level in man-made fibre roving has to be set lower than the twist level for cotton. Too high levels result in drafting difficulties in the ring spinning process, which are reinforced by high air-moisture levels because of the higher mutual adherence of the fibres. Certainly, the twist level still has to be high enough to avoid false drafts in the roving and ring spinning process.
In general, it can be said that the twist level must be higher with:
- coarser fibres
- shorter fibres
- finer roving fineness.

Recommendations for the twist level of man-made fibre roving according to the fineness of the roving and to the fineness of the fibres can be seen in Fig. 42. For blended yarns the twist level should be set between those for cotton and those for synthetics in correspondence with the blend proportions.

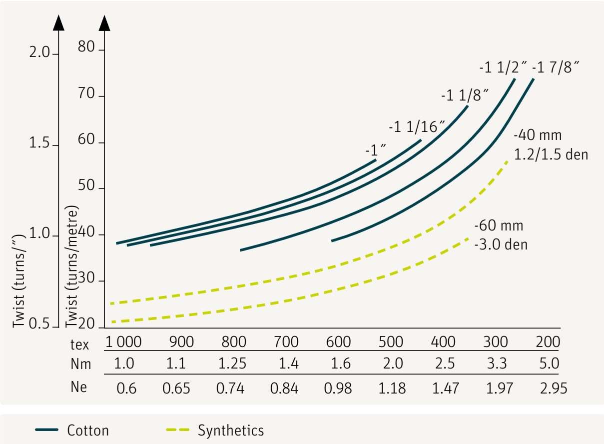


Fig. 42 – Roving twist level recommendations

5.8.1.5. Flyer speed

The speed of the flyer is limited because at higher speeds the higher centrifugal forces lead to bursting of the roving layers on the bobbin. This limitation increases with bigger bobbin diameters so that the speed of the flyer has to be reduced proportionally to the size of the bobbin.
Optimum flyer speeds have to be determined by tests but the following Fig. 43 shows recommended maximum and minimum flyer speeds with different fibre materials and twist coefficients.

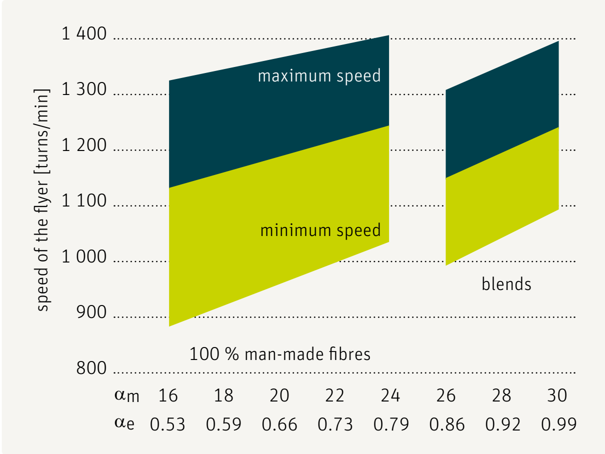


Fig. 43 – Flyer speed recommendations according to fibre material and twist coefficients

5.8.2. Problems

Once again, problems arise mainly from spin finish. In addition to those already mentioned, long exposure of the top-roller coatings and aprons to spin finish can lead to swelling of those elements and to formation of deposits. This effect is especially noticeable after long periods of inactivity. Furthermore, the aprons often become smeared with spin finish which results in a stickiness of these elements. They should be washed from time to time.
If the roving has too many thick places, or even slubs, the causes could be one or more of the following:
- exit opening of the drafting arrangement too narrow
- condenser too narrow
- spacing of the nip lines too short
- top-roller loading inadequate
- feedstock sliver too coarse
- damaged aprons.

5.8.3. Process environment

Temperature	23 - 27 °C
Rel. Humidity	48 - 56 %
Water Content	9 - 12 g/kg

Table 17 – Good ambient conditions for processing of man-made fibres on the roving frame

5.9. Ring spinning
5.9.1. General settings
5.9.1.1. Roller settings and cradle length

Like the roller settings in the draw frame and in the roving frame, the roller settings at the ring spinning machine have to be adjusted according to the fibre length. As it was explained in the other processes that use a 3-over-3 roller drawing system, there are two roller distances that have to be adjusted: the break draft (B in Fig. 44), which has the function of pretensioning the fibres, and the main draft (A in Fig. 44), which has the function of drawing the fibre material to the required yarn fineness.

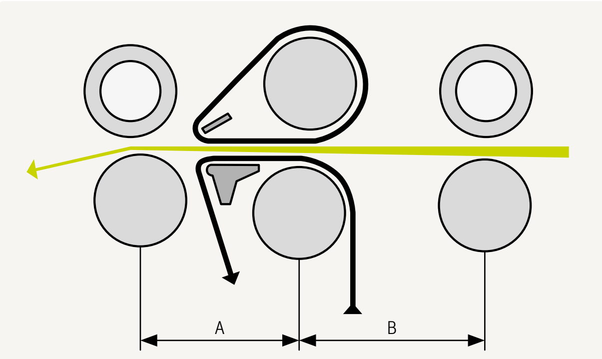


Fig. 44 – Roller settings in a ring spinning machine
(A: main draft; B: break draft)

As mentioned in the appropriate chapter of the roving production setting (chapter 5.8.1.1.), the optimum setting of the break draft distance is not only influenced by the fibre length but also by the drafting resistance of the fibre material. The higher the drafting resistance the higher the break draft roller setting has to be chosen.
Examples for settings of the main and the break draft distance with different fibre materials can be found in Table 18.

Fibre Material	Break Draft Distance	Main Draft Distance
Blends < 40 mm	70 mm	42.5 mm
Man-made fibres < 40 mm	70 mm	42.5 mm
Man-made fibres 51 mm	70 mm	54 mm
Man-made fibres 60 mm	80 mm	68 mm

Table 18 – Examples of break draft and main draft field distances

For different main draft field distances that are necessary when processing fibres with different lengths, cradles with different cradle lengths are available (see Fig. 45). Examples for the right cradles with different fibre lengths can be seen in Table 19.

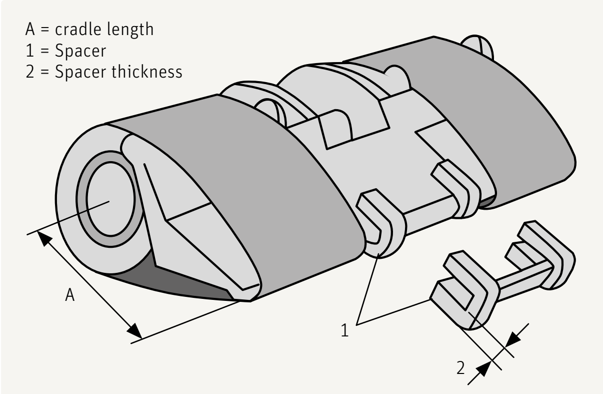


Fig. 45 – Cradle length and cradle spacer

Cradle Length	Maximum Fibre Length
36 mm	32 - 40 mm
43 mm	40 - 51 mm
59 mm	50 - 60 mm

Table 19 – Examples of cradle lengths according to the fibre length

If for economic reasons fibres have to be spun that exceed the specified length of the cradles in use (for example fibres longer than 40 mm with the 36 mm cradle) the middle bottom roll can be moved backwards up to 8 mm to accommodate the increased staple length. Then the middle top rolls with the cradles and the back rollers have to be adjusted accordingly.
The spacer thickness (see Fig. 45) has to be adjusted according to the fineness of the fibre material. When adjusting the spacer thickness, the higher bulkiness of the fibres has to be taken into account in order to avoid over control of the fibres which leads to a higher ends-down rate and a high number of thick and thin places in the yarn.

5.9.1.2. Top roller pressures and top roller cots

Top roller pressures may have to be raised in older drafting arrangements. They should not lie below 12 daN, on the front cylinders, possibly even as high as 15 daN.
In general it can be said that softer front top roller cots result in a better enclosure and guidance of the fibres. But especially when running man-made fibres and blends, softer front roller cots have a higher tendency to form laps and they wear out quickly. To avoid these disadvantages, harder cots should be chosen. In addition, treatment of at least the delivery roller, as described in chapter 5.7.3., is advantageous.
Recommended shore hardness of top roller cots when running man-made fibres are 65-75° for the feed rollers and 75-85° for the delivery rollers. In the processing of blends, those cots should be selected which provide a good yarn quality with a minimal lapping tendency.

5.9.1.3. Draft distribution

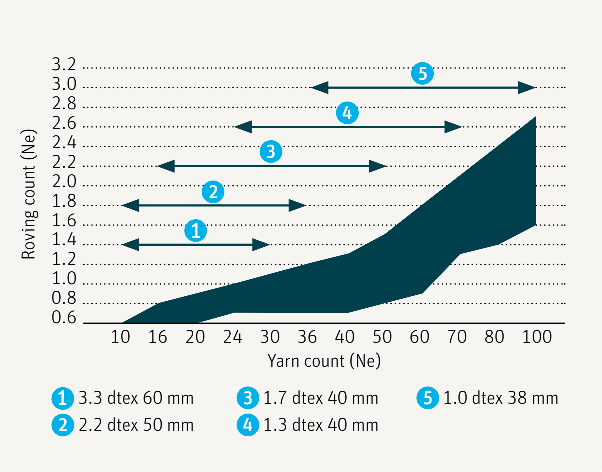


Fig. 46 – Recommendations for roving fineness depending on the required yarn fineness and on the fibre material

The total draft in the drawings system of a ring spinning machine depends, of course, on the relationship of the roving and the yarn fineness. To avoid process problems and yarn quality losses, the total draft has to be set within practical limits which depend on the properties of the used fibre material. In the end, the roving fineness has to be adjusted stepwise to the required yarn fineness in order to avoid a drawing process outside the practical limits. In Fig. 46 recommendations for the roving fineness according to the required yarn fineness and to the used fibre material can be found.
Once the total draft has been evaluated within the practical draft limits, it has to be divided into the break draft and the main draft.
Like the total draft, the break draft has to be set within limits. On the one side, it has to be high enough to fulfill the task of pretensioning the roving for an optimum drawing process in the main draft zone. On the other side, the break draft has to be low enough to avoid stick-slip motion (see Rieter Manual of Spinning – Volume 1) or to avoid overload of the drive system when processing fibres with high draft resistance on long spinning machines. As general rules it can be said that:

- with higher break drafts the break draft distance should be reduced to maintain yarn quality
- with lower break drafts the break draft distance can be higher, which results in a less sensitiveness to variations of fibre length, roving draft resistance and climatic conditions.

Examples for normal break drafts with processing different fibres and different draft levels can be found in Table 20.

Fibres	Total Draft	Break Draft
Blends	< 70	1.16 - 1.22
Man-made fibres < 40 mm	< 60	1.16 - 1.20
Lyocell < 40 mm	< 60	1.10 - 1.14
Cohesive Polyester< 40 mm	< 60	1.09
Man-made fibres < 50 mm	< 50	1.16 - 1.18
Man-made fibres < 60 mm	< 45	1.16 - 1.18

Table 20 – Examples for normal break drafts with processing different fibres and different draft levels

The main draft has to be set after choosing an appropriate break draft according to the required yarn fineness.

5.9.1.4. Traveler speed

The traveler speed is the most important limiting factor regarding production speeds on a ring spinning machine. In comparison to spinning cotton, the maximum traveler speed for spinning man-made fibres or blends has to be reduced. Higher traveler speeds increase the risk of thermal damage of the fibres which is described in chapter 5.9.2.. Thus, manufacturers of man-made fibres usually suggest maximum traveler speeds of 28 to 30 m/s. When processing fibres with a low melting point such as polypropylene or low-pill fibre types, a further decrease of the maximum traveler speeds well below 28 m/s is necessary. When spinning blends, the risk of thermal damage of the fibres can be ignored.
Additionally, an increase of end-down rates limits the maximum traveler speeds to both ends of the yarn fineness spectrum because of high centrifugal forces with coarse yarn counts and low yarn breaking forces with fine yarn counts. In Fig. 47 the maximum traveler speed ranges for normal synthetic fibres are illustrated depending on the yarn fineness.

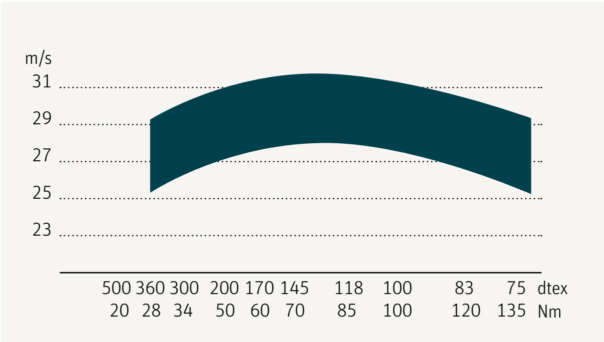
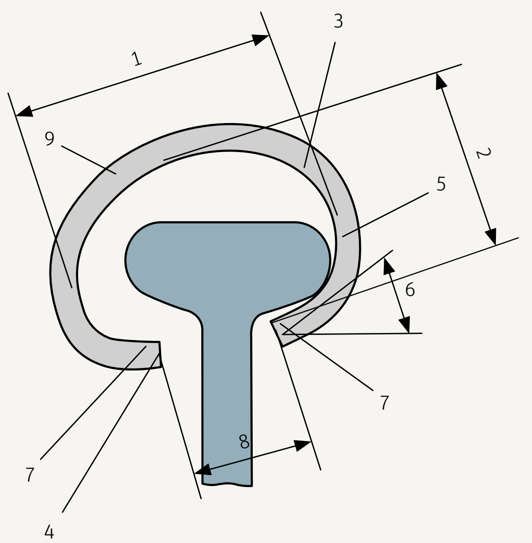


Fig. 47 – Maximum traveler speed ranges for synthetic fibres

5.9.1.5. Traveler form

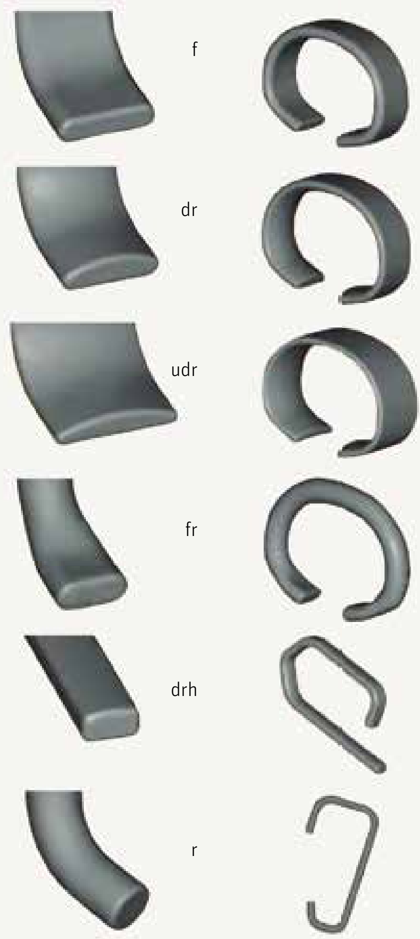
The traveler has many parameters (see Fig. 48) and has to be selected according to:
- type of flange
- fibre material
- yarn count
- ring flange size
- ring profile.

The manufacturers of rings and travelers support the selection with recommendations to find the optimum traveler for each application.
In general, travelers with a high bow should be used because of the friction sensitiveness of synthetic fibres. They avoid contact of the yarn on the ring crown which would result in melting points in the yarn.
Another important parameter of the traveler is the wire section which has an influence on the yarn quality, the spinning stability and on lifetime of the travelers. Different forms have been developed for specific applications which can be found in Fig. 49.



1 – Inner traveller width
2 – Height of bow
3 – Yarn passage
4 – Wire section
5 – Traveller – ring contact surface
6 – Angle of toe
7 – Toe
8 – Opening
9 – Upper part of traveller bow

Fig. 48 – Parameters of a C-shaped traveler



f
Good results regarding hairiness. Suitable for fine cotton yarn and viscose.

dr
For blends, cotton and synthetics. Good results for low twisted yarns.

udr
For cotton, blends and synthetics. Extremly wide half-round profile offers a large contact surface. For high speeds.

fr
For acrylics, special synthetics and core yarn. Flat toe, round traveller bow (yarn passage), for higher speeds.

r
For synthetics and core yarn, for lower speeds.

drh
For SU travellers. Also available with **udr** and **r** profile.

Fig. 49 – Wire sections and their recommended application

Raw blend	PES / CO								PES / MOD	Pure PES
	Carded				Combed					
Blend proportions %	67/33		50/50		67/33		50/50		65/35	
Fibre length PES (mm)	32	38/40	32	38/40	32	38/40	32	38/40		
Min. numbers of fibres in cross-section	70	60	75	65	65	55	70	60	60	50 (-60)

Table 21 – Spinning limits of various spun yarns out of man-made fibres

5.9.1.6. Spinning limit and yarn twist

In ring spinning of man-made fibres and blends this spinning limit usually lies in the region of 50 to 75 fibres (see Table 21). This limit is lower than that for cotton because of greater fibre adherence and lower length variation of man-made fibres.
For the same reasons it is possible to spin yarns of man-made fibres with lower twist levels than yarns with cotton and also the critical twist level (maximum tensile loading) is lower for man-made fibres (see Fig. 50). The appropriate values for blends are between these maxima, depending on the percentage distribution of the materials: the higher the percentage of man-made fibres is, the closer the values are to the 100 % man-made fibre values and vice versa.

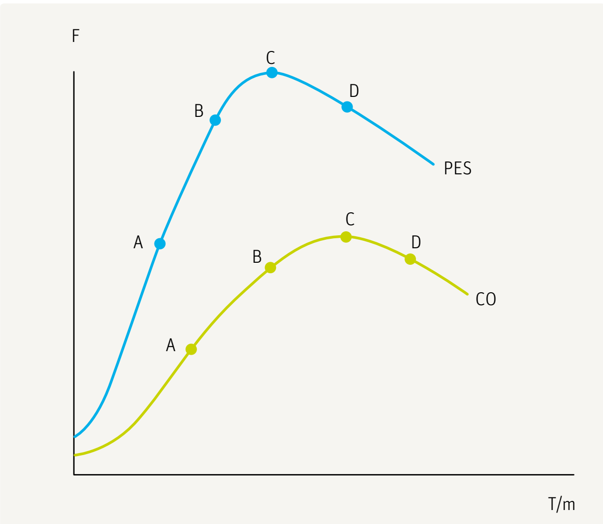


Fig. 50 – Relationship between the number of turns of twist and the strength of a yarn; F, strength; T/m, turns of twist per meter in the yarn; PES, polyester fibres; CO, cotton fibres

Common twist multiplier for weaving yarns out of polyester fibre material and blends can be found in Fig. 51. Knitting yarns out of these materials lie about 10 % below these levels. Acrylic-fibre yarns are about 5 % above the appropriate yarns made of polyester.

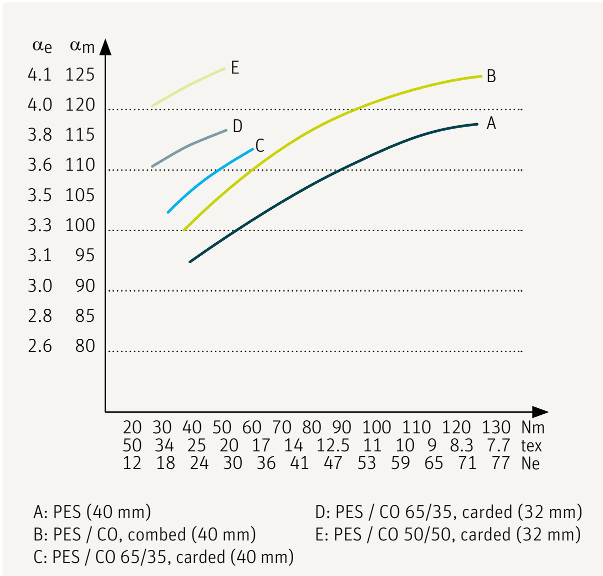


Fig. 51 – Common twist multipliers

5.9.2. Problems
5.9.2.1. General problems

Problems in the ring spinning process with man-made fibres can be caused by:
- the fibres
- the machine
- the roving
- the air conditioning.

Problems caused by the fibres can arise from:
- poor spin finish (high fibre/fibre adherence, smearing)
- low plasticizing point (this is the main cause and it leads rapidly to thermal damage).

On the machine side, the factors to be considered are:
- incorrect settings
- incorrect cradle opening in the drafting arrangement
- wrong break draft
- too low top-roller loading
- excessive lift of the roving-guide movement
- incorrect or damaged top rollers and guide aprons
- too low aspiration pressure
- incorrectly selected rings and travelers
- damaged thread guides, rings and travelers, inadequate centering of ring, spindles and thread guides (very important factors in processing man-made fibres), excessive speed.

The problems in the roving are:
- too high hairiness level
- excessive unevenness
- too high twist level.

In the air-conditioning system, the moisture level may be:
- too low (static electricity, lap formation, hairiness)
- too high (smearing of spin finish, stickiness of spinning elements, lap formation.

An additional problem can crop up at the winders. If the wrong kind of plastic tubes at the ring frame has been used, the fibres are charged in running over the tube. This causes the yarn to break repeatedly in back winding and it can no longer be unwound. This happens mainly in the lower part of the bobbin.

5.9.2.2. Thermal fibre damage [10] [11] [12]

The biggest problem in the processing of synthetic fibres is the risk of thermal fibre damage on the balloon-control ring and in the region of the ring and traveler. At the balloon control-ring such damage arises when the balloon is too large and the yarn is pressed against the balloon control ring resulting in high fibre/metal friction. The time of contact is long enough to permit significant warming of the fibres. This leads to changes in the fibre substance, going as far as melting. The results are:
- reduction of yarn strength
- lowering of yarn elongation
- generation of fibre particles
- a rise in ends down and dust levels, especially in the subsequent processes such as winding
- slub formation when rubbed over thread guides
- variable dyeability.

Damage of this kind does not affect the yarn over its whole length. It arises only intermittently, in particular when the contact pressure of the yarn on the balloon-control ring is high, i.e. when the balloon is large. A large balloon is formed in the lower part of the ring-rail movement (winding onto the largest bobbin diameter) and in the first phase of winding of the bobbin (until the bobbin build is about half complete) (Fig. 52). This is why melt points are only rarely found in lengths of yarn lying in parts of the bobbin having medium or small diameter (layer winding) and in lengths lying in the upper layers of the whole bobbin.

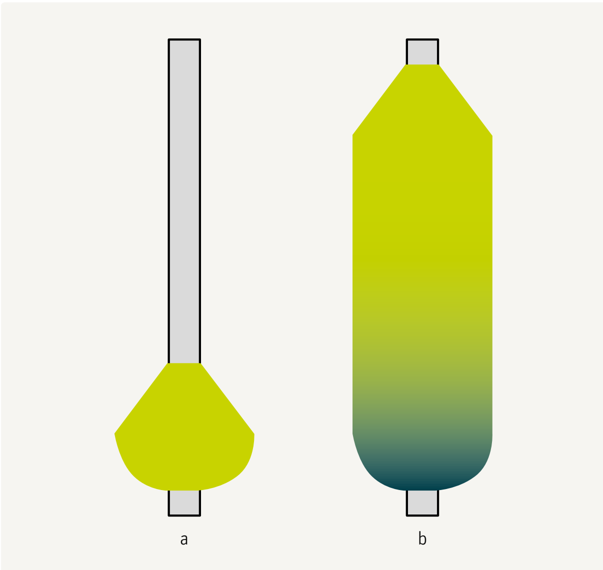


Fig. 52 – (a) Melt points in the lower part of the layer winding
(b) Melt points in the bottom half of the bobbin

Damage arises as a linear function of spindle speed. Apart from reducing speed, damage can be limited only by using smaller rings and a shorter lift. The balloon-control ring can possibly be eliminated if the ring and lift are made very small. No melt points will occur under these conditions even in spinning at traveler speeds of 35 m/s. Spinning with smaller rings is a viable possibility in the production of finer yarns with an automatic doffer on the ring frame and a splicer on the winder.
This kind of thermal damage can be easily detected in dyeing but detection is very difficult during spinning. Often, there is a deposit of fine, flour-like dust.
Thermal damage also arises in the region of the ring and the traveler when the yarn is pressed against the ring and as a result the fibres are heated by friction. The yarn always adopts this low position in the traveler when tension is high because of the narrowing or drawing in of the balloon (see also The Rieter Manual of Spinning – Volume 1, sections 8.5.3.). High tensions of this order arise only during winding in the upper portion of the lift stroke and the upper portion of the ring rail movement (smaller diameter) (Fig. 53). Accordingly, such damage is only found in the upper part of the layer winding and usually only in the upper half of the overall bobbin structure. It can often be recognized by a rather coarse, splinter-like deposit on the ring rail.
A high-bow (C-shaped) traveler is usually needed in processing synthetic fibres in order to avoid damage of this kind. This traveler form has a larger space permitting passage of the yarn.

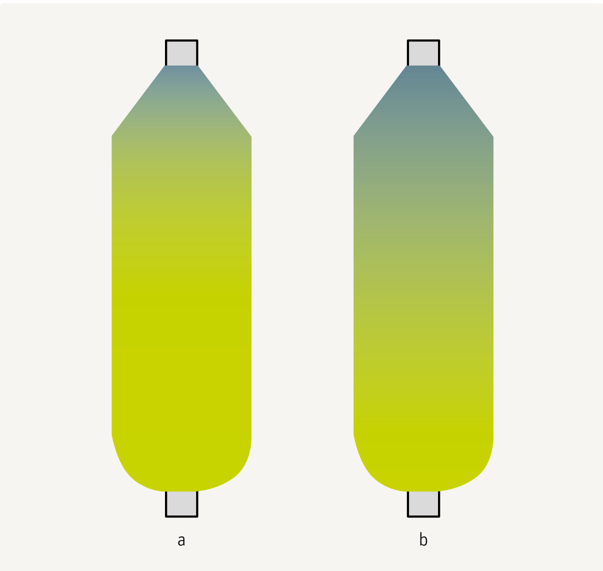


Fig. 53 – (a) Melt points in the upper part of the layer winding
(b) Melt points in the upper half of the bobbin

5.9.3. Process environment

A water-vapor content of 9.5 - 11.5 g per kg dry air has proved to be favorable. At spinning temperatures of 23 - 27 °C, this moisture content gives relative humidity in the range of 45 - 55 %. However, to avoid the risk of static charge, it is often better not to let relative humidity drop below 50 %.

5.10. Compact spinning

Compact spinning is a further development of the ring spinning technology and provides an improved yarn quality including higher yarn tenacity and lower yarn hairiness (see Rieter Manual of Spinning – Volume 4). The drawing and the twist insertion elements in a compact spinning machine though are the same as in a ring spinning machine, so the settings of these elements as well as the problems that arise from them are similar to those in ring spinning and are described in the appropriate chapters 5.9.1. and 5.9.2. In this chapter the additional setting of the compact zone and issues that are related to the special compact yarn structure are described.

5.10.1. General settings
5.10.1.1. Compacting zone

The elements of the Rieter compact system can be seen in Fig. 54. Depending on the fibres and on the required yarn fineness the appropriate suction unit and air guide element have to be chosen.

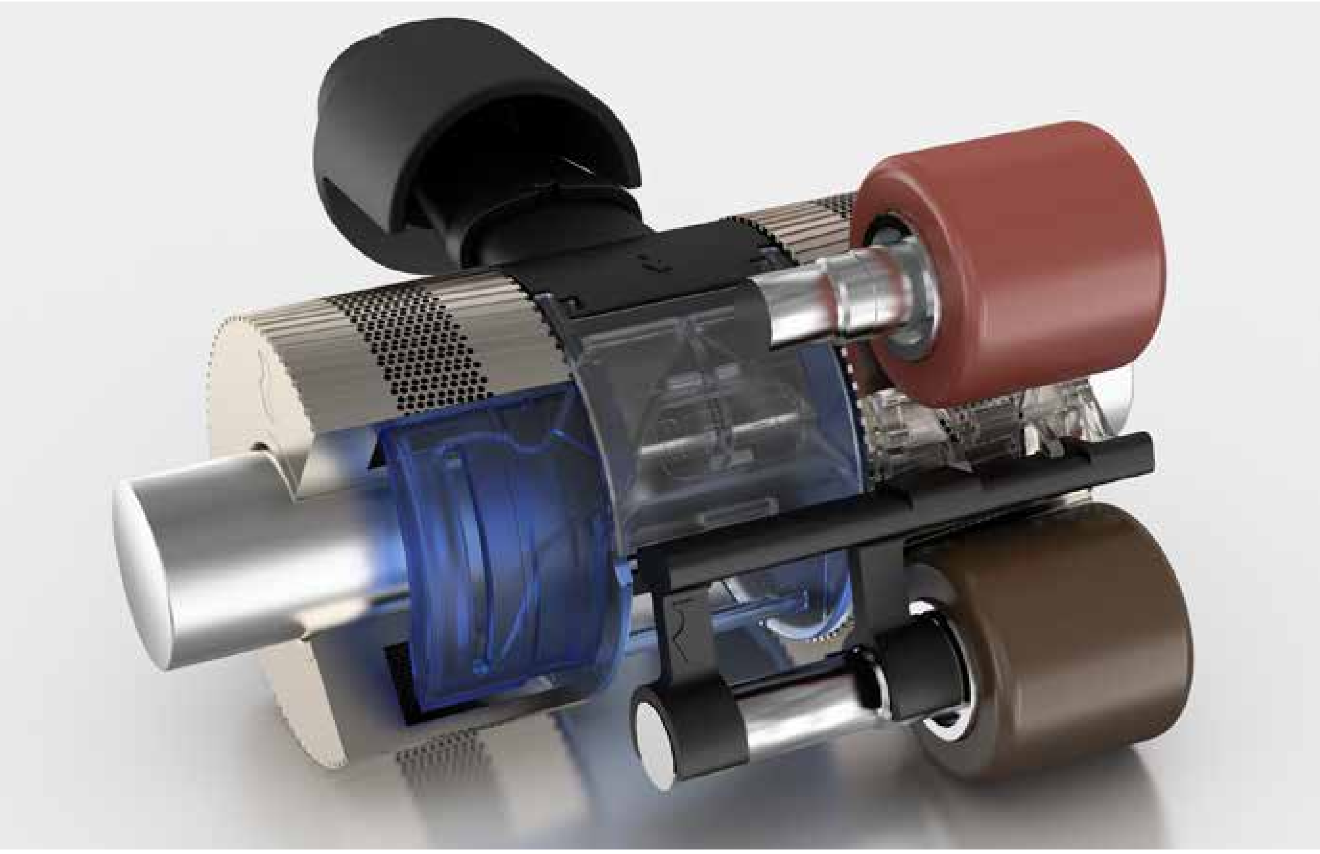


Fig. 54 – Compacting elements

The recommended suction unit for man-made fibres and blends is the linear suction unit (Fig. 55).

Fig. 55 – Recommended suction unit for man-made fibres and blends

5.10.1.2. Ring finish

As described in The Rieter Manual of Spinning – Volume 4, the traveler lubricates itself by fibre fragments which are taken out of the hairiness of the yarns. The low hairiness of the compact spun yarns results in a lower lubrication of the traveler. Although the lubrication can be increased by choosing the right traveler form (see chapter 5.10.1.3.), a higher wearing of the ring/traveler system has to be expected. For this reason rings with a high wear resistant finish (like TITAN rings from Bräcker) are highly recommended.

5.10.1.3. Traveler form

As described in the last chapter, the low hairiness of compact-spun yarns leads to a lower lubrication of the ring/traveler system. To compensate this effect as much as possible, travelers with low yarn clearance should be chosen to bring the yarn hairiness closer to the contact area between ring and traveler in order to get more lubricating fibre fragments.
Because of the lower lubrication the friction between ring and traveler is higher and lighter numbers should be used.

5.11. Rotor spinning
5.11.1. Fibre selection

Because of limitations in the rotor spinning technology, the selection of appropriate fibres plays an important role in the rotor spinning process. Two fibre parameters have to be considered:
• fibre fineness
• fibre length.

The fibre fineness is limited by the required significantly higher number of fibres in the yarn cross section than the number needed in ring yarns. As described in chapter 4.1.1.3. rotor yarns usually need at least 100 fibres which limits the finest possible yarn that can be spun depending on the fibre fineness as indicated in Table 22.

Fibre Fineness	Yarn Fineness		
dtex	tex	Ne	Nm
1.7	20	30	50
1.3	16	38	64
1.1	13	45	77

Table 22 – Limitations of rotor yarn fineness with given fibre fineness

The fibre length is limited by the rotor diameter. If the fibre length with a given rotor diameter is too long, the following disadvantages have to be expected:
• higher number of wrapper fibres
• lower spinning stability
• lower yarn quality.

As a general rule, the maximum recommended fibre length can be calculated by the formula:

Maximum Fibre Length ≤ 1.3 ×Rotor Diameter

5.11.2. General settings
5.11.2.1. Opening roller type and opening roller speed

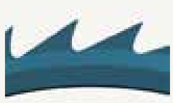
When running man-made fibres and blends, the right choice of the opening roller is very important to ensure good separation of the fed fibres with minimized fibre damage. Parameters that have a high influence on the opening process are:
• clothing type
• opening roller coating
• opening roller speed.

In general, the more aggressive these chosen parameters are, the better the opening action and the higher the risk for damaging the fibres are. Therefore opening roller clothings for the sensitive man-made fibres are less aggressive than the clothings for cotton. The coatings of the opening rollers (wires or solid rings) were developed to extend their lifetime. The most common coating is a layer of diamond particles embedded in a nickel base (DN coating). To reduce the roughness of this coating, an additional nickel layer is coated on top of it. However, when spinning very sensitive fibres it is advisable to use only a nickel coating (N coating) in order to avoid fibre damage. In the latter case, a shorter lifetime has to be expected.
In Fig. 56 recommendations for opening roller types and opening roller coatings can be found for different fibre types.

CLOTHING WIRE

Form / Type	Form								
	Type	OB 20 B		OB 20/4	OB 20		OS 21		OS 43
Coating / Raw material	Coating	DN	*	DN	DN	*	DN	*	DN
	Cotton	Recommended	Recommended	Possible	Recommended	Possible	Possible		
	Regenerate	Recommended			Recommended		Possible		
	Viscose	Recommended		Possible	Recommended		Possible		
	Polyester/-acryl						Recommended		Recommended
	Blends like PES/CO	Recommended	Recommended	Possible	Recommended	Possible	Recommended	Possible	Possible

SOLIDRING

Form / Type	Form								
	Type	B 174		B 174 - 4.8		B 20		S 21	S 43
Coating / Raw material	Coating	DN	N	DN	N	DN	N	DN	DN
	Cotton	Recommended	Recommended	Possible	Possible	Possible	Possible	Possible	
	Regenerate	Recommended						Possible	
	Viscose	Recommended		Possible				Possible	
	Polyester/-acryl							Recommended	Recommended
	Blends like PES/CO	Recommended	Recommended	Possible	Possible	Possible	Possible	Recommended	Possible

– Possible
– Recommended

D – Diamond coating
DN – Diamond-nickel coating

N – Nickel coating
* – Needle finish treatment of wire

Fig. 56 – Rieter opening roller recommendations

The optimum speed of the opening roller has to be found by spinning trials. The limitations for maximum opening roller speeds are fibre damages and the generation of melt points by fibre/metal friction. In addition, the limitations for minimum speeds are inadequate fibre separation and occurrence of opening roller laps. In Table 23 typical opening roller speeds for processing man-made fibres can be found.

Fibre Material	Opening Roller Speeds [turns/min]
PES/CO	8 000 - 10 000
PES	7 000 - 9 000
PAC	7 000 - 9 000
PA	6 500 - 8 000
Viscose	8 000 - 9 000

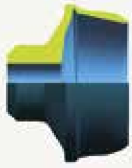
Table 23 – Opening roller speed recommendations

5.11.2.2. Rotor type and rotor speed

The rotor has a big influence on the yarn quality, the spinning stability and of course the production rate. According to the used material and yarn quality requirements, the following parameters of the rotor have to be chosen:
• type of rotor groove
• coating of the rotor
• rotor diameter
• rotor speed.

Inside the rotor groove the fibres are collected and the twist is inserted. The geometry of the groove affects the yarn quality parameters as well as the spinning stability. It should be chosen according to the fibre material and yarn application. In Fig. 57 recommendations for Rieter rotor groove types with different materials and applications are given.

The task of the rotor coating is to extend its lifetime by a higher wear resistance. In most cases a boron treatment of the rotor groove plus an additional diamond coating in a nickel matrix of the whole rotor is used (BD-types) for all kind of fibre materials including man-made fibres. Especially for spinning yarns out of viscose, rotors with boron treatment plus additional nickel coating (B-types) are of advantage because of the smoothness of the slip surface of the rotor. Recommendations for rotor coatings according to the used fibre material and application can be also seen in Fig. 57.
The limitation of the rotor diameter depending on the fibre length is described in 5.11.1., but there are also limitations by the yarn fineness and by the rotor speed. The yarn fineness exerts an influence because the coarser the spun yarn is, the larger the rotor diameter that has to be chosen. The rotor speed exerts an influence as each rotor diameter has an optimal speed range. Running below this speed range results in too low spinning tensions and unstable spinning conditions while running above the speed range results in too high spinning tensions and yarn breaks.
The maximum possible rotor speed that can be used for a given man-made fibre material is influenced by the material itself (e.g. polyester, viscose, etc.), by the quality of the fibres and by the spin finish (e.g. high performance types, normal types, etc.). In general, blends with cotton can be spun faster than pure man-made fibres and viscose can be spun faster than polyester or polyacryl. For example, it is possible to spin high quality viscose with rotor speeds up to 130 000 rpm [13].
The maximum speed that can be achieved has to be determined by spinning trials. It has to be kept in mind that the higher the rotor speed and the smaller the rotor diameter are, the higher the number of wrapper fibres will be and the harsher the feel of the finished fabrics will become.

Type / Application	Form					
	Groove	XG	XGM	XK	XK5	XT
	Application	1., 2.	1., 2.	1.	1., 2.	1., 2., 3.
Coating / Raw material	Coating	BD	BD	BD	B	BD
	Cotton	■	■	■		■
	Regenerate	■				■
	Viscose				■	■
	Polyester/-acryl	■				■
	Blends like PES/CO	■				■

Type / Application	Form					
	Groove	XT5	XTC	XU	XV	XDS
	Application	1., 2.	1., 2., 3., 4.	1., 2., 3.	4.	1., 2.
Coating / Raw material	Coating	B	BD	BD	BD	BD
	Cotton		■	■		
	Regenerate		■			■
	Viscose	■				
	Polyester/-acryl		■	■	■	
	Blends like PES/CO		■	■	■	

1. – Weaving
2. – Knitting
3. – Denim
4. – Prevents fibre shift

B – Boronized steel
BD – Boronized Diamond coating
■ – Applicable

Fig. 57 – Rieter rotor recommendations

5.11.2.3. Channel inserts

Usually the channel insert is chosen according to the rotor diameter but when spinning man-made fibres, special channel inserts with SPEEDpass can be used (see Fig. 58). With the SPEEDpass additional air is sucked through the spin box which provides a better fibre control in the trash removal area and a higher air speed in the fibre channel, which is noticeable in constant and stretched transport of the fibres [14].
Furthermore, particles of the fibre finish are sucked away by the SPEEDpass after they are detached from the opening roller. Rotor contamination due to fibre finishing deposits is therefore significantly reduced.

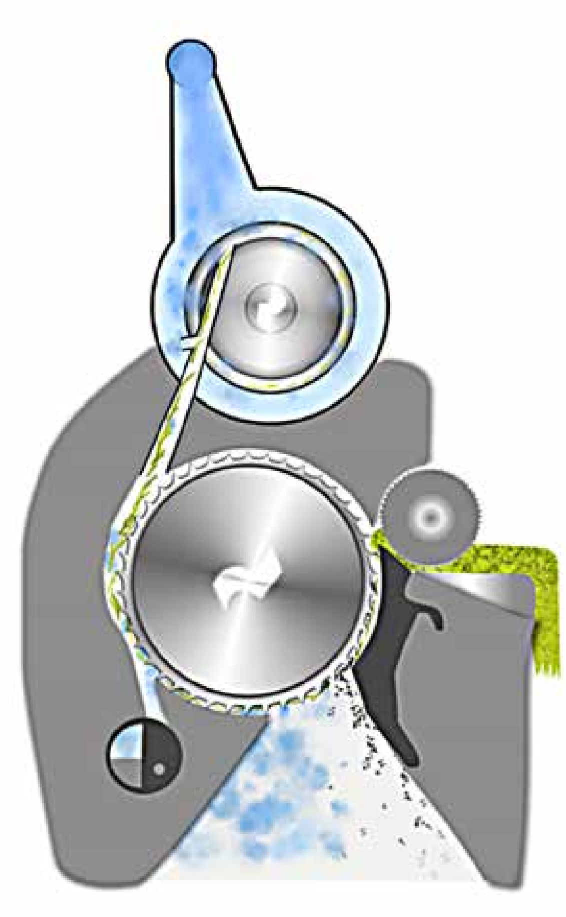
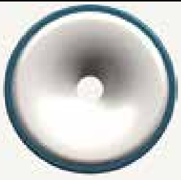
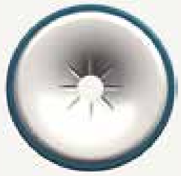
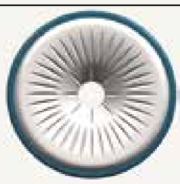
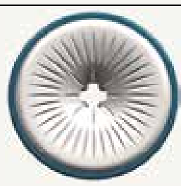


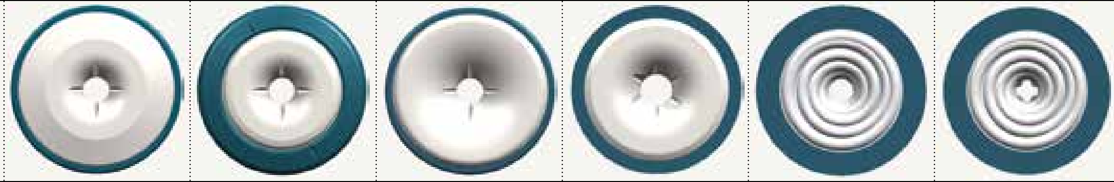
Fig. 58 – Rieter fibre guide channel with SPEEDpass

5.11.2.4. Draw-off nozzle

Draw-off nozzles are crucial for yarn characteristics. Depending on the required feel of the yarn – hairy or smooth – and the downstream processes in knitting or weaving, a wide range of nozzles for all spheres of application have been developed.
Recommendations for draw-off nozzles depending on the fibre material and on the application can be found in Fig. 59. Smooth nozzles often give better yarn characteristics and the yarn is more resistant to rubbing. They have good heat conductivity but generally less false twist. A higher ends-down rate must be expected. In contrast to that, grooved nozzles can operate with lower twist levels. Running performance is better because of the greater false-twist effect, but hairiness increases. Melt spots could also occur. Ceramic nozzles with 4 - 6 grooves have proved to be advantageous in spinning blended yarns and fibres that are not strongly sensitive to heat.

Application	Ceramic Form												
	Model	KG		KG R		K3K		K4K		K4K R or RR		K8K	
	Remarks	1.		–		1., 2.		1., 2.		2.		2.	
		Knitting	Weaving	Knitting	Weaving	Knitting	Weaving	Knitting	Weaving	Knitting	Weaving	Knitting	Weaving
Raw material	Cotton												
	Regenerate												
	Viscose												
	Polyester/-acryl												
	Blends like PES/CO												

Application	Ceramic Form												
	Model	K8K R or RR		KR8K		KR8K R or RR		KS		KS R or RR		KS-NX	
	Remarks	2.		2.		2.		1.		–		–	
		Knitting	Weaving	Knitting	Weaving	Knitting	Weaving	Knitting	Weaving	Knitting	Weaving	Knitting	Weaving
Raw material	Cotton												
	Regenerate												
	Viscose												
	Polyester/-acryl												
	Blends like PES/CO												



Application	MIMA 1-4K		MIMA 2-4K		nano4		nano6		KSF		KSF-NX	
Ceramic Form												
Model	MIMA 1-4K		MIMA 2-4K		nano4		nano6		KSF		KSF-NX	
Remarks	2.		2.		–		–		–		–	
	Knitting	Weaving	Knitting	Weaving	Knitting	Weaving	Knitting	Weaving	Knitting	Weaving	Knitting	Weaving
Raw material												
Cotton	Possible	Possible				Possible	Possible	Possible		Possible	Possible	
Regenerate												
Viscose	Possible	Possible	Recommended	Recommended	Recommended	Recommended	Possible	Possible				
Polyester/-acryl	Recommended	Recommended	Possible	Possible	Possible	Possible	Possible	Possible				
Blends like PES/CO	Recommended	Recommended	Recommended	Recommended	Possible	Possible	Possible	Possible				

– Possible
– Recommended

1. – Denim
2. – Prevents shifting fibres during weaving process (warp)
3. – Also for Rotors with Ø ≤ 30 mm

Fig. 59 – Rieter draw-off nozzle recommendations

5.11.2.5. Spinning limit and yarn twist

Because of the lower utilization of the fibres, rotor yarns need a higher number of fibres in the yarn cross-section (spinning limit: 100 for all fibre materials) and higher twist coefficients than ring spun yarn.
Table 24 lists typical ranges for the twist coefficient depending on different applications.

Knitting yarns	αe	αm	αtex
PES	3 - 3.3	90 - 100	2 800 - 3 150
PAC	3.1 - 3.5	95 - 105	3 000 - 3 300
PA	3 - 3.3	90 - 100	2 800 - 3 150
CV	3.3 - 3.6	100 - 110	3 150 - 3 450
Weaving yarns	αe	αm	αtex
PES	3.3 - 3.8	100 - 115	3 150 - 3 600
PAC	3.3 - 4	100 - 120	3 150 - 3 800
PA	3.1 - 3.8	95 - 115	3 000 - 3 600
CV	3.3 - 3.6	100 - 110	3 150 - 3 450

Table 24 – Rotor yarn twist coefficients for different man-made fibres and applications

Twist levels for blended yarns should be set between these values and those for cotton yarns depending on the percentage distribution of the blend components.

5.11.3. Problems

Problems in the rotor spinning process with man-made fibres can be caused by:
- the fibres
- the machine
- the air conditioning.

Problems caused by the fibres can arise from:
- poor spin finish (smearing on opening roller and draw-off navel, contamination of rotor groove)
- low melting point of fibre material (leads to thermal damage because of high friction on opening roller, rotor and draw-off nozzle)
- high friction coefficients (leads to lapping on the opening roller).

On the machine side, the factors to be considered are:
- incorrect settings
- lapping on opening roller because of low roller speed
- thermal fibre damage because of too high opening roller or rotor speeds
- incorrect or damaged opening roller
- incorrectly selected spinning components like opening rollers, rotors or draw-off nozzles.

In the air-conditioning system, the moisture level may be:
- too low (static electricity, lap formation, hairiness)
- too high (smearing of spin finish, lapping).

5.11.4. Process environment

A water-vapor content of 9.5 - 11.5 g per kg dry air has proved favorable. At spinning temperatures of 23 - 27 °C, this moisture content gives relative humidity in the range of 45 - 55 %. However, to avoid the risk of static charge, it is often better not to let relative humidity drop below 50 %.

5.12. Air-jet spinning

The term air-jet-spinning is generally used for spinning technologies where staple fibres are twisted with the use of airstreams. Historically there were a few different air-jet spinning technologies that were developed but due to various reasons only two of them achieved market relevance:
- the two nozzle air-jet spinning technology
- the one-nozzle air-jet spinning technology.

The one-nozzle air-jet spinning technology has got much more potential, is advantageous over the older two nozzle technology and is about to substitute it.
Compared to existing spinning processes, because of its typical yarn structure air-jet yarns create new possibilities in downstream processing which are complementary to the established spinning processes [15].
For these reasons, in the following chapters only the one-nozzle air-jet technology is considered.

5.12.1. Fibre and sliver requirements

There are special requirements on the fibre and on the sliver quality which are related to the air-jet spinning technology. The most important fibre parameters for this technology are:
- fibre length
- fibre fineness.

The fibre length is crucial because usually with longer fibres the distance between the output rollers of the drawing system and the spinning nozzle (spinning nozzle spacing, see chapter 5.12.2.3.) can be increased. This usually results in a higher amount of the wrapper fibre proportion and in a better yarn strength. Rieter trials with Lyocell fibres however have shown that with this kind of material the optimum spinning nozzle spacing is only influenced by the yarn fineness [16].
Especially in blends with cotton there is always a higher risk of fibre loss because of the higher amount of shorter fibres in the fed sliver.
When spinning man-made fibres, approximately 75 fibres in the yarn cross section are required with air-jet spinning technology. Though this number is lower than in rotor spinning, it is still higher than in ring spinning. Therefore the fibre fineness is limited by the yarn fineness that has to be spun.
The following sliver parameters are important for the air-jet spinning technology:
- fibre parallelization
- sliver fineness.

As the air-jet spinning process needs a high parallelization of the incoming fibres it is advisable to use 3 draw frame passages after carding in order to optimize the yarn quality. Because of the textile technological limitation of the total draft in the air-jet spinning drawing system to approximately 180 to 220 fold, the sliver fineness has to be adjusted to the yarn fineness.

5.12.2. General settings
5.12.2.1. Roller settings

The drawing of the fed sliver on an air-jet spinning machine is done by 4 over 4 roller drawing systems. The 3 drawing fields between these roller pairs are called predraft, middle draft and main draft (see Fig. 60).
Similar to the drawing system of the roving frame or of the ring spinning machine, the draft distances have to be set according to the fibre lengths and to the draft resistance.
To avoid fibre damage, the draft distances should always be higher than the maximum fibre length.

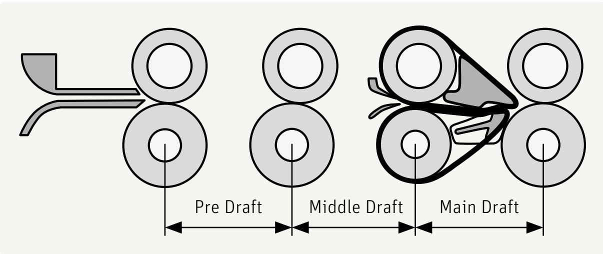


Fig. 60 – Air-jet 4 over 4 roller drawing system

The distance of the main draft rollers are usually fixed by the used cradle to ensure an optimum fibre control in the main draft field. This is very important because of the high drafting ratios, the high airflow induced by the fast rotating output rollers and the low amount of fibres in that area. The optimum setting of the draft distances in the predraft and middle draft has to be found by spinning trials in combination with the right draft distribution (see 5.12.2.2.). In Table 25 an example for roller settings according to the fibre length and the yarn count are given for Lyocell fibres.

5.12.2.2. Draft distribution

The total draft can be calculated by the sliver and the yarn fineness. As was mentioned in chapter 5.12.1., there is a textile technological limitation of the total draft to approximately 180 to 220 fold. Higher total drafts reduce yarn quality and running performances in an unacceptable manner.
Because of the use of aprons in the main draft and the resulting superior fibre control by these elements, the highest draft ratios can be achieved here. However, to obtain optimal results, the main draft should not be less than 30 fold or higher than 60 fold.
As with the setting of the optimal roller distances, the right setting of the draft ratios in the pre, middle and main draft has to be found by spinning trials. Recommended ranges for:

- predraft is 1.7 - 2.2
- middle draft is 1.3 - 2.6

Examples for draft distributions according to the fibre length and to the yarn count can also be found in Table 25.

Effective distance

Staple length [mm]	Total draft	Ne	Pre Draft		Middle Draft		Main Draft	
			Draft	Distance	Draft	Distance	Draft	Distance
36	124 191 190	18 36 50	1.76	45	2.3 2.6 2.6	43	31 47 41	49
38	124 191 191	18 36 50	1.76	49	2.3 2.6 2.6	46	31 47 41	48
42	124 191 191	18 36 50	1.76	50	2.3 2.6 2.6	47	31 47 41	52
44	124 191 191	18 36 50	1.76	50	2.3 2.6 2.6	47	31 47 41	52

Table 25 – Example for roller settings and draft distributions according to different fibre lengths and yarn counts

Fig. 61 – Spinning nozzle (1-housing, 2- fibre feeding element, 3-tip)

5.12.2.3. Spinning nozzle

The spinning nozzle consists of several parts (see Fig. 61) which can be changed according to different requirements as e.g. fibre material and yarn application:
• fibre feeding element (2)
• spinning nozzle tip (3).

For different fibre materials and different yarn applications (e.g. weaving or knitting) various geometries of these spinning nozzle parts have been developed. The right choice of these parts is important to get the best yarn quality. Recommendations can be found in the appropriate machine operating manual.

5.12.2.4. Spinning nozzle spacing

The right distance between the output top roller and the top of the nozzle tip (distance “A” in Fig. 64) has got a huge impact on the yarn structure and therefore on the yarn parameters and on the fibre waste. The optimum setting depends on the fibre length and on the yarn fineness that has to be spun. Usually it is set slightly shorter than the average fibre length. In addition, the setting should be shorter with finer yarn counts.
Examples for typical ranges of the spinning nozzle spacing according to the processed fibre material can be found in Table 26.

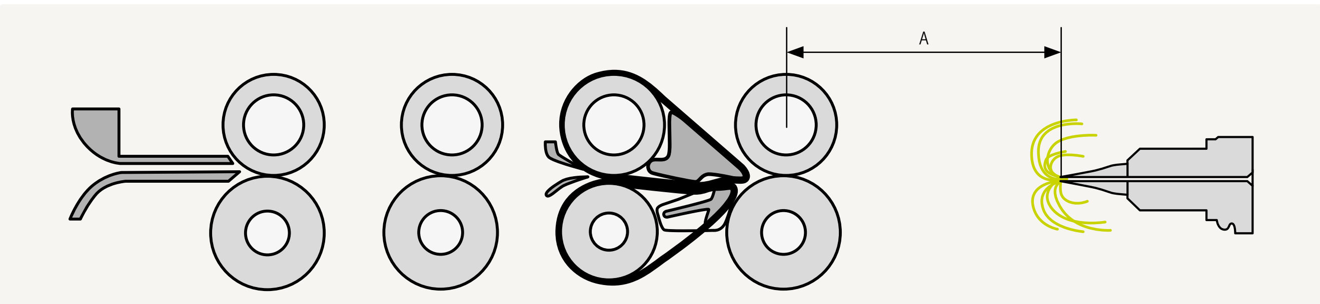


Fig. 62 – Spinning nozzle spacing

Fibre Material	Spinning Nozzle Spacing
Cotton / Man-Made Fibre Blends	19.5 - 21 mm
100 % Man-Made Fibres	20 - 22 mm

Table 26 – Typical spinning nozzle spacing according to fibre materials

5.12.2.5. Spinning Speed

Another very important parameter for air-jet spinning is the spinning speed. Like the spinning nozzle spacing it has a big influence on the yarn structure and on the yarn parameters respectively. Optimum spinning speed setting depends on the fibre material, the yarn count and on the yarn application. The speed has to be set lower with:
• shorter fibre lengths
• finer yarn counts
• for weaving yarns (in comparison to knitting yarns).

Examples for typical spinning speed settings can be seen in Table 27.

Yarn Fineness	PES / CO - Blends		100 % Man-Made Fibres	
	Weaving	Knitting	Weaving	Knitting
Ne 20 - Ne 30	380 m/min	400 m/min	420 m/min	440 m/min
Ne 30 - Ne 40	360 m/min	380 m/min	400 m/min	420 m/min
Ne 40 - Ne 50	350 m/min	360 m/min	340 m/min	360 m/min
Ne 50 - Ne 60	-	-	300 m/min	320 m/min

Table 27 – Typical spinning speeds according to fibre materials, yarn counts and yarn applications

5.12.2.6. Spinning Pressure

Similar to the spinning speed (see chapter 5.12.2.5.) the spinning pressure has an influence on the yarn structure and on the yarn parameters respectively. Within certain limits the higher the spinning pressure is, the higher is the twist level in the yarn. Like the spinning speed the spinning pressure has to be set according to the fibre material, the yarn count and the yarn application in the following way:
• higher spinning pressure for shorter fibre lengths
• lower spinning pressure for finer yarn counts
• higher spinning pressure for weaving yarns (in comparison to knitting yarns).

5.12.3. Problems

Problems in the air jet spinning process with man-made fibres can be caused by:
• the fibres
• the machine
• the sliver
• the air conditioning.

Problems caused by the fibres can arise from the spin finish and resulting smearing on the spinning nozzle tip. This smearing leads to a high friction between the fibre and the spinning nozzle tip and highly disturbs the twist insertion. Especially when running 100 % polyester this problem arises very often.
On the machine side, the factors to be considered are:
• incorrect settings
• high evenness and low spinning stability because of wrong draft distribution in the drawing system
• high evenness and low spinning stability because of incorrect, worn out or damaged top rollers and guide aprons
• low tenacity or high hairiness because of incorrectly selected nozzle parts
• low tenacity, high hairiness or low spinning stability because of incorrect spinning speed and spinning pressure.

The problems in the sliver are:
• excessive unevenness
• low fibre parallelization.

In the air-conditioning system, the moisture level may be:
• too low (static electricity, lap formation)
• too high (smearing of spin finish, lapping).

5.12.4. Process environment

The ambient conditions (temperature and relative humidity) play a very important role in the air jet spinning technology. A wrong condition has a huge impact on spinning stability and yarn quality. For spinning man-made fibres, the following conditions have to be secured in the spinning mill:

• relative humidity:	48 - 56 %	
• temperature:	25 - 28 °C	
• replacement of air:	minimum	25 - 28 times per hour
	optimum	28 - 32 times per hour.

5.13. Steaming and stabilization [17]

5.13.1. General considerations

Steaming is treatment with water vapor at temperatures below 100 °C. Steaming serves to reduce twist liveliness of both singles and plied yarns.
Stabilization is treatment with steam at temperatures above 100 °C. Stabilization is carried out to reduce shrinkage of staple-fibre yarns for package and warp-beam dyeing.

5.13.2. Packaging of yarn for treatment

Steaming and stabilization should be performed on the cop if possible. In the course of thermal treatment, the tubes are subjected to radial-compression loading arising from the shrinkage forces of the yarn. Preferably, therefore, specially developed tubes that are resistant to the stabilizing process should be used. Single-use tubes are also employed for steaming, but they are easily deformed so that the body of yarn may slip off the support.
In order to ensure that the steam reaches all cops as evenly as possible and without hindrance, the cops should not be arranged in a predetermined array but should rather be randomly disposed in containers.
Steaming of staple-fibre singles and plied yarns in cross-wound packages must be performed as far as possible on stable, perforated tubes to optimize the effectiveness of the steam. Efficiency can be improved still further if package supports with tube-receiving pins are used in place of containers.
Perfect package build-up and a high winding angle assist in ensuring even penetration of the steam and hence favor the steaming effect.

5.13.3. Steaming equipment

Steaming and stabilizing of yarn in cops and cross-wound packages should always be carried out in vacuum-steaming devices. Equipment using shell heating is especially suitable for steam treatment. An automatic pressure and temperature control system – possibly with automatic program control – is more reliable in operation than a manual control device, and will effectively exclude critical temperature variations.

5.13.4. Mode of operation

Wet steam must be avoided at all costs during steaming and stabilizing. When working below the saturation point in treating staple-fibre blended yarns consisting of cellulosic fibres (for example, blends of PES with cotton, modal, or viscose fibres), the surplus water would lead to different degrees of swelling for the cellulose-fibre components. This in turn would lead to dye-shade variations and to stripes in the resulting fabric.
In order to prevent formation of condensate, it is preferable, for safety, to operate somewhat above the saturation point. For the same reason, the steaming apparatus should be operated once in an empty condition before starting actual treatment.

5.13.5. Operating procedure for steaming and stabilizing

The procedure for steaming and stabilizing is as follows:

- load material
- evacuate
- feed steam for the first time
- evacuate
- feed steam for the second time
- evacuate
- feed steam for the third time
- evacuate
- let in air and open the assembly
- remove the material.

If the procedure described does not give the desired effect, the steaming time for the last steaming step should be increased. The temperature must not be increased under any circumstances, since otherwise there is a danger that yarns from different steaming batches will exhibit varying degrees of dye affinity. Care should be taken to ensure thorough evacuation (approximately 0.6 - 0.8 bar) between the individual operating steps.

5.13.6. Steaming

The following guidelines are recommended for twist stabilization of singles and plied yarns.

Material	Temperature	Length of the steam phase
100 % PES PES/Cotton PBS/Modal PBS/Viscose PES/Wool	70 °C (max. 80 °C)	Phase 1 and 2 always 2 min each Phase 3,15 - 20 min with a cop build and 20-30 min with a package.

Table 28 – Recommended steaming guidelines

For pure polyester-fibre yarns, dyed in the form of tufts or combed sliver, or with plied yarns, an extension of the period of subjection to steam may not bring a reduction in twist liveliness under all circumstances. In such cases, the treatment temperature must be increased. However, in every case, a test should be made beforehand to determine whether the dye shade will resist this change.

5.13.7. Stabilization

This process can be performed to reduce the shrinkage of singles and plied yarns made from PES-B types not subjected to fixing.
According to the dying process to be used – HT dyeing, mostly at a water temperature of 125°C or carrier dyeing, usually at boiling temperature – the shrinkage capacity of the yarn should be set at wider 4 % for the treatment.

Material	Temperature	Length of the steam phase
100 % PES staple-fibre yarn in cops PES / Cotton PES / Modal PES / Viscose	Max. 115 °C	Phase 1 and 22 min. Phase 3: at least 15 min.

Table 29 – Recommended stabilization guidelines

Temperature constancy is especially important in stabilizing, as in all treatment processes at temperatures above 80°C. Care should also be taken to ensure thorough evacuation to extract air from the material between the individual operating phases of the stabilizing process (Table 29).

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ILLUSTRATIONS

The Rieter Manual of Spinning

Volume 7 – Processing of Man-Made Fibres

The last volume in this series deals with the important field of man-made fibres. Ever since their introduction on a commercial scale, the market share of synthetic fibres has shown an impressive rate of growth. The variety of man-made fibres with different properties is continuously increasing. For numerous applications today, fibres that are practically „tailor-made“ are available. It is therefore essential for the spinner to have a detailed understanding of the properties of these fibres and of the specific characteristics that affect their processing.

Rieter Machine Works Ltd.
Klosterstrasse 20
CH-8406 Winterthur
T +41 52 208 7171
F +41 52 208 8320
sales.sys@rieter.com
parts.sys@rieter.com

Rieter India Private Ltd.
Gat No 134/1, Vadhu Road
Off Pune-Nagar Road, Koregaon Bhima
Taluka Shirur, District Pune
IN-Maharashtra 412216
T +91 2137 308 500
F +91 2137 308 426

Rieter (China)
Textile Instruments Co., Ltd.
Shanghai Branch
Unit B-1, 6F, Building A,
Synnex International Park
1068 West Tianshan Road
CN-Shanghai 200335
T +86 21 6037 3333
F +86 21 6037 3399

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