TECHNICAL BULLETIN

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COTTON SPUN YARNS FOR KNIT AND WOVEN FABRICS

This report is sponsored by the Importer Support Program and written to address the technical needs of product sourcers.

INTRODUCTION

A spun yarn is a twisted assembly of fibers formed into a linear strand. Since cotton (at a length of less than 2.0 inches) is a fiber less than 2.5 inches in length, cotton yarns are classified as short staple spun yarns. These yarns are characterized by their inherent hairiness and non-uniformity. Spun yarns are many times the yarn of choice in apparel, home furnishings, and industrial textile products, because of their uniqueness and intrinsic values compared to other yarn types.

This bulletin reviews the critical steps in processing cotton spun yarns, and the different spinning systems predominantly used today. Emphasis will be placed on process options, yarn properties, and quality determinants.

YARN CLASSIFICATIONS

Many times cotton spun yarns are classified according to the spinning system used for yarn formation. The major systems utilized today are ring spinning, open-end spinning, and air-jet spinning (MJS and MVS). Preparatory processes of fiber for these systems are somewhat different, and each spinning system is unique in its operation, yarn characteristics delivered, and production levels.

The fiber preparatory processes needed for each of these different classifications are indicated in the following table:

SPINNING SYSTEM					
Processes	**Ring (Carded)**	**Ring (Combed)**	**Open-End**	**Air-Jet**	**Vortex**
Bale feeding	X	X	X	X	X
Opening	X	X	X	X	X
Cleaning	X	X	X	X	X
Blending	X	X	X	X	X
Carding	X	X	X	X	X
Pre-drawing		X			X
Lap winding		X			X
Combing		X			X
Breaker drawing	X	X	X	X	X
Intermediate drawing				X	
Finisher drawing	X	X	X	X*	X*
Roving	X	X			
Spinning	X	X	X	X	X
Winding	X	X			

* Finisher drawing may not be required for certain products. MVS could be made of carded or combed stock. MVS combed does not require finisher drawing.

PROCESSING OF COTTON SPUN YARNS

Bale Feeding

Bale feeding is normally done by hopper feeders or by top feeders. In bale feeding, the compressed bale of cotton is broken down into smaller tufts of fiber. This aids in better subsequent opening, cleaning, and blending. Of the two feeding systems, top feeders are more prevalent today when processing cotton fibers. Cotton bales are selected for desired properties and arranged in a row formation, two or three bales wide. This is referred to as a laydown and normally consists of 40 to 80 bales. The top feeders move across the top of the laydown from end to end plucking a very thin layer of fibers from each bale. Those tufts of fibers are then transported through air ducts to the opening/cleaning/blending equipment.

Fiber Opening and Cleaning

Cotton fibers then pass through a succession of machines designed to gradually and progressively open the dense tufts of fibers and reduce tuft size. Less intensive opening action will proceed to action that is more intensive. This gradual reduction and opening of the tufts helps preserve fiber quality, creates less fiber entanglements (referred to as neps), and promotes better cleaning and blending. Impurities of concern in cotton are plant leaf, stem, seed particles, neps, short fibers less than 0.5 inch (12.7 mm.), and immature or not fully developed fibers. These initial opening and cleaning machines utilize large beaters covered with either spikes or coarse saw-tooth wire. These machines will be followed by beaters with finer and finer wire surfaces. Initially larger particles of waste will be removed followed by smaller particles removed with more intensive action. Care is taken to preserve fiber quality.

Fiber Blending

Blending brings together fiber tufts from many bales to form a consistent, homogeneous mix. A popular machine for blending fibers from bales of the same fiber type is the cell mixer. Fiber stock is fed from the top into a series of parallel vertical cells or chambers and removed at the bottom or delivery end of the chambers. Fibers from the different cells are randomly mixed due to each cell delivering its fibers in different time intervals. For this reason, these machines are also called time-delay blenders or blender/reserves.

When blending different fiber types such as cotton and polyester, each type can be weighed by a weigh-pan type hopper feeder. Many times, six to eight of these machines will be parallel to one another, each with the potential of dropping a designated weight of fiber onto a conveyor belt. The combined drops of different fibers are then moved forward and blended by a mixing beater. They then move into a cell mixer for further blending to promote a more even product in subsequent processing. When fibers are blended in this way, it is referred to as an “intimate blend.” In addition to weigh-pan type machines, there are belt-weighing and chamber-type machines available.

Carding

Opened, cleaned, and blended fibers are transported by air ducts to a chute feeder, which prepares the fibers for feeding into the carding machine. The chute will form a uniform mat of fibers about 40" wide and 3" thick. The card makes use of a series of saw-tooth, wire covered surfaces that move in close proximity to one another and at different speeds. This speed differential and wire action causes the fibers to be brushed and is designed to remove trash matter, short fibers, and neps. The carding action also achieves a total opening of the cotton fibers, which further enhances fiber cleaning. In addition, the fibers are also aligned somewhat parallel in the direction of material flow out of the card. Finally, due to the wire surface orientation and speed differences, the fibers are actually "drafted" or thinned down to a spider web-like structure. The thin web of fibers will be 38-40 inches in width and at the front of the carding machine will be condensed into a rope-like strand called a card sliver. Card slivers are then leveled and coiled into large cylindrical cans. The delivered card slivers will be routinely monitored and checked for correct weight per unit length and degree of uniformity. Variations in the card sliver will lead to eventual variations in the final yarn product.

Drawing

Multiple cans of card sliver are then fed into drawing machines. Ideally, the cans should be from different carding machines for better cross blending. Strands of sliver going into the drawing machines are typically called "doublings" or "ends." The number of doublings or ends is normally six to eight. The ends of sliver can be of different fiber types, creating what is called a draw blend. For example, four cotton slivers and four polyester slivers of the same linear density would eventually form a 50 cotton/50 polyester blended yarn. One or more slivers could contain dyed fiber, and the result would be a heather blend for an eventual heather yarn such as used in fleece wear and underwear.

On the drawing frames, these multiple ends of sliver are fed into a roller-drafting system. A series of pairs of top and bottom rollers grip the mass of fibers coming through, and with successive increases in roller speeds, the fiber mass is reduced or drafted. Therefore, only one sliver is leveled and delivered from each drawing machine. The roller action helps to further align the fibers, and the multiple ends fed create further blending of fiber variables and/or different fiber types.

There may be multiple processes of drawing. Drawing before combing is called pre-drawing. When not combing, first process drawing is called breaker drawing, and a second process drawing is called finisher drawing. As noted on an earlier flow chart, there are several variations of drawing steps according to the method of yarn spinning.

Combing

For combing, multiple ends of drawn sliver are wound onto a large spool in a process called lap winding. Each lap will typically contain 20-48 slivers and is fed to an individual combing position on the comber machine. A rotating wire-covered cylinder called a half-lap will "comb" through a short segment of fibers from the lap. These combed fibers are then separated from the comber lap and pieced together with previously combed fibers. The combing action removes short fibers, neps, and trash particles while promoting fiber parallelization and blending. The items removed in combing as waste are referred to as “comber noils.” There are different degrees of combing as related to the percent noil removed.

Combing is a value-added process and can significantly improve resultant yarn uniformity, hand (softness), strength, luster, and overall general appearance. Finer yarn counts are often spun from combed cotton fibers. Combed yarns can also be spun with lower twist levels compared to carded yarns since the shorter fibers have been removed. Longer fibers allow for more fiber-to-fiber cohesion. The lower twist levels allow for an increase in production speeds. Combed yarns will also generate less lint (fiber shedding) in subsequent processes.

After combing, there should be more drawing processes. Normally, one or two drawing processes will follow combing in order to improve the short term variation created by the combing and piecing action.

Roving

Roving is a process utilized only in the production of ring-spun yarns. Drawn carded or combed sliver is fed into a set of paired top and bottom drafting rolls. The mass of fibers in the sliver is thinned to a cross-section about the size of a pencil. Because of this small cross-section of fibers, aprons (small flexible rubber belts) are used for better fiber control. Because of such a thin strand (roving), there is not a sufficient amount of inter-fiber cohesion to give the roving adequate strength for transporting to the ring-spinning process. Therefore, a small amount of twist is added as the roving is delivered from the machine by a rotating device called a flyer. The rotating flyer aids in twist insertion and the laying of the roving onto a roving bobbin. These bobbins are in turn transported to ring spinning where they become the input material for making ring-spun yarn.

Ring Spinning

The basic design for ring spinning was developed in 1830. In ring-spinning, roving is fed into a roller-drafting system with aprons, which has the responsibility of drafting (thinning down) the fiber mass to that which is desired for a given yarn size (count). As the fiber stream leaves the front or delivery roll of the drafting system, it forms into a triangular shape. Fibers on the fringe of the triangle tend not to be totally attached to the yarn core and thus increase the yarn hairiness and potential shedding of fibers. Compact spinning is a relatively new innovation where an additional attachment to the delivery roll of the ring-spinning machine causes the yarn to be “compacted.” This add-on unit helps create a ring-spun yarn with greater strength, reduced hairiness, greater yarn elongation, increased luster, and the possibility of reducing yarn twist resulting in an improved fabric hand.

From the front roll of the spinning machine, the yarn is directed downward and then through a small “c-shaped” steel clamp called a traveler. The traveler is free to rotate around a metal ring, hence the term “ring” spinning. The package (ring bobbin) that the yarn is wound onto is located inside of the metal ring. The ring bobbin is situated on a rotating spindle, which can rotate clockwise to produce Z-twisted yarn or counterclockwise to produce S-twisted yarn. As the yarn is taken up on the spinning bobbin, the yarn itself pulls the traveler around the ring at speeds up to 8,000 feet per minute. The twist in the fibers created by the rotation of the bobbin and traveler migrates all the way up to the front roll of the drafting system. This twist gives the yarn its final strength values. The amount of yarn on each spinning bobbin is only a few ounces in weight, which necessitates a subsequent winding operation where numerous spinning bobbins will be individually wound onto a much larger yarn package.

Ring-spun yarn properties can be altered according to customer requirements or to meet a specific need mainly by changing the level of yarn twist. Higher twisted yarns will tend to be stronger and more abrasion resistant, but harder, less flexible, and have more torque.

<u>Open-End Spinning</u>

Open-end spinning (sometimes called rotor spinning) was first used in production in the mid 1960's. In this spinning process, sliver (not roving) is fed through a feed roll to a rapidly revolving comber (opener) roll, which is covered with either saw-tooth wire or short pins. The comber roll opens, separates individual fibers from the end of the sliver, and removes trash particles. These opened and separated fibers go through a tapered transport channel and then into the groove of a rapidly revolving rotor (up to 150,000 revolutions per minute). Fibers are impinged into the rotor groove on top of each other to create the needed mass for the desired yarn size. The fibers are twisted together as the rotor revolves, while the just formed yarn is removed from the spin box. Instead of being twisted together, some fibers are wrapped around the waist of the yarn and do not contribute to yarn strength. These "wrapper" fibers are unique to open-end yarns. The speed of the delivery roll divided by the speed of the feed roll is what determines the yarn size (count). The amount of twist in the yarn will be determined by the speed ratio between the rotor and the delivery roll. After the yarn leaves the delivery roll, it is normally passed through some type of mechanism designed to "clear" (remove) objectionable defects from the yarn. The yarn is then waxed and wound onto a large package that will be used in knitting and weaving (requiring no wax). Productivity of each open-end spinning position is about eight to ten times greater than a typical ring-spinning position.

Open-end yarn characteristics can be altered by changing the navel, which is located at the center of the rotor in the spin box. As the yarn leaves the rotor via the navel, it can be made softer and bulkier by using an aggressive (higher surface friction) type of navel. A stronger and smoother yarn with more torque can be attained by using a less aggressive, smoother navel. Open-end yarns with ring-spun like characteristics can be produced by using computer-aided systems, which help introduce additional variations in the yarn structure. Different types of rotor grooves can also alter yarn properties.

<u>Air-Jet Spinning</u>

There are two types of air-jet spinning, MJS and MVS-Vortex. In either case, finisher sliver is fed to a high-speed drafting system, consisting of three pairs of rolls and an apron. The amount of draft determines yarn mass (size). After leaving the front roll, the fibers are introduced to an air-jet or vortex to create a yarn.

In MJS spinning, the finisher drawn sliver is subjected to an air vortices located in a pair of air-jet nozzles. This initial air vortex in the first nozzle adds twist to the leading ends of fibers, while trailing ends are held by the front roll. This vortex also helps to separate a small ribbon of fibers from the main core fibers. This ribbon of fibers wraps around the parallel core fibers in a spiral configuration and provides sufficient fiber-to-fiber cohesion for needed yarn strength. Unlike the open-end yarn wrapper fibers, the binder fibers that wrap around the air-jet yarn are critical to yarn strength, because they hold the internal bundle tightly together. They are more organized than those of an open-end yarn. The second air nozzle creates another vortex, which imparts false twist to the yarn bundle with air revolving in the opposite direction to that of the first nozzle. As the yarn exits the second jet, the false twist is removed and core fiber twist is reduced to zero. As in open-end spinning, the air-jet yarn passes through a yarn clearer and is then wound onto a large package. At this point, the package is ready to be the yarn supply for knit and woven fabrics. Productivity for air-jet spinning is 15-20 times higher per position compared to ring spinning.

Vortex Spinning

In this most recent modification of air-jet spinning, the fibers leave the roller drafting system and enter a single nozzle where an air vortex is created by three air inlets. The air vortex creates a circular movement of the fibers and causes the fiber ends to flare or curve outward just before entering the vortex. These flared fibers are then wrapped around the central core of fibers by the air vortex. Fiber ends from the flared fibers give the vortex yarn characteristics and appearance of a ring-spun yarn. Shorter fibers in the fiber flow are removed from the main yarn bundle and end up as process waste. This newer system can produce 100% cotton yarns, which is not normally done successfully on conventional air-jet machines.

Winding

While winding of yarn packages is a part of open-end and air-jet spinning systems, it is a separate operation when producing ring-spun yarns. Yarn is unwound from individual ring bobbins, passed through a “clearer” mechanism to remove undesired defects, and then wound onto large packages. Due to more torque in ring-spun yarns, the yarn packages are many times conditioned by heat and moisture under pressure in order to relax the torque created by the twist in the yarn.

Twisting (Plying)

Sometimes individual cotton spun yarns are plied (twisted together) to introduce different yarn characteristics. Plying of spun yarns can accomplish the following:

- Add to or increase the strength of single strand yarns.
- Yield a balanced yarn with no twist liveliness.
- Utilize multi-strands of fine yarns to produce a thick strand.
- Produce a smoother yarn.
- Produce a yarn with a more uniform diameter.
- Introduce novelty effects.

- Add color.
- Introduce different fiber yarns.
- Combine spun and filament yarns.

Normally, yarns are ply-twisted in the opposite twist direction from that which is found in the singles yarn. If singles yarn is twisted in the Z-direction, then the ply-twist will be in the S-direction, thus reducing yarn torque (liveliness). For example, if two Ne 40's yarns are plied, the resultant yarn number would be denoted as 40/2. This yarn size would be equivalent to a 20/1 yarn.

SPUN YARN CHARACTERISTICS BY SPINNING SYSTEM

Ring Spun	Open-End (Rotor)
1. Strongest yarn	1. More even
2. Finest yarn	2. Higher strength uniformity
3. Softest yarn	3. Higher production rate
4. "Z" and "S" twist	4. Fewer processes
5. Lowest productivity	5. Lower cost
6. Most uneven	6. Fewer imperfections
7. Most expensive	7. Harsher hand (feel)
8. More hairy, generally	8. Not as strong
9. More torque	9. Limited counts-coarser yarns
10. Widest range of yarn counts	10. "Z" twist only

Conventional MJS Air Jet	MVS = Vortex Air Jet
1. Very high productivity	1. More ring-like
2. Fewer processes	2. Lower hairiness
3. Good evenness	3. Dyes darker
4. Less pilling	4. Good hand
5. Fewer imperfections	5. Highest productivity
6. Weaker yarn	6. More torque
7. Limited to mostly medium counts	7. More waste in spinning
8. Harsher and stiffer hand	8. Limited count range

YARN NUMBERING

Cotton-spun yarns are specified by a number (numerical value) that is a relative indicator of its linear density or fineness. Yarn count is another term used to relate to the yarn number. There are two systems used for numbering yarns, the ***indirect*** system and the ***direct*** system. The indirect system is used in the U. S. when numbering spun yarns. In this system, the coarser yarns are identified by lower yarn numbers, and the finer yarns are identified by higher yarn numbers. The yarn number itself is a length-to-weight ratio where the length is expressed in 840-yard units called hanks, and the weight is one English pound. For example, the yarn number 24/1 would represent a yarn in which each pound would equate to 24 hanks or 20,160 (24x840) yards of yarn. On the other hand, a 36/1 yarn number would represent a yarn containing 36 hanks (36x840) or 30,240 yards per pound. From these examples, one must remember that the yarn number is simply the number of hanks (840-yard lengths) per pound of yarn. In the U.S., the count for cotton is referred to as the English count or Ne. In Europe and some other foreign countries, the metric system, many times denoted as Nm, is sometimes used to number spun yarns where the yarn number represents meters per gram of yarn. Still other countries use a direct numbering system called tex to specify spun yarn numbers. In the tex system, the yarn number represents the number of grams of yarn per 1000 meters of the given yarn. The following numerical relationships can be useful in converting from one numbering system to another:

- 590.54 divided by tex equals Ne count
- Nm count divided by 1.69336 equals Ne count

Please refer to Cotton Incorporated's technical bulletin on yarn numbering, TRI 1014.

RAW MATERIALS FOR YARN PRODUCTION

Textile Fibers

Cotton, a natural fiber, is the predominant choice of fiber for producing short staple yarns. Synthetic fibers such as rayon, polyester, and acrylic can be blended with the cotton fibers to produce blended yarns. Other natural fibers such as flax, wool, and silk can also be blended with cotton fibers, but these blends are not as common as the cotton/synthetic blends.

After ginning, cotton fibers are formed into packages called bales, each bale weighing 480-500 pounds on average. The bales are under extreme compression for shipping purposes. This high-density condition of the fibers must be overcome through proper fiber opening and conditioning practices.

Bale Storage and Selection

A specified number of bales are brought from the bale storage area to the manufacturing area. These bales form what is referred to as the ***bale laydown***. Opening of the bales to opening room conditions of temperature and humidity at least 24 hours before their use, contributes to consistency of product and process and helps reduce the variability of properties in the final yarns produced.

Computer systems are used today to precisely select bales from different groupings in storage and these systems help to maintain uniform laydowns from day to day, week to week, and even month to month. Ideally, each laydown will be a cross-section or mini-representation of what is in the overall bale inventory. The best known system for fiber management is the Cotton Incorporated, Engineered Fiber Selection® software.

Cotton fiber properties used to establish bale groupings usually include the following:

1. Micronaire (a number related to fiber thickness).
2. Fiber strength.
3. Fiber length and length uniformity.
4. Trash content.
5. Color.
6. Growth region.

OVERVIEW OF YARN REQUIREMENTS FOR WEAVING AND KNITTING

Warp yarns for weaving need to be strong, uniform in strength, have good evenness values, and a low degree of hairiness. These yarns are subjected to the stresses and strains of the weaving process and are in very close proximity to one another. Air-jet weaving places the highest demand on warp yarn quality due to the air used in filling yarn insertion being easily disrupted by any non-uniformity in the warp yarn. In most cases, cotton-spun yarns used in the warp are slashed (sized) with a protective coating or film to provide lubricity and abrasion resistance as the yarns go through the different weaving machine elements. It is very essential that yarn elongation values are adequate, since yarn is under relatively high tension during the rigors of weaving. Yarn imperfections, especially thick places, should be avoided since the yarn path on the weaving machine includes various eyelets and other devices that could cause the yarn to catch, increase tension levels, and/or cause the yarn to break.

Filling yarns do not need to be as strong as warp yarns and therefore will typically have lower levels of twist. This lower twist level will lead to a more bulky yarn structure, which is advantageous for filling yarns because of added cover in the fabric produced. For air-jet weaving, the filling yarns need to have a good level of evenness so the air will not blow the yarn apart at thin places. Hairiness in these yarns needs to be uniform, so the air and yarn interaction will remain consistent leading to fewer miss picks and partial picks.

Cotton-spun yarns for knitting should exhibit good hand or softness. This is made easier, because these yarns do not need to be as strong as weaving yarns and therefore need no sizing and less twist. This lower twist leads to softer yarn and fabric. Yarn torque or liveliness should be at a minimum to help prevent excessive fabric shrinkage, skew, and torque. Good elongation values in the yarn will reduce fabric holes. Good evenness values will prevent machine stops and fabric holes. Thick places in the yarn need to be minimized because they can lead to yarn tension problems, broken needles, and bent latches.

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Importer Support Program

The Cotton Board and Cotton Incorporated are funded by U.S. upland cotton growers and importers of cotton and cotton products (this includes raw cotton, piece goods, and finished apparel). A percentage of the importer funds are devoted for importer specific programs organized under the Importer Support Program. Examples of projects funded from this fund include training schools, educational programs, focus groups, economic meetings, and research initiatives.

Selected technical issues have been identified by importer members as relevant to their business. This report is a condensed, less technical report of those issues intended to provide the reader with basic, yet useful information on the topic.

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