Introduction

The dimensions of the Reference State, i.e. the number of courses per unit length, the number of wales per unit width and the weight per unit area are determined by the average size, weight and shape of the knitted loop.

If the average size, weight and shape of the knitted loop is altered then the Reference Dimensions of the fabric are changed accordingly.

There are several key variables in the production of a knitted fabric that directly affect the size, weight and shape of the knitted loop. These are considered in the following topics.

- Effect of Yarn Quality Variables
- Effect of Knitting Variables
- Effect of Wet Processing Variables
- Effect of Finishing Variables

Effect of Yarn Quality Variables

The dimensions of the Reference State, i.e. the number of courses per unit length, the number of wales per unit width and the weight per unit area, are determined by the average size, weight and Shape of the knitted loop.

If the average size, weight or shape of the knitted loop is altered then the Reference Dimensions of the fabric change accordingly.

Several yarn quality characteristics can influence the size, weight and Shape of the knitted loop and therefore have a direct effect on the Reference Dimensions of the knitted fabric.

The most important are

- Average Yarn Count
- Yarn Type
- Twist Multiple
- Fibre Quality

The first two are the key variables that are directly allowed for by STARFISH. The influence of the yarn twist and fibre quality is for the time being taken account of indirectly through the yarn type and yarn count parameters.

For practical purposes, this is not too serious a disadvantage since only a narrow range of twist factors is actually used for knitting yarns and moreover the quality of fibre used tends to be related to the yarn type and the yarn count.

However, it is important for the knitter to understand and monitor the twist in his yarns and to ensure that the fibre quality stays more or less the same from lot-to-lot in order to ensure the consistency of his finished fabric.

Provided that the average Yarn Quality that is used is consistent then any discrepancy that may be observed between the STARFISH predictions and measurements made on actual production samples that can be attributed to differences in the average yarn quality can be allowed for by Calibration.

Yarn Count

The average Yarn Count used to produce a given fabric has a direct influence on the size and weight of the knitted loop.

A coarser (heavier) yarn knitted at the same average Stitch Length and finished to the same dimensions (course density and width) will produce a heavier fabric than if the same fabric had been produced from a finer (lighter) yarn.

In addition, the count of a yarn provides a reasonable approximation for its diameter. The diameter of the yarn affects its stiffness and the amount of space that a given length of yarn will occupy in a fabric. This influences the number of courses and wales that will be developed in the fabric in the Reference State.

A finer yarn will develop fewer courses per unit length and more wales per unit width when compared to a coarser yarn knitted at the same average stitch length.

If these two fabrics were to be finished to the same dimensions then not only would the weight of the finished fabric be different but the potential shrinkage in the fabric would be different also.

Therefore, it is important that for a given fabric style the average count of yarn is maintained consistently, from lot-to-lot and from spinner to spinner.

A difference in the average yarn count between yarn deliveries is probably one of the main sources of variation in the performance of finished fabrics.

Two-thread Fleece

The basic effect of Yarn Count on the Reference Dimensions is the same for Two-thread Fleece as for plain jersey constructions.

However, the density of both courses and especially wales is reduced compared to plain jersey due to the introduction of the inlay yarn. The heavier the inlay yarn, and the greater the difference between face and inlay yarn counts, the greater is the reduction in stitch density.

Yarn Type

There are two main spinning systems used for the production of yarns for weft knitting - Ring Spinning and Rotor Spinning. In both systems, yarn can be spun from either Carded or Combed fibre. The choice of which type of yarn (preparation and spinning system) to use depends primarily on the quality requirements (and price) of the end product.

The basic Fibre Quality, the type of fibre preparation and the spinning system used to produce a given Yarn Count all have a fundamental effect on the quality characteristics of the yarn that can be produced. This is most apparent when the appearance and softness of the finished fabric is considered.

What is perhaps less well known is that certain of the basic yarn characteristics, e.g. stiffness and Twist Liveliness, also affect the shape of the loop in the knitted fabric, and Loop Shape influences the Reference Dimensions. These basic yarn characteristics are influenced by the fibre quality, the spinning system and whether the yarn is singles or folded.

Carded vs. Combed

A fabric produced with Ring Yarn spun from Combed Fibre develops slightly more courses and more wales in the Reference State compared to an equivalent fabric knitted at the same Stitch Length and Yarn Count but produced with ring yarn spun from Carded Fibre.

This means that if both fabrics are delivered to the same finished dimensions (course density and width), then the fabric produced with the combed yarn will have slightly more potential shrinkage in both the length and width directions than that produced with the carded yarn.

Ring spun vs. Rotor spun

A fabric produced from open end Rotor Spun Yarn develops more courses and fewer wales in the Reference State compared to an equivalent fabric knitted at the same Stitch Length and Yarn Count but produced from Ring Spun Yarn.

This means that if both fabrics are delivered to the same finished dimensions (course density and width), then the fabric produced from the rotor spun yarn will have more potential length shrinkage and less potential width shrinkage than that produced from the ring spun yarn.

Single vs. Twofold

A fabric produced from Twofold Yarn develops fewer courses and fewer wales in the Reference State compared to an equivalent fabric knitted at the same Stitch Length and Yarn Count but produced from a singles yarn.

This means that if both fabrics are delivered to the same finished dimensions (course density and width) then the fabric produced from the singles yarn will have more potential shrinkage in both length and width than that produced from the twofold yarn.

In all cases the same finished fabric specifications cannot be applied to both fabrics

- If both fabrics must be delivered with the same finished weight and width then the shrinkage specification for the two fabrics must be different.
- If both fabrics must be delivered with the same shrinkage specification then the finished weight and width specifications must be different.

If the same finished fabric performance specifications of weight, width and shrinkage must be maintained then in each case either one or both of the fabrics must be re-engineered in the knitting mill, i.e. the knitting specifications (yarn count and / or stitch length) for the two fabrics must be altered.

Yarn Twist / Twist Liveliness

The amount of Twist put into a yarn during the spinning process depends on many factors. For example:

- the basic Fibre Quality, e.g. length and fineness of the fibres,
- the method of fibre preparation, e.g. Carded or Combed,
- the method of spinning , e.g. Ring Spun or Rotor Spun,
- the efficiency of the spinning process, e.g. machinery, production controls
- the properties required of the final yarn, e.g. count, strength,
- the end use for which it is required, e.g. weaving, knitting.

The actual level of twist inserted, together with the basic fibre quality and spinning system, influences such properties as yarn strength, bulk, Hairiness, stiffness and abrasion resistance. So far as the Reference Dimensions of the knitted fabric are concerned, however, perhaps the most important effect of these three spinning variables is their influence on the twist liveliness of the yarn.

Twist liveliness in yarns can be seen as the snarling and twisting of a yarn on itself when the ends of a hanging loop are brought slowly together. In knitted fabrics this phenomenon causes the loops to distort, twist and incline out of the plane of the fabric.

For yarns of similar quality (e.g. combed, ring spun) twist liveliness is directly related to the number of turns per unit length put into the yarn during spinning. The more turns per unit length the more twist lively the yarn.

In Single Jersey fabrics yarn twist liveliness is the main cause of fabric Spirality. In addition, however, yarn twist liveliness also has an effect on the density of courses and wales that will be developed in the fabric in the Reference State.

For example, two Ring Yarns, spun to the same Yarn Count but with a different number of turns per unit length, and knitted with the same Stitch Length will develop different course and wale densities in the Reference State. The yarns with more turns per unit length will develop more courses and wales than the yarns with fewer turns per unit length.

The same is also true for Rotor Spun Yarns. Yarns spun with a higher Twist Multiple will develop more courses and wales in the fabric in the Reference State than yarns spun with a lower twist multiple.

In rotor spinning, the method of twist insertion is quite different from that used in ring spinning. This also has an effect on the yarn twist liveliness. In the early days of rotor yarn, production twist levels were very high and single jersey fabrics knitted from them often developed higher levels of spirality than those knitted from ring spun yarns of equivalent count.

In modern rotor spun yarns the twist levels have been significantly reduced, although they are normally still higher than equivalent ring spun yarns. In addition, many modern rotor spun yarns produced for the knitting industry are now spun from longer, finer fibres. These two changes have resulted in a decrease in the yarn twist liveliness and consequently a reduction in the spirality that is developed in fabrics knitted from these types of yarns. Often the spirality, which will be developed in single jersey fabrics knitted from modern rotor spun yarns, will be lower compared to that which will be developed in fabrics knitted from equivalent ring spun yarns.

The average twist in the yarn must be maintained consistently between different deliveries and between different suppliers. Variation in average twist will increase the variation in Fabric Properties between individual finished fabric pieces.

Fibre Quality

The basic fibre properties - length, strength, Fineness, Maturity etc. have a direct influence on such yarn properties as strength and regularity, the amount of twist that needs to be inserted and the dyeing properties, as well as the type of yarn that can be spun.

In addition, recent research has begun to quantify the effect that the basic fibre properties can have on the Reference Dimensions of the knitted fabric.

A few years ago the International Textile Center in the USA carried out a series of trials that examined the influence of fibre variety, twist level and Rotor Spinning conditions on the Reference Dimensions of Interlock fabrics.

It was found that fabrics knitted from rotor yarn spun from Californian cotton developed fewer courses and more wales in the Reference State compared to similar fabrics (same Yarn Count and Stitch Length) produced from yarns spun from Texas cotton.

The differences were not large. Nevertheless, they implied that if a yarn which was normally made from this particular variety of Californian cotton were to be substituted for one made from the Texas cotton, and the finished fabric was delivered with exactly the same unit weight and width, then the length shrinkage would be about two percentage points greater and the width shrinkage would be about two percentage points less.

Another study investigated the influence of fibre Micronaire Value on Reference Dimensions. A set of OE rotor yarns were spun from a group of seven cottons with widely different Micronaire values, each spun to the same yarn count at three levels of twist, and all knitted into interlock fabrics with approximately the same stitch lengths.

The data did not conform strictly to our requirements since they referred only to grey fabrics. In addition the twist multiples were not identical for each cotton which contributed to the scatter in the data. However, the data did imply very strongly that a reduction in Micronaire Value of the raw fibre stock would result in an increase in the Reference Courses and a reduction in the Reference Wales. Over the range of Micronaire from 2.8 to 4.2, the changes in Courses and Wales were about 5% and 2% respectively.

These two sets of data together strongly suggest that the influence of the cotton fibre properties alone could easily amount to two percentage points of shrinkage, with length and width shrinkages moving in opposite directions for a given change in cotton

Among the world's Cotton Varieties and origins there are larger differences in basic fibre quality than the ones that were investigated here. Therefore, it is important that the average fibre quality in the yarn remains consistent from lot-to-lot and delivery-to-delivery in order to contain variation in the finished fabric.

Effect of Knitting Variables

Effect of Stitch Length

The knitted loop is the fundamental constructional unit of any knitted fabric and "Stitch Length" is the term used to describe the average length of yarn in a knitted loop.

Stitch length is calculated from the total length of yarn taken in by one feeder during one complete revolution of the knitting machine (course length), divided by the number of needles knitting.

Control of stitch length is the fundamental means for controlling the final dimensions, weight and performance of a fabric knitted from a given quality of yarn.

For a given yarn quality, the average stitch length determines the number of courses and wales which will be developed in a fabric in its Reference State of Relaxation. The course and wale densities determine the length, width and weight of the fabric.

The effect of stitch length on the Reference Dimensions can be summarised as follows:-

- The longer the stitch length the fewer courses per unit length; the shorter the stitch length the more courses per unit length.

Fewer courses means that the fabric is longer; more courses means that the fabric is shorter.

- The longer the stitch length the fewer wales per unit width; the shorter the stitch length the more wales per unit width.

Fewer wales means that the fabric is wider; more wales means that the fabric is narrower.

- Stitch density is the product of course density and wale density. The greater the stitch density the more stitches per unit area; the lower the stitch density the fewer stitches per unit area.

Fewer stitches means that the fabric is lighter; more stitches means that the fabric is heavier.

So far as the properties of the "as delivered" finished fabric are concerned, this means that if two pieces of fabric are knitted with the same yarn but with different stitch lengths then it is impossible for both fabric pieces to be delivered with exactly the same weight, width and length and width shrinkage values.

Stitch Length is the single most important variable in the production of a knitted fabric. If the average knitted stitch length is not correctly specified, accurately controlled and consistently maintained throughout the production run of a given Fabric Quality then the inevitable consequence will be variation in the finished Fabric Properties between different pieces.

Two-thread Fleece

The basic effect of Stitch Length on the Reference Dimensions is the same for Two-thread Fleece as for plain jersey constructions. That is a shorter stitch length will produce more courses and wales per unit length; a longer stitch length fewer courses and wales per unit length.

However, the density of both courses and especially wales is reduced compared to plain jersey due to the introduction of the inlay yarn. The heavier the inlay yarn, and the greater the difference between face and inlay yarn counts, the greater is the reduction in stitch density.

For a given combination of face and inlay yarns it is the stitch length of the face yarn that has the greatest effect on fabric dimensions. However, the length of the inlay yarn does have a significant effect on the fabric weight. Therefore correct specification, accurate measurement and effective control of both stitch lengths is essential.

Effect of Run-in Ratio

Run-in Ratio is used in STARFISH specifically for Crosstuck fabrics containing an all-knit course. It is the ratio obtained by dividing the length of the knit and tuck course by the length of the all-knit course.

- A run-in ratio greater than 1.0 means that the knit and tuck course is longer than the all-knit course.
- A run-in ratio less than 1.0 means that the knit and tuck course is shorter than the all-knit course.

The Run-in Ratio affects the fabric appearance and is often used by knitters to enhance the clarity of the small diamond pattern which is produced by the repeating pattern of knit and tuck loops in crosstuck constructions.

The Run-in Ratio also affects the Reference Dimensions of the fabric. The course and wale densities are affected primarily because the average stitch length is different between the different courses. The fabric weight is also affected, because the total length of yarn per unit area is different. The relative size of the effect on the courses, wales and weight depends on the fabric construction, i.e. the proportion of knit and tuck courses to all-knit courses.

In general terms, increasing the knit and tuck Stitch Length relative to the all-knit stitch length (run-in ratio greater than 1.0) has the effect of decreasing the Reference courses and wales, relative to a fabric produced with a run-in ratio of 1.0. Conversely decreasing the knit and tuck stitch length relative to the all-knit stitch length (run-in ratio less than 1.0) has the effect of increasing the courses and wales, relative to a fabric produced with a run-in ratio of 1.0.

In Single Crosstuck fabrics since the proportion of all-knit to knit and tuck courses is equal, the changes in course and wale density also result in a similar effect on the fabric weight. i.e. the fabric weight decreases at run in ratios greater than 1.0 and increases with run-in ratios less than 1.0.

In Six-thread Crosstuck fabrics the proportion of knit and tuck courses to all-knit courses is not equal. One third of the courses are all-knit courses and two-thirds are knit and tuck courses. This means that changes to the knit and tuck stitch length have a relatively greater effect on the total length of yarn per unit area in the fabric. Thus, although at run-in ratios greater than 1.0 the fabrics have lower course and wale densities, the fabric weight is actually increased, relative to fabrics produced with a run-in ratio of 1.0. Conversely at run-in ratios less than 1.0 the course and wale densities increase but the fabric weight is reduced relative to fabrics produced with a run-in ratio of 1.0.

These changes to the Reference Dimensions of the fabric mean that it is not possible to deliver the same fabric properties - weight, width and shrinkage values - in fabrics that have been knitted with dissimilar run-in ratios.

It is therefore essential that the Course Length of the knit and tuck course is measured and controlled as accurately as the all-knit course. If differences are allowed then the Reference Dimensions of the fabric will be affected. This in turn will have an influence on the balance of Properties that can be delivered in the finished fabric.

Important Note:

Although STARFISH can calculate the effect of run-in ratio on the finished fabric properties, it should be remembered that STARFISH predictions do not take account of the relative effects on the fabric appearance. It is important that fabric manufacturers establish the effect of changing the run-in ratio on the fabric appearance as well as the fabric dimensions in the context of their own production and processing conditions and the requirements of their customers.

Effect of Wet Processing Variables

During Wet Processing the Reference Dimensions are altered significantly, compared to those of 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 to the length, weight and physical characteristics of the yarn also 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 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.

For a given Knitting Quality, a change in the Finished Reference Dimensions means that the potential length and width shrinkage in the delivered fabric will not be the same if the fabric is delivered with the same finished weight and width. In other words, it is not possible to have exactly the same combination of weight, width and shrinkage in the finished delivered fabric with different Wet Processing routes.

In general terms, the operations of preparation 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 the fabric type.

These are the fundamental reasons why it is impossible to accurately predict what will be the final performance and dimensions of the 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.

Effect of Wet Processing 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 that have so far been examined (singles, twofold; carded, combed; ring, rotor) however, the amount by which cotton yarns shrink in standard processing appears to be relatively small, usually between 1 and 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.

Effect of Wet Processing on Yarn Weight

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

It loses weight due to the removal of natural impurities, pigments, contaminants and fibre, but it also gains weight due to the permanent fixation of dyestuff and chemicals.

Weight Loss

The Yarn Quality and the relative severity of the preparation process will heavily influence the amount of weight loss during wet processing.

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 or scour. The relative severity of the two processes (time, temperature, pH) may also contribute to the effective fibre loss.

For most cotton yarn types, cumulative weight losses due to the removal of impurities and fibre during a full bleach cycle are normally between -4% and -6%.

Weight Gain

The nature of the processing conditions also influences the amount of weight that can be gained during wet processing. The chemical additives included (lubricants, softeners etc), the required depth of shade and the amount of dyestuff that remains in the fibres/yarns after final wash off will all have an influence.

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. This is because in a deep dyed fabric the relatively large quantities of dyestuff that react with or become lodged in the fibres may largely compensate for any loss of weight caused by the removal of impurities and fibre.

However, the 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. It 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 quality of the fibre from which the yarn is spun. Unless significantly large quantities of chemical are applied, the result is usually a loss in weight of the fabric.

In STARFISH, the influence of wet processing on the net change in yarn weight is handled through the Standard Depth of Shade options.

The values that have been used to describe the effective changes in yarn weight are average values derived from a thorough analysis of the data so far collected. They are based on a large number of measurements on a wide variety of 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.

If more precise calculations are required then these can only be done by making the appropriate measurements on a representative number of typical fabrics processed under standard conditions in the mill. Each individual mill should make these measurements as part of a process calibration exercise.

Effect of Wet Processing 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 is dependent upon not only the Yarn Quality, but also the nature and severity of the Wet Processing and the required Depth of Shade.

The average changes in yarn tex count values that have been found to apply during standard wet processing are summarised below.

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.

Effect of Wet Processing on Loop Shape

During preparation 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. This 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.

On the other hand, 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 Wet Processing permanently alters the shape, which the loop will obtain in the Reference State. 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 depends on the nature and severity of the particular wet process being used.

Effect of Wet Processing Machinery

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 unit length 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 more bulky 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 Mercerising Variables

Fabric mercerising involves both swelling in caustic soda and stretching to enhance the lustre and to increase the colour yield.

In simple terms, piece mercerising may be considered as an extreme form of Wet Processing. The influence on the Reference Dimensions of the fabric is of the same type as that found in a Standard Wet Process, but the effects are usually more pronounced. The precise effects depend on the type of merceriser used, and the mercerising conditions employed e.g. concentration of chemicals, tensions, speed, time, temperature etc.

In general terms, piece mercerising affects the Reference Dimensions of the Mercerised and finished fabric relative to those of an unmercerised finished fabric because

- The Loop Length is reduced significantly due to additional yarn shrinkage.
- The Loop Weight may be increased significantly because of the increased affinity of the cotton fibre to dyestuffs
- the Loop Shape is altered significantly because of the increased sensitivity to the effects of tension.

In addition, the relative size of the effects depends on the type and design of the mercerising machine and the conditions of the mercerising procedure.

This means that fabrics that have been mercerised prior to dyeing cannot be finished to the same weight, width and shrinkage as equivalent fabrics that have not been piece mercerised.

Usually the mercerised fabrics have to be delivered significantly narrower to be able to achieve similar shrinkage values in the delivered finished fabrics. The weight of the mercerised fabric at the same levels of shrinkage will also be different.

Consequently, for a manufacturer to be able to deliver mercerised fabrics with similar Fabric Properties to unmercerised fabrics both the Knitting Quality and the choice of knitting machine usually have to be changed.

Effect of Mercerising on Stitch length

Wet processing reduces the Stitch Length in the finished fabric primarily because of yarn shrinkage. The amount by which the yarn shrinks in standard processing is relatively small, usually between 1 and 2%, and appears to be more or less consistent for all cotton yarn types and fabric constructions so far examined.

If the fabric is subjected to severe chemical treatments such as piece 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.).

For example yarn shrinkage during open-width, mercerising may be 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. That is they shrink by small amounts in standard processing but may shrink by large amounts if the fabric is piece mercerised.

Effect of Mercerising on Yarn Count

When a cotton fabric is subjected to chemical modification, as in the case of Mercerising, the change in the net effect on Yarn Count is different from those found after standard processing. In addition, the size of the changes is 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 relatively 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.

Average changes in yarn tex count values that have been found to apply during mercerising are summarised below.

	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 of Mercerising on Loop Shape

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, the changes in loop shape (Course / Wale Ratio) cannot be fully explained simply from the changes in Yarn Count and Stitch Length alone.

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.

Effect of Mercerising Machinery

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

Open-Width Mercerising

Open width mercerising of knitted fabrics is often carried out on chainless mercerisers that tend to restrict the amount of shrinkage in the fabric during the process. For this reason, the effect on the Reference Dimensions is usually less pronounced in fabrics that have been open-width mercerised than when the fabric is tubular mercerised. Tubular mercerised fabrics tend to have more wales (are narrower) and fewer courses (are longer) than equivalent fabrics open width mercerised.

Tubular Mercerising

The design of tubular mercerising machinery can vary significantly from manufacturer to manufacturer. Some tubular mercerisers allow the fabric to shrink fully during the process, while others restrict the amount of shrinkage. These differences in machinery design affect by how much the mercerising process affects the length and weight of the yarn and also the shape of the loops.

For example, 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 cigars of different width. It was found that 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.

Effect of Finishing Variables

Effect of Drying Conditions

The Reference Dimensions of the finished fabric are affected mainly by the changes brought about in the shape of the loops during the wet processing operations. However, further changes can also take place during the deswelling or drying stage. The conditions of the drying stage can therefore have an influence on the Reference Dimensions also - especially if excessive tensions are applied during drying.

In commercial case studies the biggest differences have been found between Stenter dried and Relax Dried fabrics of identical construction and processing history. The stenter finished fabrics were on average wider (fewer wales per unit width), shorter (more courses per unit length) and heavier (weight per unit area) in the Reference State than those which had been dried in a relaxing dryer.

From the practical point of view, the differences in Reference Dimensions that can be attributed to the drying stage are quite small, and most often will be obscured by variations in fabric production and processing conditions further downstream. However, the conditions of drying can be an added source of variation in the Properties of the delivered fabric, especially when different types of drying machinery are in use in the mill, and as such should not be ignored.

The additional influence of the drying procedure is one of the reasons why the STARFISH Standard predictions may not always correspond exactly to the results obtained by an individual mill. Any small differences that may be found as a result of differences in drying equipment or procedures can be compensated easily by using the Calibration facility.

Effect of Calendering and Compacting

At the end of the wet process and drying operations fabrics are usually run through a Calender and / or a Compressive Shrinkage machine (compactor) both to enhance the appearance and presentation of the final finished fabric and also to make final adjustments to the delivered dimensions.

It is often suggested that these operations have a significant influence on the fabric dimensions.

So far as STARFISH is concerned It is important to remember the difference between those processes that affect the Reference Dimensions and those that affect only the Delivered Dimensions or Proportions of the Finished Fabric.

The final dry (or semi-dry) finishing processes, after the main drying stage has been completed, have not been found to have any significant effect on the Reference Dimensions. They simply change the proportions at which the fabric is delivered. In other words they can assist the finisher achieve the Control Targets that are required in order to deliver the weight, width and shrinkage values that are expected in the finished fabric.

In many large-scale commercial studies carried out during the collection of the STARFISH Database, 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 "As Delivered" Dimensions (and hence the fabric weight and shrinkages) were usually quite different.

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.

Crosslinking is the creation of chemical bonds between polymer molecules to form a three-dimensional polymeric network.

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. If the process is carried out under carefully controlled conditions improvements in fabric stability, spirality and appearance retention can be achieved, but there are significant disadvantages to the system, e.g. loss of strength and abrasion resistance.

Effect on Course and Wale Density

The main reason why the application of a Resin Finish is seen to improve the potential shrinkage of the fabric is because the Reference 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 a reduction in 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 precise amount by which the Reference Dimensions of a fabric are altered depends mainly on the conditions of application, e.g. concentration of crosslinking and other chemicals, wet pick-up, evenness of distribution, drying and curing temperature, etc.

In general, the most noticeable effects are in the length direction. As the concentration of the crosslinking chemical in the fabric is increased, the number of Reference Courses per unit length is reduced.

In the width direction the effects are not always as clear cut and predictable. Most often the Reference Wale density is slightly increased (narrower fabric) as the level of crosslinking chemical is increased but, above a certain concentration the Reference Wale density may decrease (wider fabric).

The net effect is that the number of Stitches per unit area in the Reference State fabric is reduced. A reduction in the number of stitches per unit area reduces the weight of the fabric.

In general, therefore, a resin finished fabric will have improved shrinkage performance (particularly in the length direction) compared to an identical un-crosslinked fabric if both fabrics are delivered to the same finished dimensions. Conversely, a resin finished fabric finished with the same level of shrinkage performance, as the un-crosslinked fabric will be lighter in weight.

Effect on Spirality

One of the reasons for applying a resin finish to Single Jersey fabrics is to improve the degree of Spirality

In commercial case studies that have examined the effects of resin finishing treatments on the Reference Dimensions of single jersey fabrics the effect on spirality was actually found to be quite small.

In general, Resin Finishing was found to reduce the Reference Courses, Wales and Weight compared to identical un-crosslinked controls. However, the reduction in spirality due to the crosslinking procedure was found to be not much greater than the reduction that had already been brought about by the prior wet processing (preparation and dyeing) treatments.