TECHNICAL BULLETIN

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TRI 3011

WET PROCESSING OF

100% COTTON KNITTED FABRICS

INTRODUCTION

It is well established that knitted fabrics of all constructions and fiber blends are inherently more prone to shrinkage as compared to wovens. Because of the inability of a knitter to form a knitted fabric with no shrinkage, it is important for the dyer and finisher to make an effort to remove as much shrinkage from the product as possible. However, the ease with which a cotton knitted fabric is distorted during processing makes it especially difficult to deliver fabrics with no shrinkage. This bulletin will discuss in some detail the aspects of knitted fabric construction and wet processing and how they are related in terms of shrinkage.

The factors that influence the level of dimensional stability can be summarized as follows:

- knitting parameters,
- processing tensions after knitting,
- relaxation techniques in finishing, and
- mechanical and chemical finishes.

Each of these areas can be broken down into fundamental aspects.

KNITTING

As published in literature, the amount of shrinkage for any given knit fabric is primarily dependent upon the product specifications and the knitting parameters used to meet those specifications. The predominant fabric specifications that determine the shrinkage of a knitted fabric are the weight, stitch counts, and width at which the fabric is sold for cut-and-sew. The knitter uses those specifications to establish another set of specifications for knitting. Whether or not these knitting specifications are achievable is determined by the knitting machinery available to the knitter.

The gauge of machinery (number of needles per circumference inch of the cylinder) determines the range of yarn counts that can be used. For a given knitting machine gauge, a restricted range of yarn counts can be knit. Finer yarns are more expensive compared to coarser counts. In order to maintain target weights in knitting finer yarns, the stitch length must be changed. The stitch length is the amount of yarn in one stitch repeat of the pattern. Heavier yarns when knit at the same stitch length as fine yarns will result in a heavier fabric. In essence, for any given yarn count, knitting a smaller loop results in a heavier, more stable fabric. Knitting a shorter loop also results in less length shrinkage, but higher width shrinkage for any specified finished width.

The width of a fabric is related to the number of needles in the cylinder and the stitch length. Each needle equals one wale. The longer or looser the stitch in each wale, the wider the fabric, and the lighter the weight. This is important because should there be a need to knit a fabric wider by increasing the stitch length, this will affect the weight and shrinkage.

In summary, the choice of yarn count, machine gauge, the number of needles in the cylinder, and the stitch length has a profound effect on shrinkage performance of a fabric.

PROCESSING TENSIONS

The knitting set-up is the single most important aspect in shrinkage. Yet, the tensions in wet processing and apparel manufacturing can render a knit unacceptable with respect to weight, width, and shrinkage.

In the purest form, linear tension in processing increases (stretches) the fabric length and decreases the width. Where does processing tension occur? Almost every time the fabric is moved over rolls and from one point in processing to another.

A. Inspection

During inspection, rolls should move freely to prevent excessive tension, and efforts should be exercised to prevent sudden starts and stops. Care should be taken to properly unwind and roll-up the fabric. If the fabric is to be rerolled, make sure excessive tension does not cause the width to "neck-in" or be reduced. The flat tube should be kept open to prevent wrinkles and folds so as not to cause permanent creasing of the goods.

B. Lot Pulldown (Batching)

This is another "dry" area where the fabric can be stretched in the length. It is important to keep speeds at start-up slow and to increase gradually. Do not allow the strand to rope tightly if plaited into a storage bin or truck. If the fabric is plaited, take care to prevent the plaited pile from tumbling or falling over. This will create extreme linear tensions when the fabrics are subsequently moved again. If the fabrics are batched into a wet-scray, all these precautions are even more important.

C. Jet Dyeing

Some machines move the fabric by a jet flow only, while others move the fabric with assistance from a driven reel. The use of driven reels is recommended because they help move the fabric at a lower tension. Care must be exercised to prevent scuffing or abrading of the fabric surface by the reels. The speed of the reel should be controlled so that the fabric does not slip on the reel.

Some dye machines use plaiters after the jet orifice and before the storage basket or chamber. The ratio of plaiter speed to fabric surface speed is important. If the side-to-side speed of the plaiter is too fast, the "roped" tube can be stretched and unnecessarily tightened. This will result in unwanted stretching and possible rope marks in the fabric.

Loading of the fabric into the jet should be done with a lower speed than the dyeing speed to allow proper wet out and packing of the fabric in the basket. The goal is to let the goods relax in the width and the loops in the fabric to reorient themselves without forming creases, folds, "crow's feet," and rope marks. It is recommended that the jet be charged with surfactant and lubricant before the fabric is loaded. After the fabric is fully loaded, the speed of the fabric can be optimized for uniform dyeing.

The basket or chamber in which the fabric is loaded and stored during the dyeing cycle must be of adequate dimensions. If the tube is too wide, then a plaiter must be adjusted to properly place the fabric in a side-to-side manner. This will optimize space and also prevent the fabric from falling upon itself thereby resulting in tangling. As stated before, wet fabric distorts more easily than dry fabric does.

The depth of the chamber is important because a chamber that is too deep will result in forward and backward tumbling of the fabric, which will result in increased tangling and severe linear tensions in the fabric.

Unloading from the jet after processing is also an important consideration in preventing subsequent stretching during the next stage of extraction and, if required, slitting. The same consideration used during jet processing to prevent stacked fabric from tumbling should also be exercised. If the stack has tumbled, then length tension is increased when pulling the fabric from under the pile resulting in additional stretching. Fabric of high moisture content adds weight, but assists in the unloading of the fabric from the jet dye machine.

Another problem with improper truck size and rapid unloading is the accumulation of undesired twist in the knitted tube. This results in severe roping when the fabric is moved at high speeds during the untwisting step and results in more stretch, lower production rates, and resultant holes at subsequent spreading. Extra time is then required for mending of the hole and for resewing the seam if the hole is cut out of the fabric.

The ideal situation would be to have an unloading device for use at each dyeing machine that would properly unload each jet in an organized manner with low tension.

The trucks used in plaiting the fabric either should be small enough to hold only one strand from the jet or should be compartmentalized to hold each strand separately. Holes in the truck should be on all sides as well as the bottom to allow for drainage. It is recommended that the trucks be made for even weight distribution to allow for easy rotation at the detwisting step. It is preferred to use trucks that hold only a single strand, which, in most cases, is a maximum of 450 pounds (200 kilograms).

D. Detwisting

Fabric, when unloaded into a dyehouse truck from a wet processing machine, has the potential to twist upon itself. This usually occurs because of the tumbling of the fabric stack in the truck. In most cases, single jersey fabrics constructed with a single yarn will torque during wet processing and accentuate the twisting. This twisted rope must be removed before the fabric is extracted. Detwisting is usually performed at the extractor or just before extraction and can be a source of high tension.

Spreading of the knitted tube usually follows detwisting. For most applications, ring spreaders are used. Excessive tension will occur if the twist is not removed prior to spreading, and in extreme cases, holes may be formed. The holes actually occur where the spreader rings burst through the side of the fabric. Scuffing or bruising of the fabric by the spreader is also a concern.

When balloon extractors are used, an adequate balloon will not form if the fabric twist is not reduced sufficiently. In this case, the fabric will be squeezed by the pad mangle while in the roped form. This results in distinct linear folds and creases, which are often permanent.

Detwisting can also result in excessive linear tension being placed on the length of the fabric. The operator and the detwisting mechanism, whether manual or automatic, need time to sense and remove this false twist. This means there must be some distance (length of fabric) between the spreader or mangle and the truck containing the fabric. The faster this process is operated the greater the distance required and the higher the tension.

For some machines, detwisting is performed vertically to save floor space. In this case, fabrics might be raised as high as fifteen to twenty feet (4.5 to 6.0 meters). If not previously extracted or if the truck containing the wet fabric has not had sufficient time for the water to drain, then the fabric is stretched lengthwise due to the force of gravity pulling down on the heavy, wet fabric as it is being lifted. This adds to the linear stretching of the knitted fabric.

On some extraction ranges and slitters, the fabric is squeezed in rope form by soft rollers, followed by either spreading for tubular processing or slitting for open width.

For both systems, a turntable is used to detwist the fabric once the twist and twist direction are determined. In this case, the cloth truck is placed on the turntable which turns clockwise or counterclockwise as needed. The larger the truck, especially if not properly filled by a plaiting system, and the faster the range runs, the greater the chance the fabric will be stretched as it is rapidly pulled from the truck. This is another source of linear tension.

It is recommended that detwisting be done at a speed slow enough to allow complete removal of the twist before the fabric reaches the spreaders or mangle. The best way to detwist would be off line from the extraction or slitting process.

Distances should be kept as short as possible between the turntable and spreading. As stated previously, the speed should be decreased for the shorter distance.

Fabric paths that are more horizontal are better in terms of linear stress. This obviously reduces the length of the strand available from the sensing device to corrective responses.

Fabric storage trucks should be low in height for stability and incorporate loading systems that uniformly place the fabric in the truck. Special care to prevent twisting is better than any method to remove it.

With respect to the use of ring spreaders, carefully match the spread width to the fabric being spread. Do not overspread because this can distort or even cause holes and can also bruise the fabric. Underspreading with ring spreaders can cause bunching or "pull back" which also distorts the fabric as well as resulting in bruise marks.

E. Extraction

The use of a mangle is the most common form of extraction. Tubular fabrics may be very sensitive to distinct edge lines being formed. The hardness or durometer of the rolls should be matched to the sensitivity of the fabric to prevent crease lines. Percentage levels of water extraction should be as high as possible but without causing any edge creasing or surface bruising. Overspreading the fabric, or spreading the fabric wider than the finish width, is a compensatory practice to reclaim width reduction and increase the courses per inch as a result of length tension. The amount of overspread is dependent on the fabric type and history of length tension but usually 10-20% is adequate.

Some extraction rolls are of special porous compositions that may allow a vacuum system to be employed for removing excess water. These types of rolls must be kept clean and free of contamination to prevent nonuniform extraction.

The width of the nip impression should be checked often and recorded to ensure uniform extraction from side-to-side. This is extremely important when the next step in processing is either heat setting or the curing of resins and reactant chemistry.

F. Slitting

For open width fabrics, the slitter can be a major source of linear stretch or distortion. This process usually includes detwisting, extraction, slitting, opening, and plaiting. After extraction and detwisting, the fabrics are spread and slit with a rotary blade. The slit line (open wale lines deliberately formed in the fabric by removing needles or by knitting a special selvage) is read either by human eye or by a sensing device. Adequate detwisting prior to this process produces a straight cut and prevents frequent stops.

In order to open the fabric, either a ring spreader, a bar spreader, or a "bird cage" is used. Whenever the wet fabric touches these devices, linear tension results. The wetter the fabric, the greater the tension. The more the fabric touches the spreader, the greater the tension.

Driven bar spreaders or "bird cages" with rollers are used to reduce the tension. Coating the contact points with a low surface friction material such as Teflon® is also incorporated.

Immediately after slitting, fabrics are normally opened so that they can be uniformly plaited into a fabric truck. The use of helical scroll rolls to open the fabric is common. The fabric must be moved through this system by contact rollers that are driven. They must have a composite or "gripper" fabric covering the rolls to prevent slippage. In some cases, a low-pressure mangle is used to help move the fabric.

G. Padders for Chemical Application

In general, the finisher should be concerned with common problems encountered with any pad arrangement whether it is for wet-on-wet or wet-on-dry applications. The first concern is that the number of guide rollers or "change of direction" rollers should be kept to a minimum.

These rollers should be driven at the same speed as the extraction rollers. Scroll rolls should only be aggressive enough to open the fabric without stretching. Where tubular fabrics are ballooned, the amount of ballooning should be sufficient to open the tube of fabric without stretching the length or causing stitch deformation.

Immersion rolls used to submerge the fabric into the finish solution should be driven if possible, but certainly be engineered to turn freely. The angle of wrap should be at least 90° to ensure the best grip when the roll is turned by the moving fabric.

H. Open Width Tenter Frame

Once the fabric leaves the nip of the rolls, the linear speed of the fabric must be equal to the same speed as the overfeed rolls on the tenter frame. This is usually accomplished by the use of a slack loop compensator that is mechanically or automatically adjusted.

Mechanical methods make use of a roller which takes up the slack if the padder runs faster than the tenter. As the roller drops when taking up the slack, the padder slows down. If the roller is pulled up because the padder is running slower than the tenter frame, then the padder speeds up. The compensator roll is turned by the moving fabric and should offer little or no resistance to the movement of the fabric, otherwise stretching will occur.

Sonic or optical sensing methods maintain a slack loop by controlling the upper and lower limits of the fabric loop. The speed of the padder is increased if the slack loop gets too short and decreases if the loop gets too long.

On tenter frame entry systems, the fabric passes over special rolls that perform different tasks. Scroll rolls are used to keep the fabric open. Other rollers are used to correct for bias or skew. Usually there is at least one overfeed roll. Other rolls are simply used for changing the direction of the fabric. Whenever possible, these rolls must be driven to prevent the stretching of the fabric. Scroll rolls are usually driven in the opposite direction that the fabric is moving; therefore, the angle of wrap must be kept to a minimum. In general, the more rolls encountered by the fabric, the more tension.

When the fabric leaves the last overfeed roll, the edge locators sense the edges of the fabric, and the fabric is placed on the pins with a pin wheel. Decurlers for the edges are also used. The key to shrinkage reduction at the tenter is to prevent stretching the fabric prior to placing it on the pins. The fabric must be placed onto the pins with overfeed. The overfeed roll provides the extra fabric to the pins, but the pinwheel actually places the fabric onto the pins. The better systems make use of a pinning apron. This apron is a continuously moving belt that ensures little or no drag on the fabric. The pinwheel rests upon the apron with the fabric trapped between the two. This allows for a positive grip on the fabric and guarantees a consistent amount of overfeed as the fabric is placed onto the pins.

Before entering the tenter frame, the fabric should be supported by a center cord that runs between the overfeed roll and the oven. This cord should be driven at the same speed as the tenter rails.

The fabric is then brought to a predetermined width and passed through the tenter oven for drying and/or curing. The overfeed level should be maximized so that as the fabric exits the oven, the overfeed ripples have disappeared leaving only a slight sagging of the fabric across the pin rails. This indicates the proper relationship between the amount of overfeed with the required width of the fabric.

The proper amount of overfeed is of course dependent on many variables such as specified fabric yield (ounces per square yard, ounces per linear yard, etc.) and shrinkage requirements. However, general discussions would indicate that too much overfeed can lead to bowing of the pattern, unwanted width-wise folds in the finished fabric, and in some cases, the fabric can be blown off the pins. Spreading is also dependent on width specifications; however, too little spreading results in forward, backward, or "S" bowing. Too much spreading can lead to high width shrinkage and possibly the fabric being pulled off the pins.

The amount of airflow in the tenter frame is critical. The rate of drying and the level of shrinkage are related to the rate of air flow. The combinations of overfeed and the mechanical action of the air flow vibrating or shaking the fabric results in shrinkage. The most shrinking takes place during the time where the moisture content of the fabric is below critical moisture. For cotton fabrics this is in the range of 25-30% moisture. As the water evaporates and the fiber, yarn, and fabric collapse, the greatest shrinking occurs.

Finally, the take-up system of the tenter is a source of stretching the fabric. After the fabric is depinned by means of depinning wheels, it should be rolled onto a desired system such as a batcher for individual rolls, an “A” or “T” frame, or into a truck. At this point, every roll that comes in contact with the fabric must be driven as near the actual fabric speed as possible.

RELAXATION DRYERS

Perhaps one of the most significant advances made towards shrinkage reduction, especially for the finisher, is the relaxation or belt dryer. These units incorporate tensionless, mechanical action at production speeds to complete the drying of both open width and tubular knitted fabrics. In principle, the wet fabric is placed onto the open mesh belt in a relaxed form and is dried by forced hot air. The air flow is controlled for maximum drying efficiency with allowance for shrinkage. Because there is no width restriction, this is the direction that normally shrinks first. It is because of this that some width adjustment must be made after relaxation drying.

Overfeed during relaxation drying is just as important as overfeeding during drying on the tenter frame. Therefore, tensionless entry and controlled overfeed are important for consistent results. Fabric may be introduced to the dryer from a roll or fabric truck (typically, the fabric is plaited into a truck). Overfeed is achieved by the speed differential between the delivery roll and the belt.

The amount of overfeed should be adjusted so that the dried fabric would exit in a smooth or unrippled condition. Too much overfeed will result in the fabric folding upon itself and not completely drying in those areas. Higher length shrinkage will result when insufficient overfeed is used.

Some belts may have a vibrating mechanism that provides even more mechanical action. This will assist in the relaxation of stresses previously introduced; however, control of the tube or the belt may be lost. The belts are open construction (mesh) to allow for passage of the heated air. Depending upon the design of the dryer, air flow can be from one side or both sides of the fabric. In some cases, the fabric is passed between two belts spaced close together to restrict the side-to-side and upward movement in the dryer and to prevent stretching by the force of air. Dryer designs may also include various arrangements for fabric passage which can allow for the entrance and exit at opposite ends or the same end.

Both the entry and exit ends are potential sources for tension. Fabric should be pulled freely from the truck or roll, and speed differentials between rollers should not cause stretching. As the fabric exits, the plaiting device should not pull the fabric from the belt.

RESIN FINISHING

Resin finishing or crosslinking of cotton is one of the most prevalent chemical treatments given to cotton fabrics. Crosslinking occurs through reactions of polyfunctional reactants with hydroxyl groups of adjacent cellulose chains. Some of the benefits that result from this reaction are:

1. wrinkle recovery
2. fabric smoothness after laundering
3. dimensional stability
4. improved washfastness of some dyes
5. pilling resistance
6. ease of ironing
7. increased durability of finishes (softeners, repellents, embossing, etc.)

There are some disadvantages that must be balanced with the benefits in order to maintain performance. Some of those disadvantages when applying resins are:

1. reduction in strength (burst for knits)
2. reduction in abrasion resistance
3. discoloration or shade change for some dyes
4. reduced moisture regain
5. potential odors
6. sewing problems

The most widely used resin for today’s fabric is the reactant product or urea, glyoxal and formaldehyde, and its derivatives. Other finishing components usually incorporated in the bath are wetting agent, catalyst, and softeners. The wetting agent aids in saturating the fabric with the finish solution, and the catalyst promotes crosslinking. A wide range of softeners can be incorporated for improvements in hand and softness. The products of choice are listed below:

Product	Chemical Type
Resin	Dimethyol dihydroxyethylene urea
Catalyst	Magnesium chloride, hexahydrate
Wetting Agent	nonionic or anionic
Softener	Polyethylene, cationic or silicone, or a combination

The most common method of application is the immersion/pad technique, which applies the resin finish solution evenly across the width of the fabric. This can be done either open width or tubular. The amount of solution remaining on the fabric after padding is termed the wet pickup, which for knits is typically 80%. This determines the amount of resin/softener applied to the fabric.

Of critical importance is selecting the amount of resin which will give the properties of smoothness, color retention, improved surface after multiple launderings as well as shrinkage control but will not reduce the strength (burst) values below the required value. Trials should be conducted to determine the amount of resin needed for balanced properties. Controlling the degree of cure by time and temperature exposure is a practical method of achieving required burst values.

COMPACTION

Many textile manufacturers have, and still do, rely on compaction as a means of shrinkage control. Compaction is a method whereby the course loops are compressed upon themselves. Different machines incorporate a variety of techniques to accomplish this. There are basically two classifications of compaction: heated rolls and shoe units or belt shrinking units. Both methods rely on speed differential and their patented compaction zones to accomplish the compaction. Tubular and open-width systems are available. The fabric is steamed to add moisture and then introduced to the compacting zone. The compaction mechanism, along with heat and moisture, forces the length stitches (courses) to be compacted.

It is also possible to use the Sanforize™ unit as a compactor for knits (normally used for wovens). This machine uses an endless elastic belt that is stretched over rollers. While the belt is in this elongated stage, the fabric is introduced between the belt and a drum. The belt is then allowed to shrink, and with the aid of the drum, compresses the fabric. The drum is normally steam heated and the fabric passes through a vaporizing unit for moisture regain prior to compaction.

Tubular fabrics are introduced to the compactor at one to two inches (2.5 to 5.0 cm) below finished width. The fabric width is adjusted with spreader bars and overfeed rollers for stability. Open width fabrics may lose width since there is no width restriction. Therefore, open width fabrics are introduced at one to two inches (2.5-5.0 cm) over the desired finish width.

The type and amount of softener will influence the level of compaction and the stability after compaction. Cationic and polyethylene softeners are commonly used with few problems. Excessive amounts of silicone may prevent compaction or release compaction during the cut and sew operation. It is also possible to use compaction after resin finishing to reduce the initial amount of length shrinkage. Due to the heat associated with compaction, some additional curing may take place and bursting strength may be lowered.

RESEARCH AND TECHNICAL SERVICES

Cotton Incorporated is a research and promotion company representing cotton worldwide. Through research and technical services, our company has the capability to develop, evaluate, and then commercialize the latest technology to benefit cotton.

- Agricultural research leads to improved agronomic practices, pest control, and fiber variants with properties required by the most modern textile processes and consumer preferences. Ginning development provides efficient and effective machines for preservation of fiber characteristics. Cottonseed value is enhanced with biotechnology research to improve nutritional qualities and expand the animal food market.

- Research in fiber quality leads to improved fiber testing methodology and seasonal fiber analyses to bring better value both to growers and then mill customers.

- Computerized fiber management techniques result from in-depth fiber processing research.

- Product Development and Implementation operates programs leading to the commercialization of new finishes and improved energy and water-conserving dyeing and finishing systems. New cotton fabrics are engineered -- wovens, circular knits, warp knits, and nonwovens -- that meet today's standards for performance.

- Technology Implementation provides comprehensive and customized professional assistance to the cotton industry and its customers -- textile mills and manufacturers.

- A fiber-to-yarn pilot spinning center allows full exploration of alternative methods of producing yarn for various products from cotton with specific fiber profiles.

- The Company operates its own dyeing and finishing laboratory, knitting laboratory, and a laboratory for physical testing of yarn, fabric, and fiber properties including High Volume Instrument testing capable of measuring micronaire, staple length, strength, uniformity, color, and trash content.

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