Textile Technology

Sample Chapter 3:
Principles and Machinery for Yarn Production
3 Principles and Machinery for Yarn Production

Staple fiber yarns can be produced from natural fibers (Section 2.1) as well as from chemical fibers cut to staple length (Section 2.2). In contrast to the chemical fibers, which can be manufactured industrially in almost every desirable length and shape the various natural fibers are available only in specific lengths, titers, and cross-sections, and with certain crimp and stress–strain behavior depending on their type and origin.

The development of spinning processes was based on these characteristics. This is another reason that the properties of chemical fibers are often adjusted to those of natural fibers so that they can be mixed or blended and also processed on conventional spinning machines.

The functions of the spinning machines are the preparation of the fibers for the actual spinning process, the organization of the fibers in a coherent, continuous structure, and the production of packages or units suitable for further processing. The basic principle of producing a yarn by organizing, parallelizing, drawing, and twisting of the fibers has not changed since the very beginning of spinning thousands of years ago.

German technical terms used in spinning are explained in the German standards DIN [1]. For further explanations about spinning, see also [2 – 12].

3.1 Cotton Spinning

At present, the short staple, also called cotton or three-roller spinning process, is the most common spinning method worldwide. The name three-roller spinning comes from the arrangement of the rollers in the drafting zone at the most commonly used spinning machine, the ring spinning frame. This spinning principle is suitable for all fiber types with lengths up to 40 mm. It is very flexible with regard to the properties and applications of the produced yarns. Yarns manufactured by ring spinning are processed into wovens, hosiery, knits, and braidings in the areas of apparel, home textiles, and technical textiles.

Yarn properties are parameters to describe the yarn, such as

- Fineness or titer,
- elongation,
- hairiness,
- tenacity,
- twist, and
- volume.
It takes several processing steps to manufacture fibers into a yarn. Figure 3-1 gives an overview of the various processing steps from the bale of raw cotton or cut synthetic fibers to the final yarn. Depending on the desired yarn properties and the fiber material, various different machine sequences and spinning principles are applied to reach a compromise between optimum yarn properties and cost-saving manufacture.

Table 3-1 shows the main function of each machine during processing. The generic term mixing means a thorough blending of nonhomogeneous fibers of the same type as well as a quantitatively defined combining of different fiber types. Opening is the disentanglement of compressed fiber packages into single fibers. Cleaning is the removal of particles such as wood, leaf, or seed coat fragments (cotton) or fiber knots and neps that cannot be opened. Parallelizing leads to an orientation of the fibers in one direction. Drawing is the drafting of an oriented fiber web in a drafting field. The purpose of drawing is to provide an optimally straightened, parallel, and uniform fiber orientation.
Figure 3-1: Overview of short staple spinning [3]
Table 3-1: Main function of the various processing steps

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<th>Mixing</th>
<th>Opening</th>
<th>Cleaning</th>
<th>Parallelization</th>
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</table>

3.1.1 Spinning Preparation Machines

The functions of the spinning preparation in the blow room are:

- Bale opening,
- removal of contamination particles,
- dust removal,
- disentanglement into fiber flocks,
- homogenization of the raw material, and
- mixing of various raw materials.

Figure 3-2 schematically depicts two typical setups for the spinning preparation of cotton [2, 11 – 17].
3.1.1.1 Bale Opening

Bale opening consists of opening the bales and converting them into single-fiber flocks. The type and intensity of the individualization of the fibers critically influence the further processing steps. The more intensively the cotton fibers have been individualized, the more contamination particles appear on the surface of the fiber bulk and may be removed. Target weights for the individualized flocks are about 0.02 to 0.03 g.

![Figure 3-2: Typical blowroom for cotton [2]](image)

3.1.1.1.1a) bale breaker  b) remover for heavy contaminant particles  c) double-roller cleaner  d) 6fold-mixer  e) single-roller super cleaner  f) 4fold-mixer  g) 4-roller super cleaner  h) dust extractor  i) card  j) bale breaker  k) cleaner with free beater  l) 6fold-mixer  m) super cleaner  n) card

![Figure 3-3: Working elements of a bale breaker [11]](image)
With modern bale reducing systems, up to 80 bales are lined up on the floor and reduced by a programmable bale breaker in layers from top to bottom. Fiber flocks are removed mechanically with the help of beaters (Figure 3-3). The fiber flocks are then transported by air streams through pipelines.

**Opening and Cleaning**

The main functions of the opening and cleaning machines are the further separation of the fiber flocks and the removal of contamination particles and dust from the cotton. High fiber throughput with as little fiber damage as possible is desired.

With the working principle *free beat* the flocks are caught in free fall and accelerated by the cleaning elements. The opening is created by the interaction of forces of acceleration and inertia. Contaminating particles resulting from the effect of centrifugal and gravity forces can be separated by grids. There are machines with one roller (single-roller cleaner) or with two rollers (double-roller cleaner).

With the *restricted beat* the flocks are “squeezed” between two feed rollers or between one feed plate and one feed roller during the operation of the beaters. Depending on the degree of opening, the beaters are nose beater, pins, or saw teeth (Figure 3-4). Because of the squeezed position of the fibers, the effect of opening with the restricted beat is more intense, but also more aggressive compared to the free beat. This may lead to fiber damage if the flocks have not been sufficiently preopened.

![Diagram of a saw-tooth cleaner](image)

**Figure 3-4: Principle of the saw-tooth cleaner [11]**

Contaminants are removed by centrifugal forces with grids and knives. The “knifes” can be a sharp edge positioned very closely to the toothed roller surface. While fibers stay in the air stream rotating with the roller owing to their small mass and high air resistance, dirt particles are carried to the outside due to their high mass and small air resistance and can then be removed at the knife. The cleaning effect depends on the machine model and the fiber material. The
degree of cleaning $R_G$ is a measure for the cleaning effect of a machine and defined as:

$$R_G = \frac{T_{r_0} - T_{r_1}}{T_{r_0}} \cdot 100\%$$  \hspace{1cm} (3.1)

where: $T_{r_0}$ = Trash content before cleaning,

$T_{r_1}$ = Trash content after cleaning.

The degree of cleaning may refer to single machines as well as to groups of machines, for example, to all preparatory machines.

### 3.1.1.3 Mixing

The consistency in yarn quality depends heavily on the homogeneity of the material composition. The objective of mixing is to optimize the homogeneity of the material mixture by combining several bales.

Further objectives of mixing are:

- Decrease of irregularities in bales of different origin,
- economic processing,
- recycling of comber waste and other offal,
- effect on the properties of the final product, and
- reduction of raw material costs.

The expression mixing is divided into the two functions: dosage (blending) and mixing thoroughly (mixing).

**Blending** is the adjustment of defined mass percentages of several raw material components. It is achieved by the following processes:

- Manual layup of the various mixture components,
- automated bale reduction systems,
- hopper feeder, and
  1) continuous metering hopper.

In noncontinuous hopper feeders or modern continuous metering hoppers a high mixing precision with an error margin of less than 1% can be achieved. Blending by manual layup or with automated bale reduction systems is less precise.
The purpose of mixing *thoroughly* is to achieve a homogeneous distribution of the various components in the final product. The machines most often used for this task are the mixing chamber and the multiple mixer. With the mixing chamber principle a very large volume (e.g., 230 m$^3$) is filled in horizontal layers and subsequently reduced vertically from one side. This may be done continuously or noncontinuously. The largest mixers are used in mock-worsted spinning (Section 3.3).

![Diagram of a multiple mixer](image)

**Figure 3-5: Multiple mixer (Rieter system) [17]**

![Diagram of a multiple mixer](image)

**Figure 3-6: Multiple mixer (Trützschler system) [11]**

A multiple mixer (Figures 3-5 and 3-6) is composed of multiple chambers lined up behind each other. There are two working principles: either flocks that had been fed at the same time are processed at different times, or flocks fed at different times are processed at the same time.
3.1.1.4 Carding

The card is the first machine in the spinning preparation that delivers a sliver. The tasks of the card are [2, 3, 15, 16]:

- Removal of dirt particles and short fibers,
- disentanglement of the flocks into single fibers,
- parallelizing of the fibers,
- mixing thoroughly,
- drafting,
- sliver formation, and

2) sliver delivery.

The separation and parallelization of the fibers is caused by the carding action. The regions where carding action takes place are called carding fields. Carding is caused by the mutual action of the sharp-pointed teeth of the card clothing that are oriented in the same direction and move relatively to each other (Figure 3-7). If \( v_2 < v_1 \), carding occurs between the card clothings. The intensity of the carding depends on the difference in velocity of the carding elements and the angles of inclination or the geometry of the teeth of the card clothings.

If the working elements are opposed to each other, fibers are transferred from one clothing surface to the other, which is called stripping action (Figure 3-7).

Figure 3-7: Carding action and stripping action

Figure 3-8 depicts a high-speed revolving flat card used for cotton and chemical fiber processing.

The fiber material is continuously delivered to the card via a pneumatic feeder system. The feeding cylinder and feeding plate present the fibers to the licker-in which is a roller covered with saw teeth. Caused by the difference in peripheral speeds, the tufts are separated. At the same time, the licker-in removes about 70% to 75% of all contamination particles with knives. The main working element of the card is the tambour. Its surface is covered with more than 4 million clothing teeth and rotates at a surface speed of about 26 m/s. The doffer
and the tambour provide a carding action, which causes a further separation of the fibers. The major part of the carding action is accomplished between the tambour and the flats whose teeth are positioned toward each other for carding action. This causes separation into single fibers and the parallelization of the fibers. At the same time, contaminants and short fibers are removed. Modern cards often provide additional rigid carding segments and dirt separation elements before and after the revolving flats. Even though carding action takes place between tambour and doffer, fibers are transferred from the tambour to the slower moving doffer because of the particular angles of the teeth. The transfer behavior is described by the transfer ratio, which quantifies the percentage of the fibers present on the tambour that are transferred to the doffer during one revolution of the tambour. Below the card, contaminants and dust are removed from the fiber material on the tambour with help of grids or, for modern cards, adjustable knives.

Figure 3-8: High-speed revolving flat card [2]

A brushing roller picks the condensed card web up from the doffer. Two nip rollers squeeze remainders of contaminants before the web is combined to a sliver. The sliver formation is accomplished with crossover draw-off or with a
trough-shaped cone. The card sliver is deposited in cycloids in a rotating can. This method ensures a gentle deposition and a high degree of filling of the cans. To compensate mass irregularities, cards are equipped with short-term and long-term control devices.

Trützschler has recently introduced a card with an integrated draw frame that is supposed to improve process efficiency and to reduce throughput time combined with lower costs for can transport and so forth.

The latest developments in microfiber carding can be found in [69]. New developments in online measurement technology of cards are given in [70].

### 3.1.1.5 Draw Frames

After carding, the processing usually continues with one or more drawing passages (Figure 3-9). The draw frame has the following tasks:

- Doubling of multiple slivers and drafting for mixing and homogenizing,
- removal of dust from the slivers,
- production of homogeneously mixed slivers from slivers of different materials, for example, 4 cotton slivers and 2 slivers of chemical fibers for the production of a yarn of cotton/chemical fibers 67/33, and
- additional control for sliver homogenization.

Draw frames consist of a can creel, a frame that holds the drive and control devices, the drawing field, and a can coiler with automated changer (Figure 3-9).

![Autolevellier draw frame](image-url)