TECHNICAL BULLETIN

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ISP 1010

DENIM FABRIC MANUFACTURING

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PROCESS FLOW FOR DENIM MANUFACTURING

The warp yarn (length-wise) used in denim fabrics is uniquely prepared for denim manufacturing compared to conventional woven fabrics. The yarn goes through numerous processing steps before it is placed on the weaving machine. Unlike the warp yarn, most filling yarn (width-wise) is put onto yarn packages and delivered directly to the weaving machine where it is inserted into the fabric without any further preparation in the same manner as conventional woven fabrics. The following flow chart reveals the necessary steps in the manufacture of denim fabrics, beginning with the production of the warp yarns used. The chart forms an outline for most of the topics that will be covered in this bulletin.

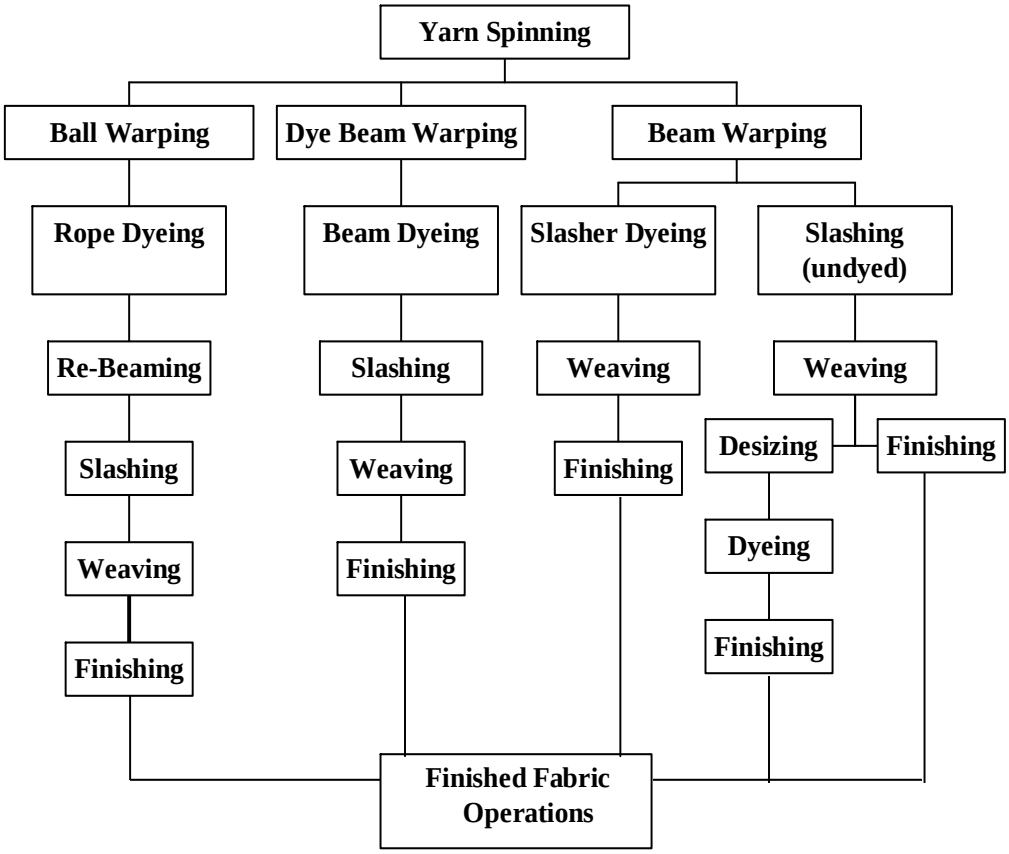


Figure 1. Process Flow for Warp Yarn in Denim Manufacturing

DENIM YARNS

Yarn Numbering

Refer to Cotton Incorporated's technical bulletin entitled "Yarn Numbering Systems-TRI 1014" for further information on yarn numbering systems and how to convert from one system to another.

Common Yarn Sizes for Denim

Warp yarns for bottom weight jeans typically range in size from Ne 4.0 to Ne 12.5/1. Finer yarns are used for lighter weight chambray shirting fabrics and lighter weight jeans, vests, dresses, and skirts. These yarns may range in count from Ne 12.5 to Ne 30.0.

Yarn Spinning Systems

Before the late 1970s, all denim yarns were ring spun. Today, denim fabrics have different combinations of ring and open-end yarns. When you hear a term such as "ring/ring, open end /open end (OE/OE), and ring/OE," it is referring to which yarn is in the warp and which yarn is in the filling, respectively. For example, ring/OE indicates a ring-spun warp yarn and an open-end filling yarn. Weaving a combination of ring-spun and open-end yarns can help to reduce fabric costs while still maintaining some favorable ring-spun fabric characteristics.

Refer to Cotton Incorporated's technical bulletin entitled "Cotton Spun Yarns for Knit and Woven Fabrics-ISP 1006" for more detailed information on yarn spinning systems.

Specialty Yarns

- Structured Denim Yarns

  Modern ring-spinning frames and open-end machines can be installed with devices that can manufacture predetermined yarn effects. These effects can vary from slubs (thick places) with different lengths, different spacing between slubs, or variations in the yarn count. Using these devices, OE yarns can have a more ring-spun like appearance, and ring-spun yarns can have an increased rough or "antiqued" quality. Yarn spinners can design patterns and effects specific to their needs, which can be downloaded into the machine's electronic control system.

- Elastic Denim Yarns

  Core-spun yarns are produced conventionally on ring-spinning machines by introducing a spandex filament at the back of the front drafting roll of the machine. The drafted cotton fibers twist around the spandex core to produce an elastic ring-spun type yarn. There are also open-end and air-jet spinning machines that have been adapted to produce core-spun yarns. The core filament yarn (normally spandex) is inserted through the rotor shaft on OE frame or the spindle of the air-jet frame, and the cotton fiber wraps around the spandex filament

during the process of spinning. The yarn is somewhat similar to the ring core-spun yarns in terms of yarn and fabric characteristics. Open-end and air-jet core-spun yarns have fewer knots and splices as compared to ring core-spun yarns.

WARPING

Warping is the process of transferring multiple yarns from individual yarn packages onto a single package assembly. Normally, yarns are collected in a sheet form where the yarns lie parallel to each other and in the same plane onto a beam, which is a cylindrical barrel with side flanges. This is known as beam warping and is shown in Figure 2. For *ball warp* denim, the yarns are brought together and condensed into a rope before being wound onto a relatively short cylindrical barrel (sometimes called the shell or log) that has no end flanges. This is shown in Figure 3. In both cases, the supply yarn packages are placed on spindles, which are located in a framework called a creel.

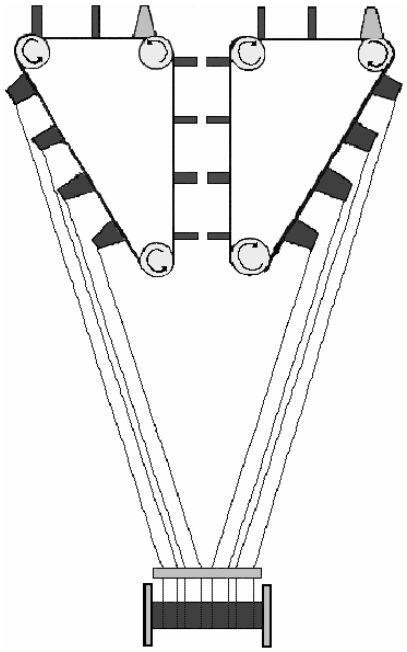


Figure 2. Beam Warping

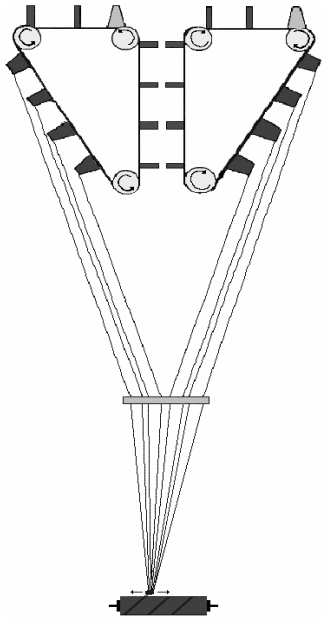


Figure 3. Ball Warping (Rope)

Types of Creels

- Traveling Package Creels

  These are V-shaped creels with the actively running yarn packages on the outside of the V and the full yarn packages placed on the inside of the V. When the running packages are depleted, the yarn spindles on the creel are rotated so that the empty packages move to the inside of the V-creel for replenishment. The full packages move to the outside of the creel. The new yarn ends have to be pulled forward and threaded properly in the machine before

running the next warp. The empty package positions are then replaced with new full packages while the warper is running. This eliminates lost time in creeling up new yarn packages.

- Magazine Creels

  These are straight-line creels with enough spindles so that each end-running has a reserve yarn package placed beside of it. The tail end of the running package is tied to the beginning end of the reserve package. Once the running package is depleted, the yarn transfers over to the reserve package and the warper continues to run. This is a random method of creeling yarn packages compared to block creeling normally used on traveling package creels.

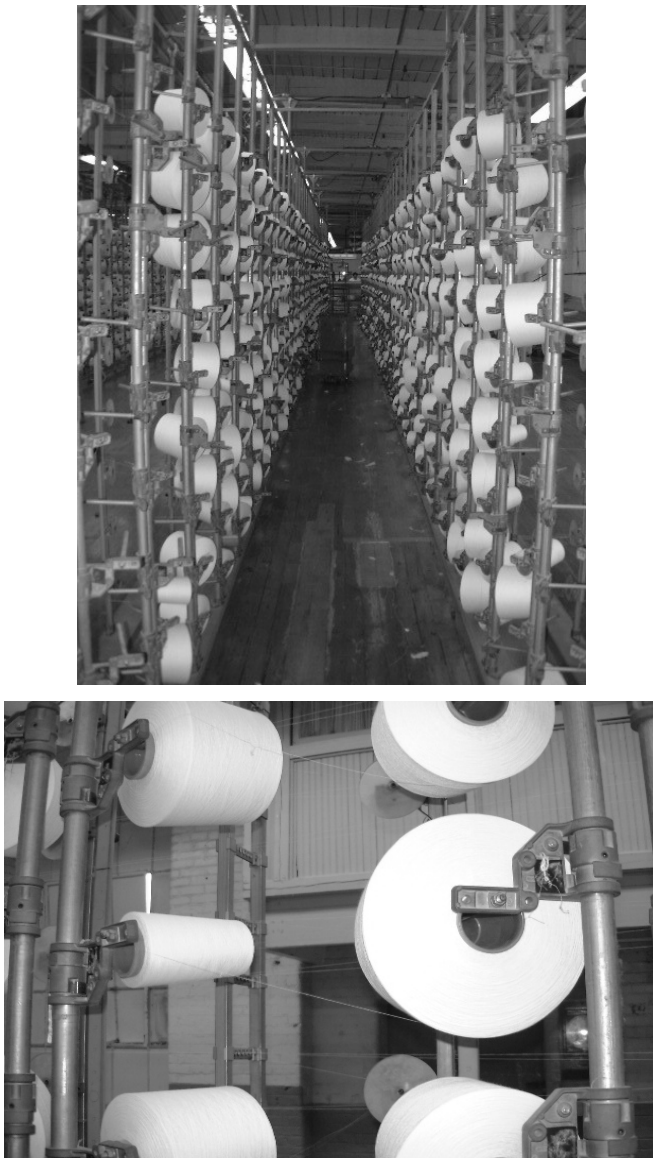


Figure 4. Magazine Creels

Ball Warping

In ball warping (Figure 5), 250 to 400 yarn ends are pulled from the creel. The yarns then pass through a comb-like device (sometimes called a hack or reed), which keeps each warp yarn separate and parallel to its neighboring ends. At intervals of every 1000 or 2000 yards (or meters), a lease string is placed across the sheet of warp yarns to aid yarn separation for the re-beaming operation, which will occur later. The yarns then go through a funnel-shaped device called a trumpet or condenser, which collapses and condenses the sheet of yarn into rope form. This device is located at the base of the warper head and traverses back and forth, guiding the newly formed rope of yarn onto a log. The rope must be wound at a constant tension to keep the yarns from tangling.

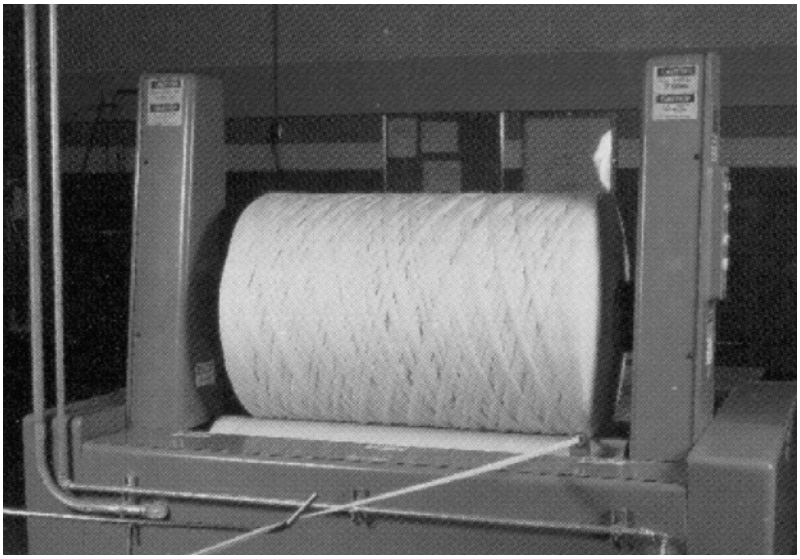


Figure 5. Ball Warping

Beam Warping

Beam warping maintains the yarns in an open sheet form and winds the yarns parallel to each other onto a slightly wider flanged beam. These yarns will not go through the rope indigo dye range, but are left "natural" and will end up either slasher dyed or in an un-dyed fabric, which can later be piece dyed, garment dyed, or left natural. Another option would be to beam dye the yarns using a dye other than indigo.

Figure 6. Beam Warping

DYEING AND SLASHING WARP YARNS FOR DENIM

Rope Dyeing

Most denim is yarn-dyed fabric with the warp yarns dyed with indigo dye and the filling yarns left undyed. There are a number of modifications or alternatives in the dyeing process that are routinely used to change the overall look or performance of the fabric. With the advent of denim garment washing techniques, the consistencies of the indigo dyeing process and its modifications have become crucially important in determining the quality and performance of indigo denim products.

The properties of the indigo dye account for the wide variety of color designs that are available on denim materials. Indigo is unique as a major textile dye, because it has a very low affinity for the cotton fiber. Because of the low substantivity of the indigo, the ball warp dyeing process ring dyes cotton. Unlike almost all other commercially successful dyestuffs, the indigo dye concentrates in the outer layers of the cotton yarn and fiber during the dyeing process. This produces an intense ring of color around a white core in the cotton yarn and the cotton fiber thus the name ring dyeing. When using most other dyes, if the ring-dyeing effect occurs, it would be considered a dyeing defect.

Indigo dye in its normal form is a vibrant blue, it is insoluble in water, and it will not dye cotton fiber. In order to dye cotton, the indigo must be converted to a water-soluble “leuco” form and then applied to the cotton. This process is known as chemical reduction. Reducing agents such as sodium hydrosulfite with sodium hydroxide chemically convert the indigo dye to its soluble form. This also temporarily converts the dye from its blue color to a very pale greenish yellow color. The leuco form of indigo is readily absorbed by the outer layers of the cotton yarn. Once

in the fiber/yarn, the indigo is made insoluble by oxidizing the yarn by passing the yarn through the air (skying). In fact, the dye will start to oxidize immediately when exposed to the air. The oxygen in air converts the dye back to its original blue and insoluble form. Thus the dye becomes trapped inside the outer layers of the cotton yarn. This results in a small amount of dye being deposited on the surface resulting in only light blue dyed yarn. In order to obtain deep blue indigo dyed yarns, the color must be built in layers. The dye is layered by using multiple passes of the rope of yarn into the soluble dye and then exposing it to the air for oxidation. This multiple passing of yarn into dye is called *dips*. Normally, this process is repeated from three to twelve times to build up a deep indigo blue color. The number of dips is limited to the number of dye boxes on the dye range. If the concentration of indigo dye in the dye boxes is doubled, this will result in slightly darker denim. This acts as a multiplier when labeling the denim. A double concentration of dye in nine dye boxes makes it an 18-dip denim. Tripling the concentration makes it a 27-dip denim. When even darker shades are desired, a sulfur black or blue dye can be applied to the yarn before indigo dyeing. This is known as a sulfur bottom. If the sulfur dye is applied after the yarn has been indigo dyed, it is known as a sulfur top.

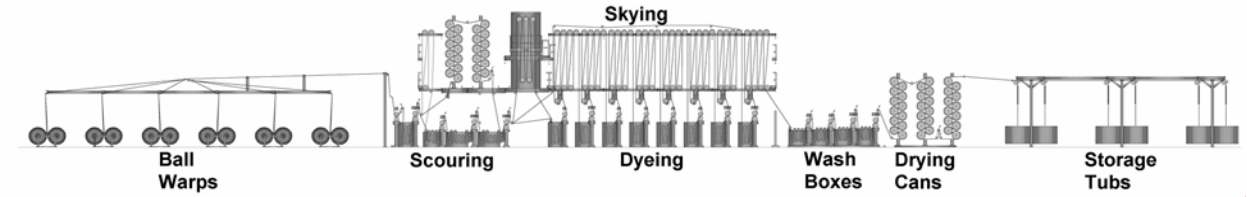


Figure 7. Indigo Dye Range

In rope dyeing, ball warps are continuously fed into the rope or chain-dyeing range for application of the indigo dyeing. Typically, 12-36 individual ropes of yarn are fed side-by-side simultaneously into the range. The ropes are kept separate from each other throughout the various parts of the dye range. For example, if the total number of ends on the loom beam is 3,456, and each ball would have 288 ends, then the dye set would have a total of 12 ball warps. If there can only be a multiple of 10 balls on the dye range, then there would be 345 ends on 9 balls and 351 ends on the tenth ball.

The ropes are first fed into one or more scouring baths, which consist of wetting agents detergents and caustic. The purpose of these baths is to remove naturally occurring impurities found on the cotton fiber such as dirt, minerals, ash, pectin, and naturally occurring waxes. It is very important to remove these materials to guarantee uniform wetting and uniform dyeing. The ropes are subsequently fed into one or more water rinsing baths.

If a sulfur bottom is required at this point, the ropes of yarn are fed into a bath of a reduced sulfur dye. Similar to indigo, sulfur dyes are water insoluble. They must be reduced to a water-soluble form before applying to cotton. Unlike indigo, the sulfur dye can penetrate into the core of the cotton fiber/yarn. The purpose of this process is to give the indigo dyed yarns a much deeper and darker shade or to slightly change the shade of the blue yarn to make it unique. Once the

reduced sulfur dye is applied to the ropes, they are skyed to allow the dye to oxidize into its normal water insoluble form.

The ropes of yarn are then fed into the indigo dye baths and skyed after each dip. The ropes of yarn are rinsed in several water baths to remove any unfixed dye. If a variant type of yarn color is desired, sulfur dye can be added at this point. Similar to the bottom-dyeing process discussed previously, this process is known as a sulfur top. Although the sulfur dye will migrate towards the core of the fiber/yarn, the sulfur top gives a different type of yarn color performance when garment washed than a sulfur bottom. The sulfur top process is then followed by a water rinse to remove any unfixed dye.

After either rinsing following indigo dyeing or rinsing following sulfur topping, the yarn ropes pass through squeeze rolls to mechanically extract water. The yarns are then dried and coiled into large tubs. The typical type of drying apparatus is a multiple stack of drying cans. These metal cylinders, which in most cases are Teflon® covered to prevent the yarn from sticking, are filled with steam under pressure. Maintaining a consistent pressure of steam within the cylinder can accurately control the temperature of the surface of each cylinder. Care must be taken not to attempt to dry the rope of yarn too quickly, which causes the dye to migrate to the surface of the rope. Additionally, if the surface of the drying can is too hot, the yarn can be overstressed producing an undesirable glazed appearance that reduces absorbency in later processing. Over-drying of the yarns will weaken them considerably adversely affecting re-beaming, slashing, and weaving.

After drying, the color of the yarn is checked either visually or instrumentally. With many modern indigo dye ranges, the color of the yarn is continuously monitored by instruments, which are electronically linked to the controls of the indigo dye baths. This type of control system can automatically adjust the dynamics of the process to obtain the most consistent color from the beginning to the end of the many thousands of yards of yarn contained within a single dye lot.

In order to minimize the color variability between denim fabric panels after garment washing, denim manufacturers employ a technique known as sequential dyeing. Basically, this method is based on the concept that the color properties of indigo-dyed yarn processed at a specific time, most closely resemble the color properties of the indigo yarn processed just before and just after that lot. This method has proven much more effective at minimizing color variability in garment washing when compared to the technique of shade sorting alone.

Slasher Dyeing

For certain manufacturers, the rope or chain dyeing of indigo is not possible or desirable. Many different types of equipment have been tried as an alternative to the dip and sky method of the rope dye range. For some producers, slasher dyeing has become a reasonable alternative method. A slasher is a range is normally employed to apply size formulations onto warp yarns before weaving. This range (Figure 8), when used for slasher dyeing of indigo, consists of section beams of warp yarn, which are forced into a sheet of yarn. This yarn sheet is then fed into a scouring section where natural impurities are removed. The next section is where indigo is applied. In order to achieve fairly deep shades, the indigo is applied in a series of multiple dip

and sky applications to allow for shade build up. If the arrangement of the slasher dyeing does not allow for multiple dip and sky applications, then only light and medium shades can be obtained from indigo. The dye application is followed by afterwashing and drying. With some machinery arrangement, warp size for weaving is immediately applied. In other arrangements, the warp size is applied onto the yarns employing a separate range.

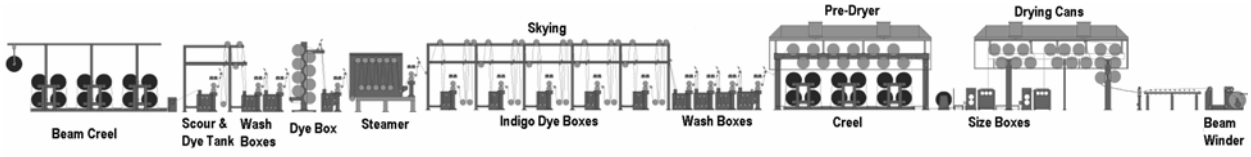


Figure 8. Slasher Indigo Dye Range

Slasher dyeing ranges have a number of advantages and unique characteristics. Slasher dyeing employs a sheet of yarn, which is wound directly onto a warp beam rather than ropes of yarn, which then requires additional handling. This type of dyeing works well with lightweight denims. In general, these machines require less floor space, enable smaller production runs, have a quicker turn over time, and are more flexible in their response to changes in the market. As an overall process these ranges have lower machinery cost; therefore, lower dye costs are realized for specific fabric types. Additionally, the slasher dyeing technique can be used for other dye types for cotton and thus can produce a wide variety of colors other than indigo blue.

Beam Dyeing

Another dyeing technique that has been used for dyeing warp yarn for denim is beam dyeing (Figure 9). In this technique, hundreds of individual yarns are wound parallel to each other around a perforated core beam with flanges on each end. The beam is then loaded into a cylindrical dye vessel that is sealed, so dye liquor can be pumped through the perforations in the beam and then through the yarn. After dyeing, the yarn is washed, extracted, dried, and added to other beams for slashing and weaving.

This technique does not lend itself to the unique dyeing properties of indigo, so it is normally used with other dye types including reactives, directs, sulfurs, and vats resulting in a wide range of colors. This is also a well known and accepted technique for many different constructions of cloth, but in denim applications, it has mainly been employed for dyeing yarns in colors rather than indigo.

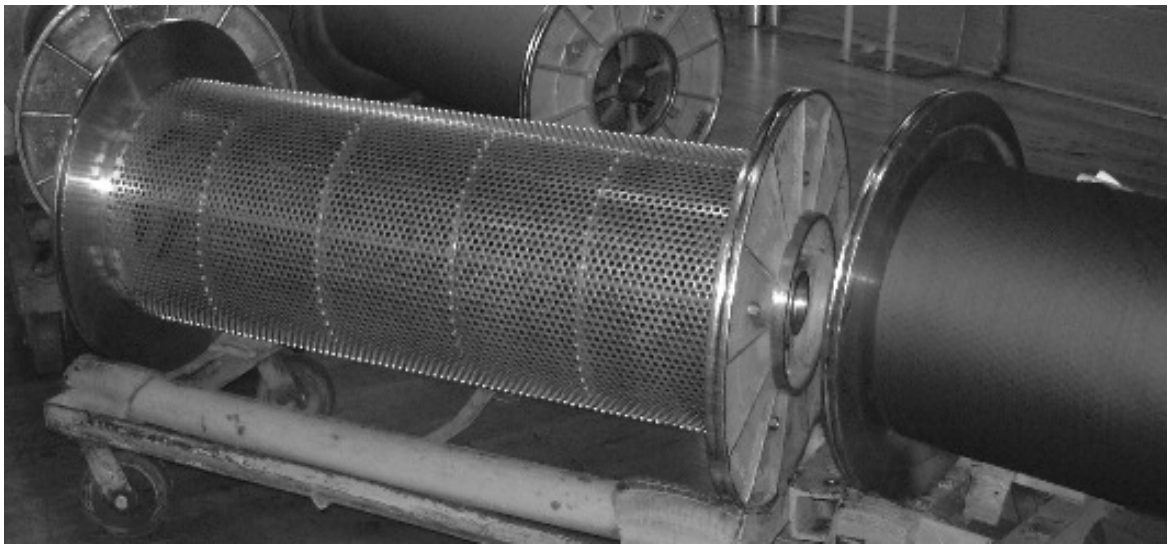


Figure 9. Dye Beams

Undyed Denim

It is possible for denim fabrics to be finished and sold without going through any dyeing process. These fabrics are known as natural denims sometimes called "bull denims." These natural denim fabrics exhibit the off-white cream color of natural cotton.

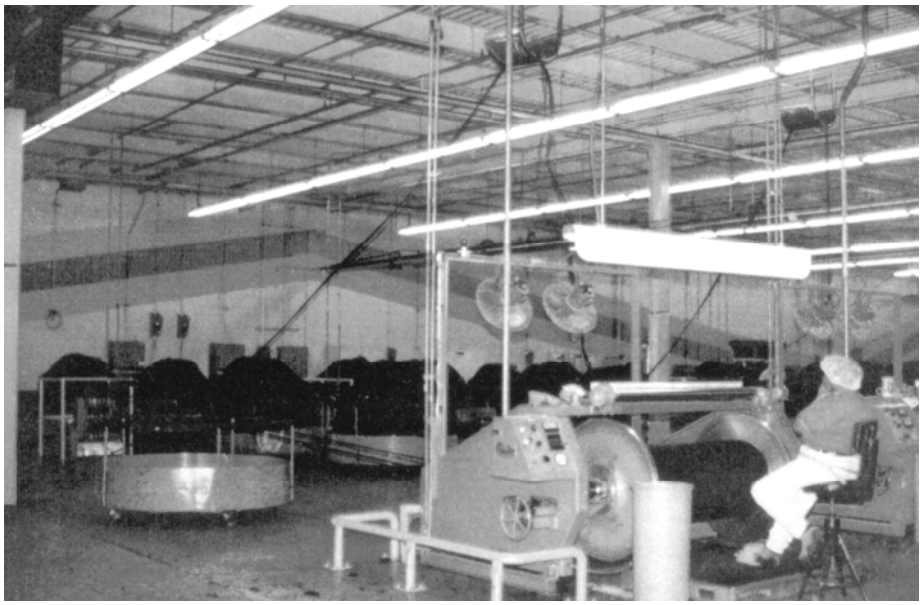
After finishing, cutting, and sewing into garments, they can be used like traditional denim garments, or they can go through garment dyeing and other wet processing to yield various properties. However, these garments will not show the color contrast effects shown by traditional denim garment processing. Also, these natural denims can be bleached to yield "white denim" products.

Additionally, it is also possible to dye natural denim fabrics into solid shades for both warp and filling yarns, employing the standard continuous dyeing techniques. This method is not usually used with indigo dyes, but is used where sulfur, vat, or reactive dyes might be applied. After dyeing, these denim fabrics are finished using the typical denim finishing sequence.

RE-BEAMING

Once the warp yarns are rope dyed, it is then necessary to change the yarn alignment from a rope form to a sheet form before entering the next process, which is slashing or sizing. Beaming or re-beaming (Figure 10) involves pulling the ropes of yarn out of storage tubs and moving them upward to a guiding device (sometimes called a satellite). This upward travel allows the ropes to untangle before nearing the beamer head. Once the ropes come down from the guiding device, they go through tensioning rollers to help further the separation of the ropes before going through a comb at the warper, which separates individual yarn ends and keeps them parallel to one another. From the comb, the warp yarns are guided onto a flanged section beam. Multiple warp section beams are made forming a set of beams, which will be the yarn supply for the slashing operation. Each set normally contains 8 to 14 section beams. At this point, there should

be no crossed, lost, or tangled ends on the beams. The total number of yarns on all the beams in the set should meet specifications for the given fabric to be woven. The beams need to be in good condition with smooth inside flanges, to be non-eccentric barrels, and to contain no high or low selvages. The selvage is the edge of the yarn sheet where it touches the beam flange at each end of the beam. It is critical that all the yarns wound onto a given section beam be under equal tension. This is maintained by using guides, tension devices, and stop motion controls.



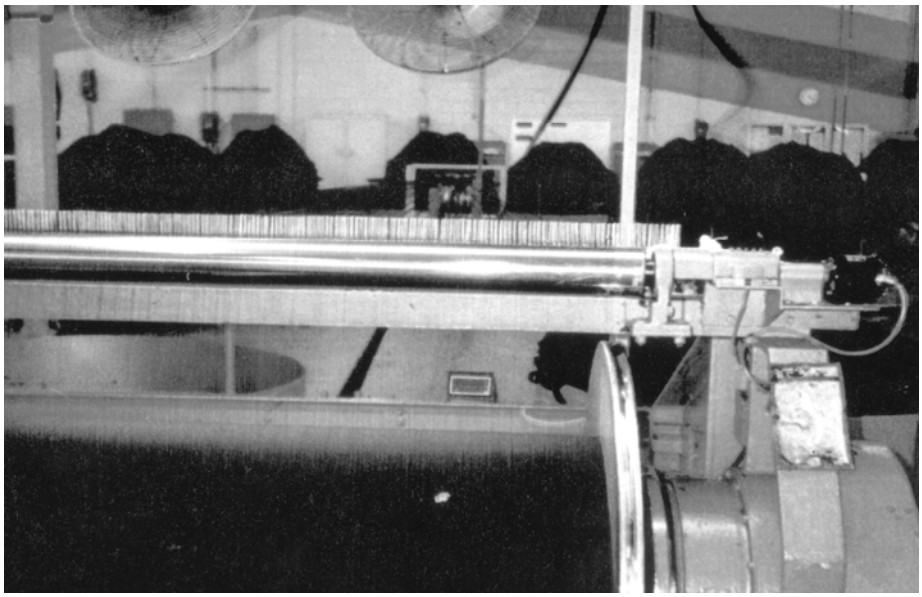


Figure 10. Rope-Dyed Yarn Being Re-beamed

SLASHING (Sizing)

The main purpose for sizing warp yarns is to encapsulate the yarn with a protective coating. This protective coating reduces yarn abrasion that takes place during the weaving operation and reduces yarn hairiness preventing adjacent yarns from entangling with one another at the weaving machine. Also, this protective coating keeps the indigo dye from rubbing off during the weaving process. For many years, native starches or slightly modified starches with corresponding binders were regarded as the most economical way to size indigo warps. However, the industry shift to garment washed denims has led to new sizing recipes. Many times the type and quantity of size used are determined by the subsequent fabric and garment finishing operations that follow.

At the back end of the slasher range, the section beams from the beaming process are creeled (Figure 11). The yarns from each beam will be pulled over and combined with the yarns from the other beams to form multiple sheets of yarns, the number of sheets corresponding to the number of size boxes (size applicators) on the machine.

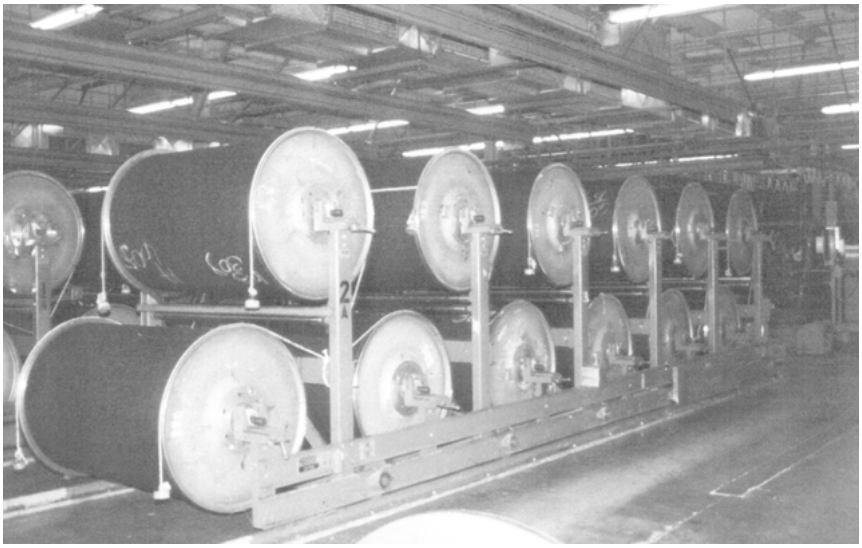


Figure 11. Slasher Creel

As each yarn sheet enters a size box (Figure 12), the yarns are guided downward and submerged in the liquid size. The yarn sheet leaves the size box via a set of squeeze rolls that helps control the wet pick-up, which influences the amount of size added onto the yarn and controls the amount of penetration of the size into the yarn. After this, the yarns are pulled over steam-heated, Teflon® coated cans or cylinders where drying takes place. At this point, the yarns are not totally dry, but are monitored to maintain from 6-8% moisture typically. Most warp yarns for weaving denim have 7-14% size add-on (actual dry solids weight added to the original weight of the yarn). This depends on what type of spinning system is used. Too much size causes yarn chaffing and excessive shedding of size particles at the weaving machine, and too little size causes excessive yarn abrasion resulting in dye streaks, clinging, broken and entangled ends resulting in low weaving efficiencies. In many denim styles, the size is left on the fabric

and acts as a stiffening agent for cut-and-sew operations. This accounts for the stiffness of certain jeans, which are purchased by the consumer.

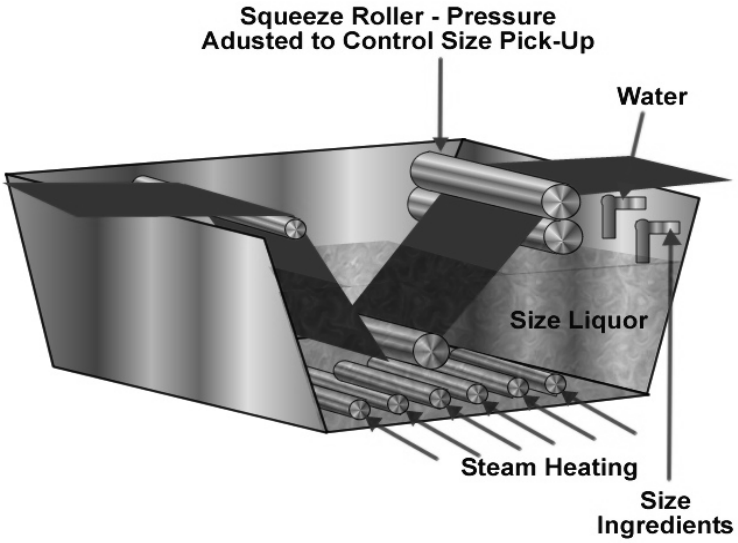


Figure 12. Size Box

All the yarns go through a set of stainless steel split rods, which help to separate them into individual sheets, equivalent to the number of section beams in the creel. This ensures that yarns from one sheet are adhering to yarns from another sheet. After passing through the split rods, the warp yarns are collected into one single sheet and passed through a comb, which helps to separate individual yarns. This expansion type of comb is adjusted to the desired loom beam width. At this point, all the warp yarns are wound onto the loom beam (Figure 13). Normally, several loom beams will be produced from a single set of section beams in the slasher creel.

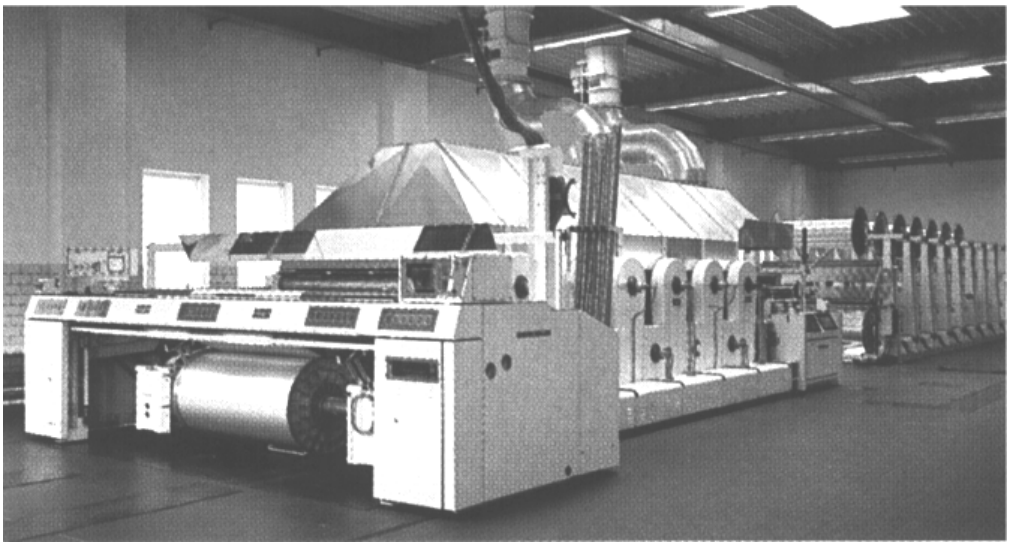


Figure 13. Slasher (loom beam at head-end)

DRAWING-IN AND TYING-IN OF WARP YARNS

When a new denim style is put on a weaving machine, it is necessary to draw (thread or insert) the warp yarns through various elements as in Figure 14, including stop motion devices (drop wires), weave design control devices (harnesses and heddles), and filling "beat-up" devices (reed). Each end of yarn must have its own individual element. This procedure can be done manually or automatically on drawing-in machines. When producing the same style and when the current loom beam is nearly empty of yarn, an identical full beam of yarn can be tied to the yarns of the old beam. This is done by a tying-in machine, which automatically selects an end of yarn from the old beam and ties it to the appropriate end on the new beam. The knots are then pulled through the weaving machine before fabric is put into production. It is well documented that many loom stops are caused by improper tying-in of the warp yarns.

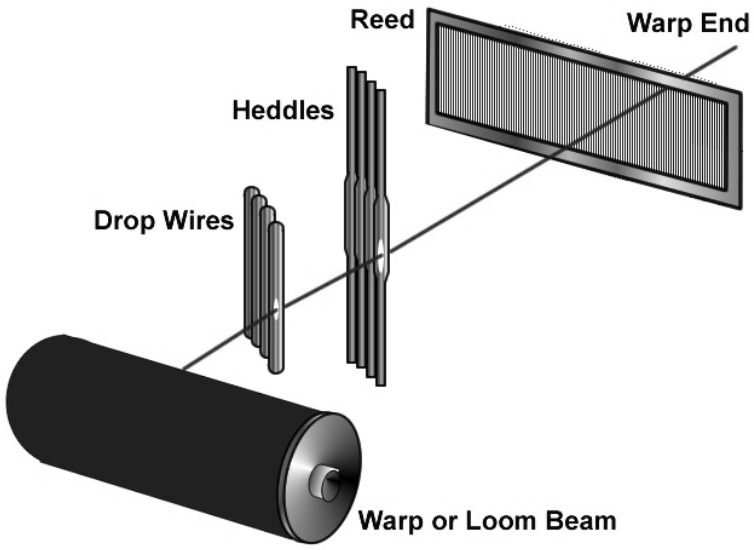


Figure 14. Warp Drawing-in

WEAVING DENIM FABRICS

Structure of Denim Fabrics

Denim fabrics are woven by interlacing two sets of yarns (Figure 15) perpendicular to one another in fabric form. Yarns in the machine direction are called warp yarns or warp ends, and these are interlaced with filling yarns or picks. The sequence or order of interlacing the two sets of yarns can be varied to produce many different weave designs. The finished fabric construction is determined by the number of warp and filling yarns per square inch or centimeter. For example, a typical construction for bottom weight denim may be 62 x 38. This is interpreted as 62 warp yarns per inch of width and 38 filling yarns per inch of length and always in that order. This thread count along with the yarn counts used will influence fabric properties such as

weight, fabric tightness, cover, drape, hand, tensile strength, tear strength, and other fabric properties.

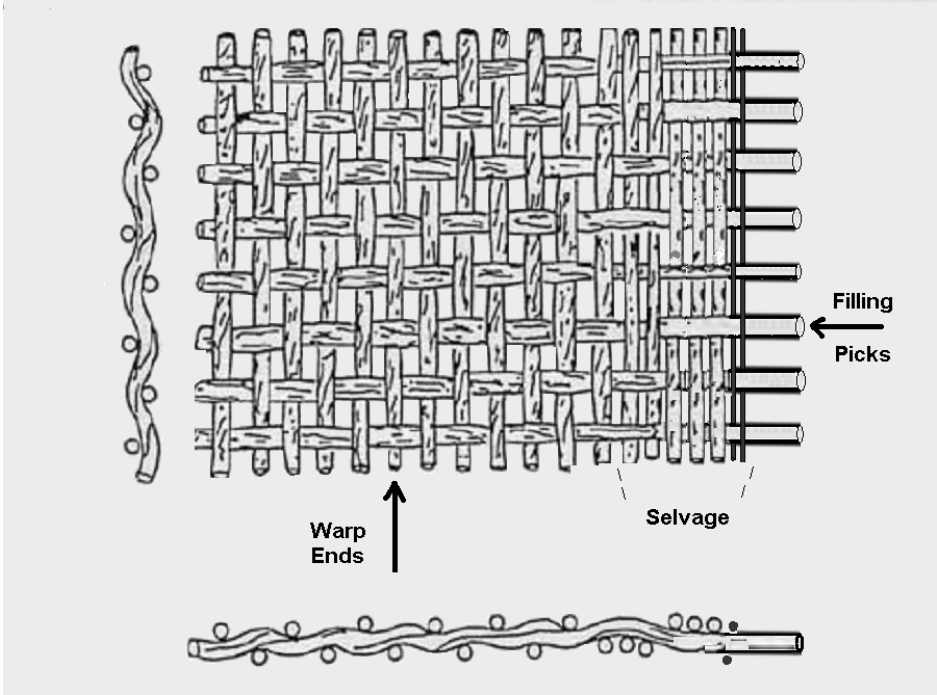


Figure 15. Woven Fabric Structure

Yarn Flow in Weaving

Warp yarns as seen in Figure 16 are fed from the loom beam and pass over a whip roll or rollers, which control yarn tension variations during weaving motions. The yarns are then directed through drop wires, heddles, and a comb-like device called a reed. The spaces between the reed wires across the width of the reed are called dents. Each reed has a certain number of dents per inch with 12 to 18 being the most common for denim and denim-type fabrics. There are normally four warp yarns drawn per dent in standard 3/1 twill denim fabrics. The heddles, through which the yarn is threaded, are located in harness frames with a designed number of warp yarns drawn through each harness. All warp yarns weaving alike in a design repeat occupy a given harness. The reed establishes the width of the warp yarn sheet and equal spacing of the yarns before weaving. It also is the mechanism used for pushing (beating-up) each inserted filling yarn (pick) into the body of the fabric at the "fell of the cloth." The fell is the point where yarns become fabric. At this point, the warp yarn is in fabric form and ready to be collected on a cloth roll. Some machines have inspection stands that are backlighted for easy inspection of the fabric as it is woven before cloth roll take-up.

The flow of the filling yarn is somewhat simpler. The filling yarn is fed from large packages located outside of the actual weaving machine. The yarn comes off the package or packages and is wound onto a storage feeder that allows the yarn to be under consistent tension for each pick

insertion. The yarn is then introduced to the filling insertion mechanism and inserted across the separated warp yarns, which have formed a tunnel or path called a weave shed.

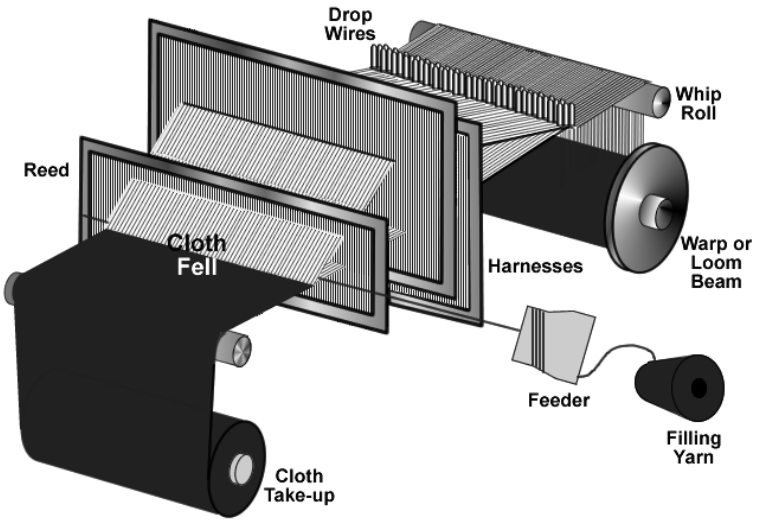


Figure 16. Weaving Machine Elements

Basic Weaving Motions

The five basic motions, which are shown in Figure 17, are required on a weaving machine to weave a fabric such as denim and are detailed as follows:

- Shedding

  Shedding is the separation of the warp yarn sheet created by some harnesses lifting yarns upward and the remaining harnesses staying in a down position. Therefore, an opening (weave shed) is formed, providing a path for the filling yarns to follow. Cam shedding methods (also know as tappet) are used for simple fabric designs, while dobbies can weave small patterns into the fabric and jacquard systems with their ability to control each warp end are used to weave complex designs. Generally, the more harnesses that are employed on a given machine, the more complex the design. Most denim fabrics are woven on machines using cam shedding. Weaving machines running 3/1 and 2/2 denim fabrics will use four or eight harnesses for the ground weave, and in some cases, two additional harnesses for the selvage, if needed. Machines running 2/1 denim fabrics use three or six harnesses for the ground weave and can use two additional harnesses for the selvage, if required. The shape and profile of the cam determines the lifting motion of the connected harness. There is an individual cam controlling each harness on the weaving machine, while dobby looms use lifting jacks to control each harness and jacquard looms use a jacquard head and cord to control each warp end separately.

- Filling Insertion

  The filling yarn is inserted through the weave shed by various methods. The oldest method, shuttle weaving, has been replaced to a large degree by methods using projectiles, rapiers, and air. Most denim fabrics are woven using projectile filling insertion or air jet filling insertion. The fastest method, air jet, can insert the yarn at a rate of 1400-2400 meters per minute. Most air jet machines weaving denim run at speeds of 600 to 900 picks per minute. Many machines today have pick-and-pick capability, meaning two filling yarn packages are available. Alternating the picks from different yarn packages helps to break up any repeating yarn pattern defects in a given package and decreases the yarn withdrawal rate from each package.

- Beat-up

  As mentioned previously, the warp yarns pass through a comb-like device called the reed. The reed recedes away from the newly formed fabric during filling insertion and moves forward towards the fabric after pick insertion. This forward motion “beats” each inserted pick into the fabric body at the fell-of-the-cloth (Figure 16).

- Warp Let-off

  The let-off device controls the rate the loom beam feeds the warp yarn into the machine. Tension sensing devices signal the let-off when more yarn is needed to maintain consistent warp yarn tension.

- Fabric Take-up

  This mechanism controls the rate of removing the fabric from the weaving machine. The faster the rate of take-up, the fewer the picks per inch inserted into the fabric. The slower the rate of take-up, the more the picks per inch inserted into the fabric. The relationship between the let-off and take-up speeds determines the picks per inch in the fabric.

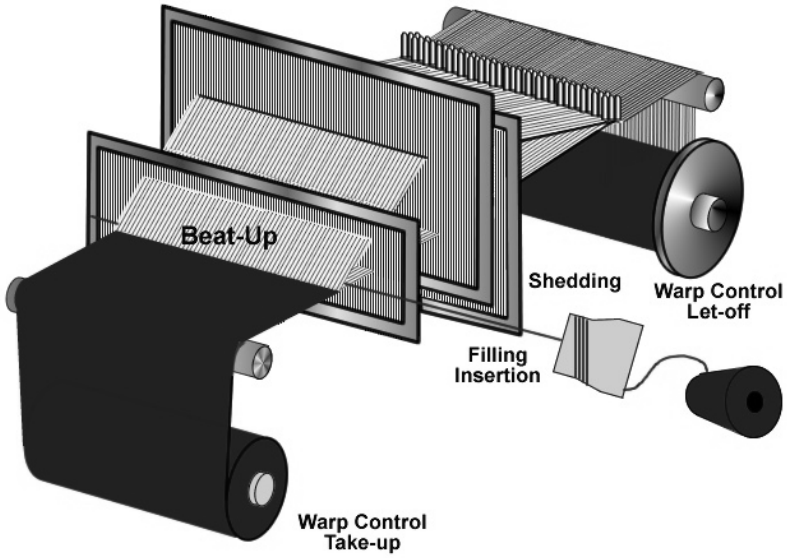


Figure 17. Basic Weaving Motions

Typical Denim Constructions, Weaves, and Weights

The classical construction of a bottom weight 14.5-ounce denim is 60-64 warp yarns per inch and 38-42 filling yarns per inch. The number of warp yarns per inch is sometimes referred to as the fabric sley. The weight is influenced by the size of the yarn used, the fabric weave design, and the fabric tightness. Also influencing the fabric weight is the amount of size left on the finished fabric. Other denim fabrics and denim "look-a-likes" may vary in construction from 52 to 70 warp yarns per inch and from 36 to 52 picks per inch. As a rule, denim is woven as 3/1 twill, 2/1 twill, 3/1 broken twill, or 2/2 broken twill. The weights of these finished fabrics can vary between 3.5 and 16.5 ounces per square yard. The weight of the fabric usually determines what the final garment application will be:

- 3.5-8.0 ounces per square yard – blouses, tops, shirts, and top of bed fabrics
- 8.0-16.5 ounces per square yard – trousers, jeans, jackets, and upholstery

Numerical notations for different denim designs, such as 3/1, denote what each warp yarn is doing relative to the filling yarns that it is interlacing with. In this case, each warp yarn is going "over" three picks and then "under" one pick. This would be verbally stated as "3 by 1" twill or "3 by 1" denim. At the next end, moving to the right, the same sequence is repeated but advanced up one pick. This advancing upward sequence continues, giving the characteristic twill line. In this case, the twill line is rising to the right, and the fabric is classified as a right-hand twill weave. If the twill line is made to rise to the left, then the design is left-hand twill. Broken twills are designed by breaking up the twill line at different intervals thus keeping it from being in a straight line.

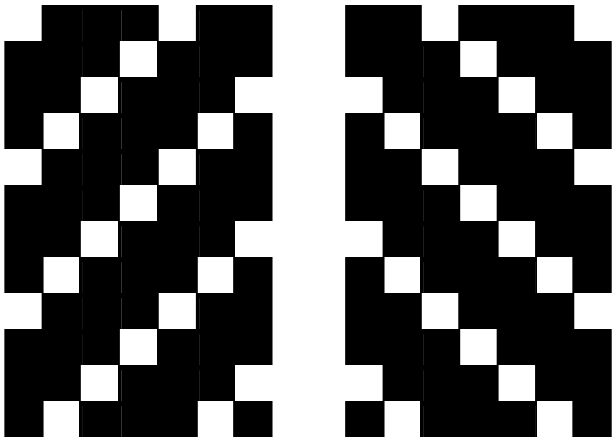


Figure 18. Diagram of 3/1 Right and Left Hand Twills

Yarn Twist Direction and Twill Line Direction

For a more pronounced twill line in a denim fabric, the direction of twist in the warp yarn should be opposite to the twill direction in the fabric. For example, if "Z" twisted yarn in Figure 19 is woven into a right-hand twill (Figure 18), the twill line is less pronounced. If "S" twisted yarn is woven into the same fabric, then the twill line is more pronounced. It must be remembered that only Z-twist yarns are formed in open-end yarns, while ring-spun yarns have either Z or S. For that reason, open-end yarn can be used in left-hand twills when a more pronounced twill line is desirable. Having the twist direction opposite from the twill line direction also tends to make the fabric hand a little softer.

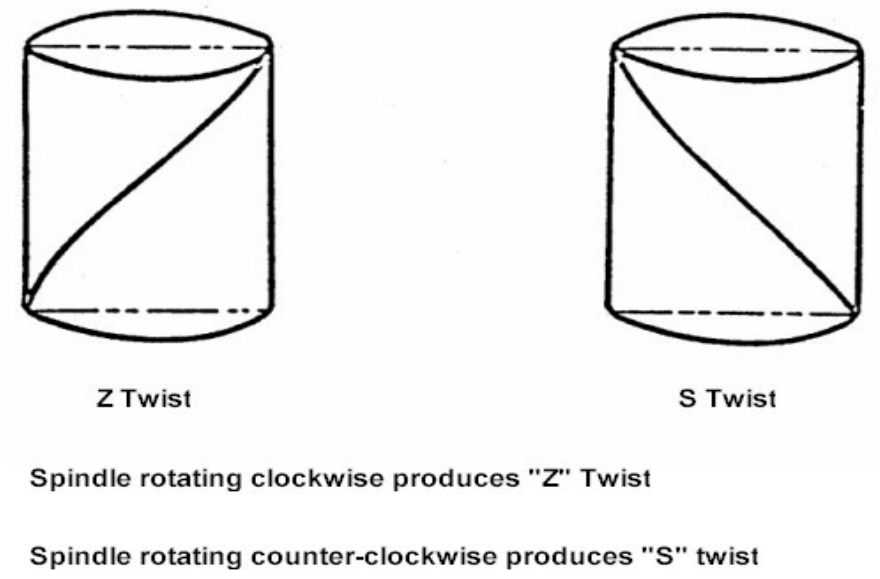


Figure 19. Z and S Twist Directions

Non-conventional Denim Fabric Constructions

Indigo-dyed yarns have been woven in plain weaves known as chambray, oxfords, baskets, herringbones, bedford cords, and combinations of 3/1 and 1/3 twills. Jacquard designs and dobby weaves have also been incorporated into denim designs to produce new looks and textures. As fashion designers create new ideas, the fabric manufacturers have to follow the demands of marketing teams and market leaders.

FINISHING DENIM FABRICS AND GARMENTS

The finishing of denim fabrics and garments is covered in Cotton Incorporated's technical bulletin entitled "Finishing of Denim Fabrics and Garments."

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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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