

5. Yarn Production

In today's highly competitive and incredibly global textile market, a spinning mill cannot remain competitive and survive if it does not produce a quality yarn in a cost-effective way, which will in turn produce high quality woven and knitted fabrics. In order to achieve this a spinner needs to know the important fibre properties of the cotton lint and how they will influence processing performance, cost and quality of the yarn and ultimately the fabric.

Why this is important to a spinner is that the purchase of the cotton lint alone accounts for 50-70% of the mill's operating costs. It is also vital that the spinner purchases cotton which is the most suitable to process on their spinning machines and achieve the quality standards desired. Most spinning mills operate continuously, which means the fibre properties of the cotton used in the first week of the operating year must be not be significantly different from the fibre properties of the cotton used in the last week. Traditionally, the most desirable cotton is said to be as white as snow, as strong as steel, as fine as silk and as long as wool. As well as this, spinners would also ask that the fibre be inexpensive.

This chapter will describe how yarn is produced and introduces fibre quality attributes desired by spinners that contribute to differences in yarn quality, and are necessary for efficient operation of their spinning machines.

Yarn - The Magic of Spinning

Have you ever wondered how all the fibres in a yarn are able to 'stick together' to produce a strong and useful yarn? Spinning utilises the power of friction between fibres to achieve this.

This 'magic' can be demonstrated and explained as follows: Hold one end of a ruler between the palms of your hands, and then ask a friend to pull on the other end of the ruler in a horizontal direction in an attempt to slide the ruler out from between your hands. The experiment is really a 'tug of war' between the frictional forces, at your end of the ruler and the force your friend can apply at the other end. As you increase the vertical pressure between your hands and the ruler, the frictional force increases and is eventually large enough to match the strength of your friend in the tug of war game.

Now let's look closely at the arrangement of the fibres in a yarn. After spinning each fibre forms a roughly spiral or helical shape as visible in the close up photo of cotton yarn (Figure 5.1). This helical shape is the key to the yarn's ability to harness the power of friction. When tension is applied to the yarn, the force tries to stretch or extend each fibre spiral within the yarn. Look closely at what happens to the helical shape of a single fibre when this happens. Figure 5.1, (A) illustrates the fibre before it is stretched and (B) after stretching. As the helical shape elongates the diameter or thickness of the helix naturally decreases. In the yarn, the diameter or thickness of the helix formed by a particular fibre is not hollow but is filled with other fibres so the particular fibre cannot move very much when

tension is applied to the yarn. However the 'desire' of helical shape to decrease its diameter or thickness will cause the fibre to press inwards on the neighbouring fibres, and just like pressing our hands together with the ruler, the pressure enables frictional forces to develop and hinder slippage of fibres relative to one another. The 'magic' of the twisted/helical structure is such that as the external forces applied to the yarn increase, the inwards pressure each fibre exerts on the structure also increases and so the friction increases to resist the slippage. Indeed normally in yarn failure, the fibres themselves actually break rather than any fibre slippage occurring. A twisted yarn is indeed a very clever structure.

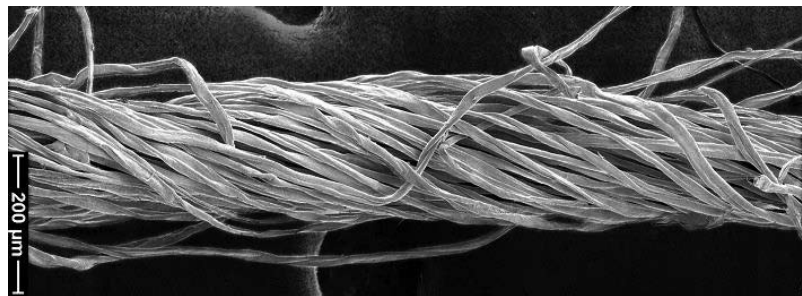
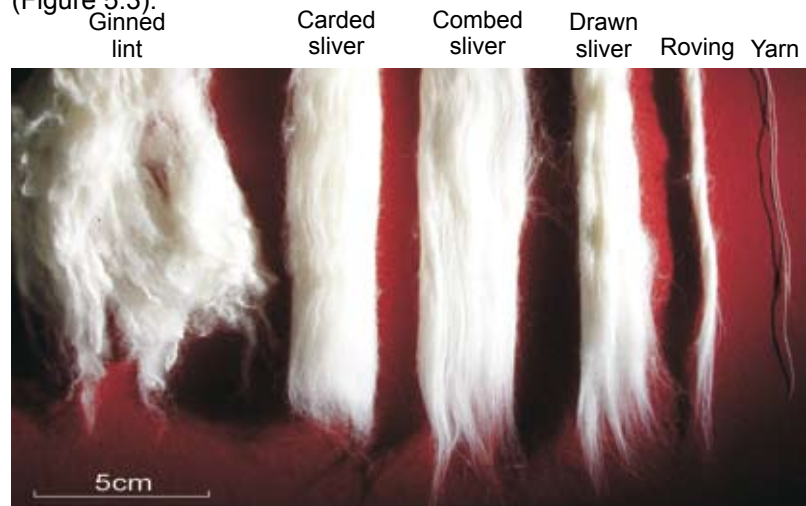


Figure 5.1: After spinning each fibre forms a roughly spiral or helical shape. It is this helical shape is the key to the yarn's ability to harness the power of friction. (Photo: CSIRO).

Spinning Yarns

The process of converting cotton fibres from ginned lint into a yarn involves a number of processes that aim to clean, remove short fibres, align fibres and ultimately spin the yarn and prepare it for delivery (Figure 5.2). Depending on the setup and machinery present in a spinning mill and the desired quality of the yarn needed to be produced will determine which processes are undertaken (Figure 5.3).



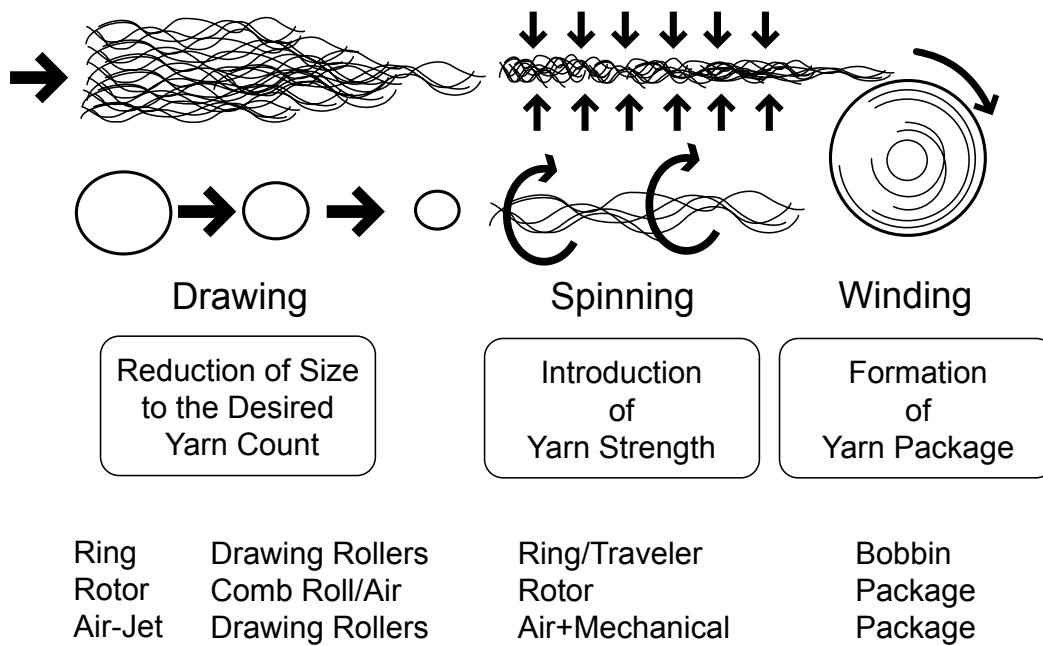


Figure 5.2: The results of various spinning mill processes that help to clean, remove short fibres, align fibres and ultimately produce yarn. (Illustration: CSIRO).

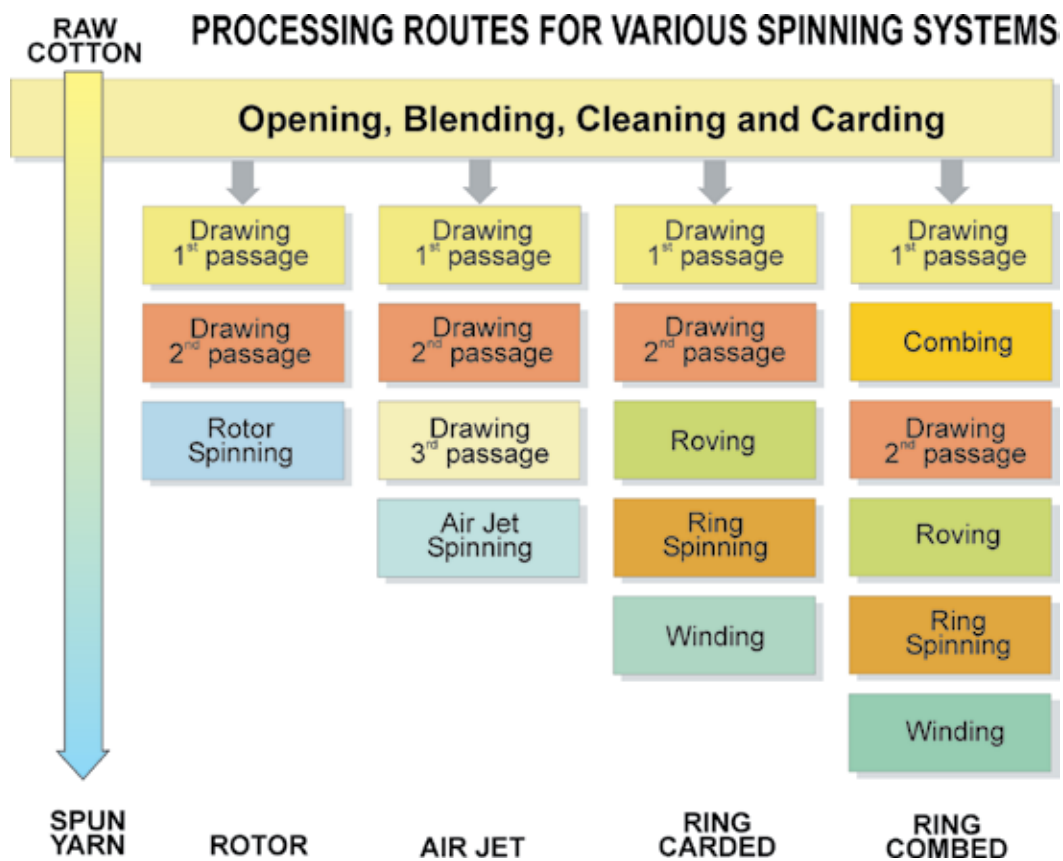


Figure 5.3: Flow chart showing processing routes for various spinning systems.



Figure 5.4: A 'laydown' takes the cotton from opened bales of differing quality. (Photo: Rene Van der Sluijs, CSIRO).

Opening, Blending and Cleaning

Opening, blending and cleaning of the fibre are the first processes in the spinning mill. In the mill, bales are selected to satisfy the requirements of a particular end use and then laid down in a row (called a laydown) to be opened and blended through a range of machines (Figure 5.4). The opening and blending processes ensure a consistent and homogeneous blend of fibres. Blended fibre is then passed through more machines to further open (loosen) the fibre tufts and to clean and remove plant-based contaminants such as leaf, sticks, boll parts, bark and seed fragments. In high-end mills a machine is also used to identify and remove contaminants such as fabric, plastic, polypropylene and other non-plant material, which create serious quality issues if contained within the cotton to the final product.

Carding

Once the fibre has been opened, blended and cleaned it is fed to the carding machine (Figure 5.5), which is often referred to as the 'heart of the spinning mill'. This is for good reason as the carding machine individualises, aligns and further cleans the fibres, before condensing them into a single continuous strand of overlapping fibres called a 'sliver'. Importantly, a large proportion of short fibres and neps are also removed during carding. The quality of the sliver assembly from the card determines both the quality and processing efficiency of products further up the processing chain.



Figure 5.5: Carding produces a sliver a single continuous strand of overlapping fibres. (Photos: CSIRO).

Drawing

Drawing is the process where the fibres are blended, straightened and the number of fibres in the sliver reduced in order to achieve the desired linear density in the spinning process. The drawing process also improves the uniformity or evenness of the sliver. The number of drawing passages utilised depends on the spinning system used and the end products (Figure 5.3).

Combing

Combing is the process that removes the final proportion of short fibre, neps and other impurities such as vegetable matter and seed-coat fragments in cotton that has already been carded. The waste material, which is predominantly made up of short fibre, is referred to as noil or comber waste and commonly makes up between 15 and 20% by weight of the fibre into the comber. Combed yarns are superior in quality when compared to carded yarns as they are generally finer, stronger, smoother and more uniform due to the removal of short fibres and the alignment of fibres (Figure 5.6). Combed yarns are however more expensive than carded yarns (approximately 10%) as combing involves additional processing stages and produces more waste.

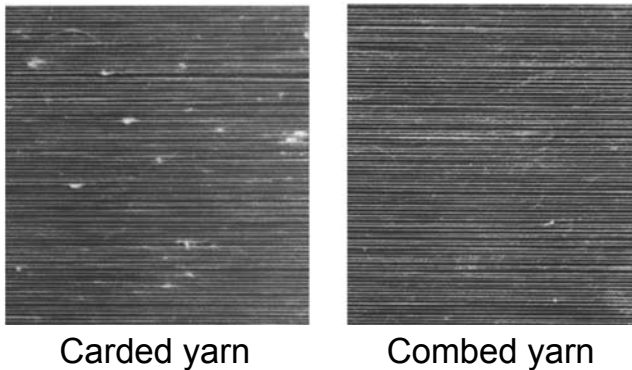


Figure 5.6: Combed yarns are generally finer, stronger, smoother and more uniform, due to the removal of short fibres and the alignment of fibres. (Photos: CSIRO).

Roving

In preparation for ring spinning, the sliver needs to be condensed into a finer strand known as a roving before it can be spun into a yarn (Figure 5.7). The roving frame draws out the sliver to a thickness of a few millimetres and inserts a small amount of twist to keep the fibres together. The drafted twisted strand is wound onto a bobbin which is then transported to the ring frame and used as the feed package for spinning yarn.



Figure 5.7: Roving bobbins on the creel of a ring spinning machine. The formation of roving reduces the sliver into a finer strand with the addition of twist. (Photo: CSIRO).

Spinning

There are three main spinning systems used commercially to produce cotton and other short staple yarns, i.e. yarns produced from fibres typically with lengths up to 50 mm.

1. Ring spinning
2. Rotor spinning (also known as open-end spinning)
3. Air-jet spinning (including Vortex spinning)

Ring spinning (Figure 5.8) was perfected as a process by the end of the 19th century. There are currently 213 million ring spindles installed world-wide that account for about 60% of all short-staple yarn production. Its prominence reflects its versatility in terms of productivity, the range of yarn counts that can be spun on it and the fibre types that can be used. Ring spun yarns are also superior in terms of yarn strength and character in terms of fabric handle and comfort. The majority of Australian cotton is spun into yarn using this system.

Rotor spinning was introduced as a new short-staple spinning system in the mid 1960's and achieved its greatest uptake during the 1980s when production speed and versatility were improved. Today, there are over 9 million rotor positions installed world-wide which account for about 30% of all short-staple yarn production.

Air-jet spinning was developed in the 1960s but was not successful commercially until the early 1980's when it was introduced by the Murata Company of Japan. Initially suited to longer staple polyester rich fibre blends, air-jet spun yarn could be delivered at speeds significantly higher than that of ring spinning. Later versions of air-jet spinning were adapted to 100% cotton fibres, e.g. Vortex spinning, and with delivery speed increased by nearly a factor of two over the original air-jet machines. There are currently around 500,000 air-jet spinning positions installed world-wide.

The advantages of rotor and air-jet spinning over ring spinning are chiefly based around their superior productivity in the delivery of medium to coarse count yarns. Furthermore, both systems use drawn sliver as their feed stock and both are able build (wind) a yarn package that can be used directly by fabric manufacturers. Hence both systems avoid two processes required in ring spinning, i.e. the roving and winding processes.

Detailed descriptions of the different spinning systems are contained in Appendix 1.

Winding

The winding process is a necessity in the case of ring spun yarn in order to transfer the yarn from small bobbins (Figure 5.8), which hold short lengths of yarn, to larger packages (Figure 5.9) that hold longer lengths of yarn suitable for subsequent processes such as warping, weaving, yarn dyeing, and knitting. Yarn faults or defects such as slubs, thin, thick and weak places as well as contaminants can be removed during winding by special fault clearing devices. The yarn can also be lubricated for knitting during winding.



Figure 5.9: Winding produces a yarn package. (Photos: CSIRO)

Plying, doubling, or folding is the process of twisting two or more yarns together. The process is normally used to improve yarn evenness, strength, elongation, abrasion resistance, to reduce hairiness and fibre shedding (fly) and to produce speciality (fancy and/or bulky) yarns. An assembly winder is used to assemble the ends of yarn on one package in preparation for twisting. A lubricant can also be applied at this stage. Yarns are generally twisted together on a two for one twisting machine where two turns of twist are inserted per spindle revolution.

Further Reading

Lord PR (2003) 'Handbook of Yarn Production – Technology, Science and Economics' (The Textile Institute and Woodhead Publishing).

Ratnam TV, Doraiswamy I, Chellamani KP (2005) 'Quantitative requirements of cotton by 2010'. Asian Textile Journal.

McCreight DJ, Feil RW, Booterbaugh JH, Backe EE (1997) 'Short Staple Manufacturing' (Carolina Academic Press).

Duessen H (1993) 'Rotor Spinning Technology' (Schlafhorst Inc.).



Figure 5.8: Ring Spinning produces the yarn which is wound onto bobbins. (Photos: CSIRO).