Effect of Wet Processing on

Reference Dimensions

Introduction

The dimensions of the Reference State, i.e. the number of courses per unit length and wales per unit width, are determined by the average shape and size of the knitted loop. If the average shape and size of the knitted loop is changed then the dimensions of the fabric change accordingly.

There are several key variables in the production of a knitted fabric that can affect the shape and size of the knitted loop. These can be discussed under the following three headings

- Knitting Variables
- Wet Processing Variables
- Finishing Variables

Knitting Variables

The key variables in the production of the knitted fabric that have a direct effect on the Reference Dimensions are

- the average Stitch Length
- the average Yarn Quality
- the average Yarn Count

The effect of these variables has been discussed and illustrated in the earlier papers on the Control of Quality in Knitting and will not be repeated here.

In this session we will concentrate on the influence of the operations of wet processing and final finishing on the Reference Dimensions.

Wet Processing Variables

During wet processing the Reference Dimensions are altered significantly compared to those in the grey fabric. This is because the operations of bleaching and dyeing affect the length, weight and physical characteristics of the component yarns.

The knitted loop is formed by the yarn, therefore changes in the length, weight and physical characteristics of the yarn affect the length, weight and physical characteristics (shape) of the knitted loop. Since the dimensions (length, width and weight) of the finished fabric are simply a reflection of the length, weight, shape and number of knitted loops within the fabric, it is not surprising that the dimensions of the finished fabric are different from those in the grey fabric.

The amounts by which the length, weight and shape of the loop are altered can be different for different process routes and different fabric types and are influenced by several key variables in the wet processing operations, namely

- the severity of the fabric preparation treatment, e.g. scouring, bleaching, mercerising
- the depth of shade to which the fabric is dyed
- the length tensions generated in the fabric during the bleaching and dyeing operations
- the amount of aggressive agitation to which the fabric is subjected
- the length of the processing cycle

Effect of Wet Processing

Wet Processing has three basic influences on the dimensions of the Reference State. It can cause changes in

- yarn weight
- yarn length
- loop shape

Effect on Yarn Weight

During preparation, bleaching and dyeing of a fabric the yarn changes weight.

- It loses weight due to the removal of natural or accumulated impurities, pigments, contaminants and fibre,
- It gains weight due to the permanent fixation of dyestuffs and chemicals.

Weight Loss

The amount of weight lost during wet processing will be heavily influenced by the yarn type and quality and the relative severity of the preparation process.

For example, a carded yarn spun from low grade short fibre to a relatively low twist factor will lose more weight through fibre loss than a combed yarn spun from high quality long fibres to a relatively high twist factor.

Similarly, a fabric subjected to a full scour and bleaching procedure will lose relatively more weight through the more complete removal of impurities etc. than one subjected to a simple wash/scour. The relative severity of the two processes (time, temperature, pH) may also contribute to the effective fibre loss.

Guideline

- Cumulative weight losses (for most yarn types) due to removal of impurities and fibre during a full standard bleach are normally between -4 to -6%

Weight Gain

The amount of weight, which can be gained through the addition of dyestuff and chemicals, also depends on the nature of the processing conditions, e.g. the chemical additives (lubricants, softeners etc.), the required depth of shade, and the amount of dyestuff which remains in the fibres/yarn after final wash off.

For example, a fabric dyed to a white or pale shade will gain less weight through dyestuff add-on than a fabric dyed to a deep shade, where the relatively large quantities of dyestuff which react with or become lodged in the fibres may largely compensate for any loss of weight caused by the removal of impurities and fibre.

Guideline

- maximum weight gain due to dyestuff addition is unlikely to exceed +5%

Net Weight Change %

The Net Weight Change in processing is the result of losses in preparation and gains due to dyeing and is affected by the nature and severity of the fabric preparation, the length of the processing cycle and the depth of shade and the quality of the yarn and the fibre from which it is spun. Unless significantly large quantities of chemicals are applied, the result is usually a loss in weight of the fabric.

STARFISH accounts for the influence of wet processing on the net change in yarn weight through the Standard Depth of Shade options.

White	-5.5
Pastel	-5.0
Light	-4.5
Medium	-4.0
Medium+	-3.5
Deep	-3.0
Heavy	-2.5
Full	-2.0

The values that have been used to describe the effective changes in yarn weight are average values derived from a thorough analysis of all the data so far collected. They are based on a large number of measurements on a wide variety of fabrics and processes and therefore provide a reasonable indication of the average changes in yarn weight that might be experienced in normal production. In most situations they will provide a good first approximation when making predictions for the finished fabric. However precise calculations can only be made by making the appropriate measurements on a representative number of typical fabrics processed under standard conditions in each mill. Consequently, these measurements should be carried out in each individual mill as part of a process calibration exercise.

Effect on Stitch Length

Fabric preparation and dyeing causes the yarn to shrink. This reduces the length of yarn in each loop making it smaller. A smaller loop occupies less space in the fabric so that the total number of loops per unit area is increased. The more loops per unit area the heavier the fabric.

The amount of shrinkage that takes place in the yarn depends on the yarn quality and can be influenced by the yarn type and construction and the amount of twist. For most yarns which have so far been examined (singles, twofold; carded, combed; ring, rotor), however, the amount by which cotton yarn shrinks in standard processing appears to be relatively small.

Guideline

- average yarn shrinkage in standard processing is usually between 1 - 2%.

If the fabric is subjected to severe chemical treatments such as mercerising, however, the amount by which the yarn will shrink can be substantially larger. In addition, the amount of shrinkage will depend on the conditions of the mercerising process (concentration, temperature, time, tension etc.).

Guideline

- average yarn shrinkage in open width mercerising is usually between 2 and 4%, whereas in tubular mercerising this can be increased to as much as 8%.

Yarns that have been mercerised prior to knitting tend to react in a similar way to unmercerised yarns; i.e. they shrink by small amounts in standard processing but may shrink by large amounts if the fabric is subsequently piece mercerised.

Effect on Yarn Count

Changes in the yarn weight (net weight change) and the yarn length (shrinkage) result in a net change in the yarn weight per unit length (yarn count). Changes in the yarn count affect the reference dimensions of the fabric.

Most often changes in yarn weight and length are taking place simultaneously during the course of the wet processing sequence. Therefore, the net effect on yarn count in any individual finished fabric ultimately depends both on the yarn type and quality, the nature and severity of the wet processing and the depth of shade.

Guideline

- The average changes in yarn tex count values that have been found to apply during standard processing are given in the following list.

White/Pale	-4	to	-3%
Medium	-2	to	-1%
Medium/Deep	-1	to	0%
Deep		no change	

When a cotton fabric is subjected to chemical modification, as in the case of mercerising, however, the net effect on yarn count will be different from those found after standard processing. In addition, the size of the changes will be sensitive to the conditions of the mercerising treatment.

Mercerising usually causes greater changes in yarn count compared to standard wet processing treatments. This is because mercerising can cause the yarn to shrink by large amounts, which results in an increase in yarn weight per unit length. In addition, mercerising can improve the accessibility of the fibres to dyestuff, which can mean that more dyestuff becomes fixed to the fibre thus also increasing the effective yarn weight.

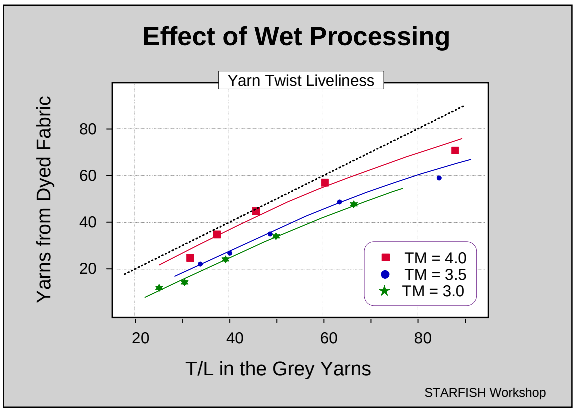
Guideline

- For fabrics which have been subjected to a mercerising pre-treatment therefore, different guide-lines are required, e.g.

	open mercerising			**tubular mercerising**		
White, Pale	-3	to	-1%	+1	to	+3%
Medium	-1	to	0%	+3	to	+5%
Medium Deep	+1	to	+3%	+6	to	+8%
Deep	+3	to	+5%	+8	to	+10%

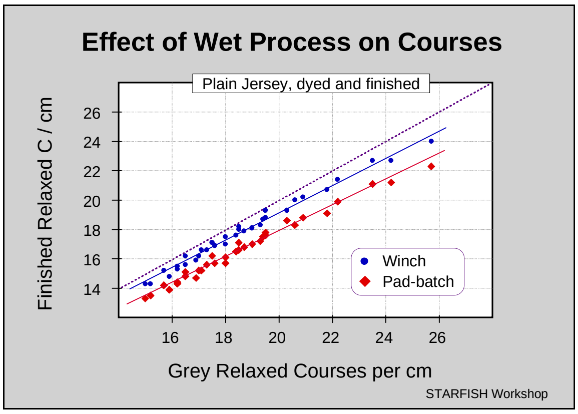
Effect on Loop Shape

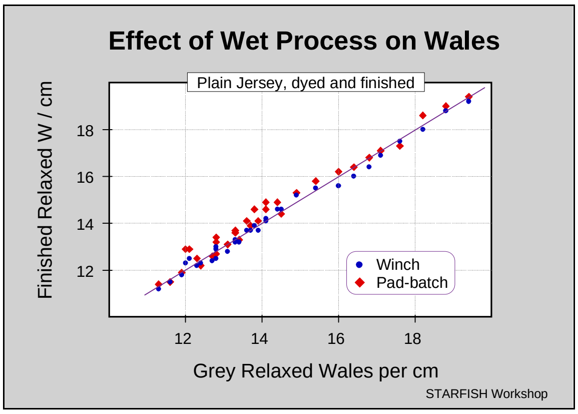
During preparation, bleaching and dyeing the physical characteristics of the yarn are altered. Changes, which can take place in the physical characteristics of the yarn, tend to work in opposing senses on the fabric dimensions. Depending on the design of the preparation and dyeing equipment and the length and severity of the wet processing operations, the relative bulk, stiffness and twist liveliness of the yarn are altered by varying degrees.

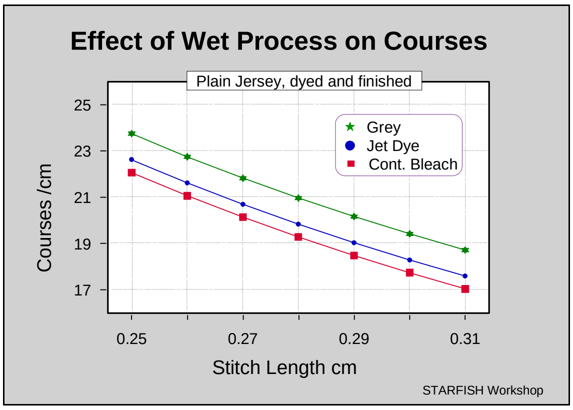


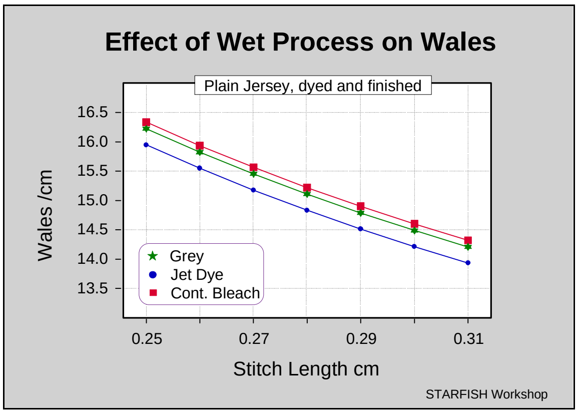
Most often wet processing causes an increase in the bulk of the yarn, and a reduction in the twist liveliness. This tends to increase the space that the loop requires in the width direction which can lead to a decrease in the number of wales per unit width and an increase in the number of courses per unit length. As a result, the fabric can become wider and shorter.

The length tensions that are imposed on the fabric during wet processing operations tend to permanently change the shape of the loop so that it occupies more space in the length direction and less in the width. This tends to decrease the number of courses per unit length and increase the number of wales per unit width, which has the effect of making the fabric longer and narrower.









The net result is that the shape, which the loop will obtain in the Reference State, is permanently altered by the Wet Processing. This is reflected in the Course / Wale Ratio.

Most often the Reference Dimensions of the finished fabric will be significantly longer and slightly narrower than those of the corresponding grey fabric. The actual length and width depend on the nature and severity of the particular wet process being used.

Effect of Machine Type

Knitted fabrics can be prepared and dyed either in open-width or in tubular form. The type of machine, the machine design and the running conditions can all have an influence on the changes that occur in the Reference Dimensions of the dyed and fully finished fabric.

Because the STARFISH Database is comprised almost exclusively of measurements made on fabrics that were prepared and dyed under commercial conditions, there are very few data which relate to the effects of systematic variation of processing conditions within and between Machine Types, on a given fabric construction. Therefore, it is not possible to be unequivocal about the effects of Machine Type on Reference Dimensions.

From the data that are available, and from comparisons of the results on similar fabrics processed on different Machine Types, a few general conclusions may be drawn. It would appear that there are three major variables involved:

- The length tension on the fabric.
- The presence of aggressive agitation.
- The time required for the wet processing.

Length Tension

In general, the larger the processing tensions, the longer will be the fabric after the wet process and the fewer the number of courses per cm in the Reference State.

In Winch and Jet machines for example, length tension is expected to be affected by; the height of lift and the drag on the fabric during lifting; fabric weight per unit area; fabric running speed; machine loading (weight of fabric in a batch) and contacts with any guidance systems.
Continuous Processes tend to generate higher running tensions than winches, but there are low-tension Continuous Processes and high-tension Winch and Jet machines.

Aggressive Agitation

Aggressive agitation means forces which tend to disrupt the yarn structure and cause a change in the bulk, or specific volume of the yarn. They can be the result of high-speed impingement of liquors on the fabric, or they may be developed whenever the fabric experiences a large deceleration.

In a Winch machine, and especially in Pad-Batch processing these types of forces are small or absent. This is why Pad-batch processed fabrics present the cleanest surface appearance.

In a Jet machine, there are at least two possible sources of such agitation forces. One is the jet itself. For a similar bleach and dye cycle, high pressure jets seem to yield fabric that is wider and thicker than winches or low-pressure jets, implying that the yarn has been made bulkier by the high-pressure jet. Such fabrics also show a more disturbed surface appearance.

A second source could be the deceleration caused in the fabric by being ejected from the tube below the jet and striking the back slider surface, but there are no hard data to support this hypothesis. The deceleration and the liquor impingement forces are experienced with every cycle around the machine. In Continuous processes there are only few such decelerations, and the fabric experiences each only once.

Processing Time

A longer total processing time gives scope for both of the above two effects, but especially the agitation effects, to proceed further. Presumably, the effect of high length tension must have a limit, which could be reached even in a relatively short processing time.

Disruption of the yarn structure must also have a limit but can be imagined to proceed at a slower rate, so that the effect of time could be more significant. In any event, there are data, which show that time is an important factor in both Jet and Winch machines - long processing cycles give a greater degree of fabric disturbance.

Note: Some fabric types and constructions seem to be more sensitive to these effects than others. Highest sensitivity seems to be shown by Interlock fabrics, which can even develop pilling during long dye cycles. Tightly knitted constructions are expected to be less sensitive than relatively loose constructions. Combed yarns are expected to be less sensitive than Carded yarns, Rotor Spun yarns less sensitive than Ring Spun yarns, and high-twist yarns less sensitive than low-twist. There is some evidence to suggest that, in a Fleece fabric, the face yarn is less sensitive than the inlay yarn.

Effect of Wet Processing Summary

In general terms, the operations of preparation, bleaching and dyeing affect the Reference Dimensions of the Finished Fabric relative to those in the Grey Fabric because

- The Loop Length is reduced due to yarn shrinkage.
- The Loop Weight is altered due to the removal of impurities, and the fixation of chemicals and dyestuffs.
- The Loop Shape is altered due to the changes that are brought about in the physical characteristics of the component yarns.

In addition, the relative size of the effects depends on the type of equipment, the processing conditions and also the fabric type.

These are the fundamental reasons why it is impossible to accurately predict what will be the final performance and dimensions of a dyed and finished fabric from measurements made on the grey fabric alone.

STARFISH has been designed and built specifically to allow for the influence of the Wet Processing operations to be taken into account when developing fabric specifications. This is achieved by means of the Standard Wet Process and Standard Depth of Shade options.

The Standard Wet Process options take into account the various combinations of length tension and mechanical action that occur in different types of preparation and dyeing equipment, and calculate their effect on the relative length and width of the finished fabric.

The Standard Depth of Shade options take into account the yarn shrinkage and the net change in yarn weight per unit length that occur during the preparation and dyeing of the fabric, and calculate the Net Weight Change % in Processing.

In addition, the Calibration Facility provides

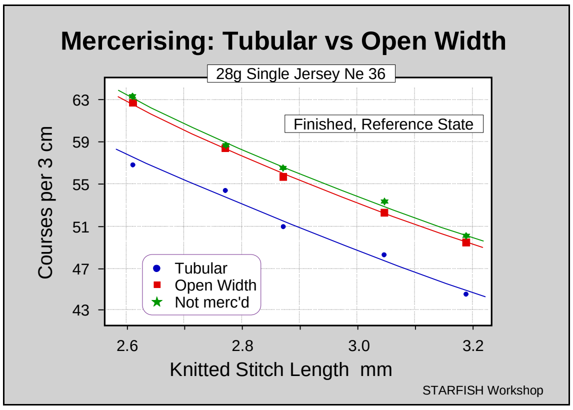
- Wider calibration ranges for all Fabric Types and Standard Wet Process options.
- Direct Calibration of the Reference Dimensions - courses, wales and weight.
- Indirect calibration via the As Delivered Dimensions.
- Calibration for Changes in Yarn Count and Stitch Length
- Calibration for Net Weight Change % in processing
- Display of both Reference and As Delivered fabric properties for each Fabric Quality as Calibration is carried out.

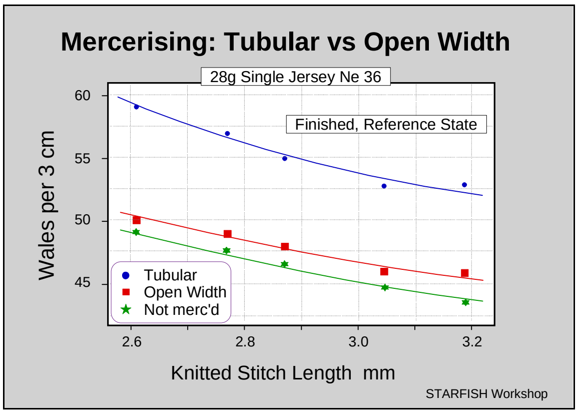
Effect of Mercerising

Since the tensions generated in standard processing can influence the Reference length of the fabric, and the conditions of processing can change the yarn characteristics thus influencing the Reference width, then one might expect that a relatively drastic process such as mercerising could have relatively large effects.

Mercerising strength caustic soda solutions cause an extremely high degree of swelling and shrinkage in cotton fibres and yarns. If the fibres are allowed to swell and to shrink, then they become extremely sensitive to tension. The range of swelling and tension conditions provided by different types of mercerising machinery and processes (or even by different conditions on the same machine) is very wide so that quite wide-ranging effects can result. Thus, the Reference dimensions of mercerised fabrics can be quite sensitive to the precise conditions employed.

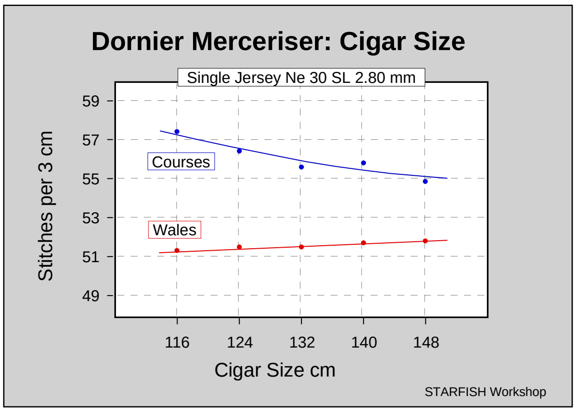
As described earlier, the length and the effective weight of the yarn can be altered by relatively large amounts due to mercerising. These changes automatically alter the Reference dimensions relative to the grey fabric for no other reason than that the fabric is much tighter in construction - as if it had been knitted from a heavier yarn and from a shorter stitch length. As in the case of standard processing, however, the changes in loop shape (course/wale ratio) cannot be fully explained simply from the changes in yarn count and stitch length alone.





The effect of different mercerising conditions can be most easily demonstrated by comparing the results obtained from fabrics mercerised through an open width mercerising route, where the fabrics were restricted in the length and width directions, compared to those obtained from similar fabrics mercerised in a tubular merceriser, with little or no restriction in the width direction during the mercerising process. The tubular mercerised fabrics have more wales (are narrower) and fewer courses (are longer) than the equivalent fabrics open width mercerised

Furthermore, within a given merceriser, the actual running conditions can also influence the Reference dimensions of the fabric.



In a trial that was carried out on a Dornier machine, identical pieces of rib and single jersey fabric were processed through the machine using different width settings for the cigar (stretching frame).

An increase in the width of the cigar had only a small effect on the Reference wales but caused a significant reduction in the Reference courses.

Finishing Variables

Effect of Resin Finishing

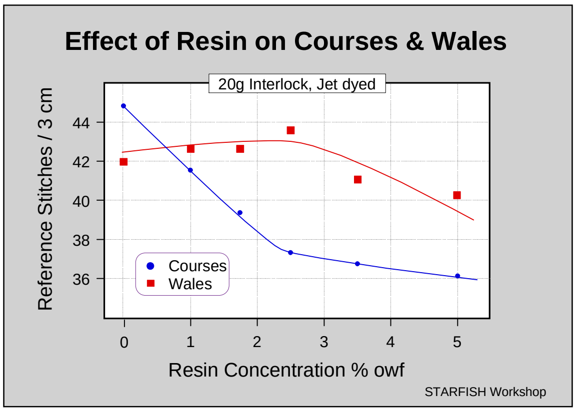
In contrast to fabrics that are produced wholly from synthetic fibres, the dimensions of a cotton fabric cannot be fixed simply by the application of heat (heat setting). For cotton processors a roughly similar effect can be achieved by the application of crosslinking chemicals. Resin finishing (crosslinking) is often advocated as a panacea for the problems of shrinkage and spirality in cotton knitgoods. This is not necessarily the case. Improvements in fabric stability, spirality and appearance retention can certainly be achieved, but there are also significant disadvantages to the system, e.g. loss of strength and abrasion resistance.

The main reason why the application of a resin finish is seen to reduce the potential shrinkage of the fabric is because the Reference State dimensions of the fabric are altered.

Generally speaking the application of a resin finish has the effect of "setting" the dimensions of the fabric in a more open state compared to if it had not been crosslinked. The effect is probably due to a reduction in the twist liveliness of the yarn and the amount by which the fibres will swell in water. Thus, if two identical fabrics were finished to the same dimensions, the fabric which had been crosslinked would have less potential shrinkage (because the reference dimensions had been altered) than the un-crosslinked equivalent.

The amount by which the Reference dimensions of a fabric are altered depends mainly on the conditions of application such as concentration of crosslinking and other chemicals, wet pick-up, evenness of distribution, drying and curing temperature, etc.

Some of these effects can be illustrated using the results obtained from a series of carefully controlled trials carried out on a wide range of interlock and rib fabrics. In these trials the concentration of crosslinking chemicals (% solids on weight of fabric) was varied while the conditions of application and drying (curing) were kept constant.



With the interlock construction, the most noticeable effects were in the length direction. The number of courses in the Reference State was reduced in line with the increase in the level of crosslinking chemicals applied.

In the width direction the effects were not as clear-cut. At low resin concentrations, the wale density was scarcely affected and may even have been slightly increased (narrower fabric) but at higher concentrations the wale density was decreased (wider fabric).

The net effect on the stitch density is to reduce the number of stitches per unit area in the Reference State. This in consequence reduces the weight of the fabric. Therefore, resin finished fabric will have improved shrinkage performance (particularly in the length direction) compared to un-crosslinked fabric finished to the same dimensions. Conversely fabrics finished with the same level of shrinkage performance, as the un-crosslinked fabric will be lighter in weight.

On single jersey fabrics the other main reason (apart from shrinkage control) why resin finishing is most often carried out, is in an attempt to improve the levels of spirality in the fabric.

However, in case studies that have examined the effects of resin finishing treatments on the dimensions of single jersey fabrics the effect on spirality was found to be small. Resin finishing reduces the reference courses, wales and weight compared to the un-crosslinked controls, but the reduction in spirality due to the crosslinking procedure was often not much greater than the reduction which had already been brought about by the prior wet processing (dyeing) treatments.

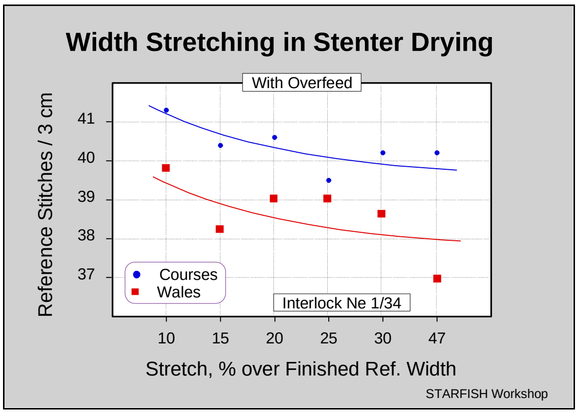
Effect of Resin Finishing on Spirality

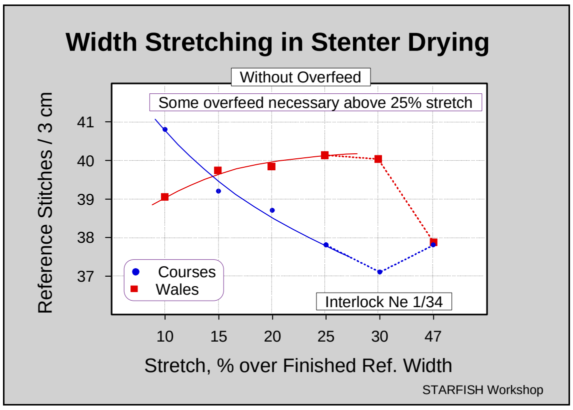
Mill 1 : 28g single jersey, Ne30, SL 2.72 mm		
	As Received	**Reference**
Grey	10.2	15.3
Dyed	3.3	8.8
Resin	2.5	8.4
Mill 2 : 24g single jersey, Ne 30, SL 2.80 mm		
	As Received	**Reference**
Grey	10.1	17.2
Dyed	8.3	12.7
Resin	3.6	9.2

Effect of Drying Conditions

As has already been discussed, the Reference dimensions of the fabric are affected mainly by the changes brought about in the shape of the loops due to the conditions of the wet processing. However, further changes can also take place during the deswelling or drying stage - especially if excessive tensions are applied during drying.

A small trial carried out on samples of interlock fabric examined the effect on reference courses and wales of applying increasing levels of width extension to the fabric during stenter drying. Samples were processed both with and without length overfeed.





It was found that stretching the fabric from about 10% to 47% over finished reference width caused a small reduction in reference courses when the samples were dried with overfeed. This effect was much larger - especially at high levels of stretching - on the samples dried without overfeed.

A similar effect was noted in reference wales on the samples dried with overfeed. In the samples dried without overfeed, however, the reference wales increased as the width stretch was increased.

We have also collected some further evidence from commercial case studies on single jersey fabrics that the conditions of drying or type of drying machine may have an effect on the reference dimensions, especially the reference wales. Although in these studies the observed changes were rather small, they were statistically significant.

Effect of Drying Machinery

24g single jersey, Ne 1/30, SL 2.80 mm

	Reference Dimensions		
Dyed only	**C/3cm**	**W/3cm**	**Wt gsm**
Winch / Kiefer	60.1	47.3	161
Winch / Stenter	60.4	46.4	157
Jet / Kiefer	60.5	46.3	153
Jet / Stenter	60.6	45.7	154
Dyed + Resin			
Winch / Kiefer	56.9	45.6	152
Winch / Stenter	57.8	45.0	152
Jet / Kiefer	57.6	45.5	151
Jet / Stenter	57.5	44.6	148

The additional influence of the drying procedure is one of the reasons why the results obtained by an individual mill may not correspond exactly to the average predictions obtained from the STARFISH average process routes. It is also one of the reasons for including the Calibration routines to enable these small influences to be taken into account.

Effect of Calendering and Compacting

The final dry (or semi-dry) finishing processes, after the main drying stage has been completed, have not been found to have any effect on the Reference dimensions. In many large-scale studies carried out during the collection of the data base, the Reference dimensions of identical fabrics have been compared after final finishing on different types of compactors and calenders. So far, no significant differences in the Reference dimensions have been identified - although the delivered dimensions (and hence the shrinkages) were usually quite different.