Management of Quality in Knitting

Part 2: Specification & Control

Introduction

The key to the production of finished fabric with the correct dimensions and performance lies in the development of appropriate specifications for the production of the knitted fabric and maintaining close control over the key production control parameters.

If the knitted fabric is incorrectly designed or specified for the end product required, or if the key production control parameters once specified are incorrectly set or are allowed to vary then there is little that the dyer and finisher can do to correct the situation. Variations that are allowed in the quality of the grey fabric cannot be eliminated during finishing.

The key production parameters, which must be correctly specified, accurately measured and effectively controlled, are the quality of the yarn used to produce the fabric and the average length of yarn in the knitted loop, (stitch length). For a given wet process route these determine the Reference Dimensions of the finished fabric and therefore the balance of properties that can be delivered at the end of the production line.

Yarn Specification

Yarn quality can have a substantial influence, not only on the properties of the fabric but also on the efficiency of fabric production and the appearance of the final dyed and finished fabric. Therefore, it is important that the knitter issues and agrees appropriate yarn specifications with his suppliers.

When deciding on appropriate yarn specifications it should be remembered that excellent average values for any given yarn quality characteristic do not necessarily guarantee that a good quality yarn will be delivered, if the variation in the values is high within or between packages.

In many instances it may be better to have a consistently lower average value for a given property with low variation than higher average values with high variation. In almost every case it is the outliers which cause the biggest problems.

For example, one very regular yarn amongst many irregular yarns, or one irregular yarn amongst many regular yarns will stand out as barré. Similarly, one yarn, which is much weaker than the majority, will cause the machine to stop thus affecting all of the stronger yarns. It is the occasional faults and weak places in a yarn, which have the biggest adverse effect on knitting efficiency, downtime etc. Therefore, yarn specifications should always include tolerances for variation in addition to mean values.

In developing yarn specifications, it should also be remembered that a yarn need not (and probably should not) be perfect in terms of all the various characteristics. For example, yarns with low regularity and high nep content may still be appropriate depending on the end use. It is only if the neps cause difficulties with subsequent processing or fabric appearance that the yarn should be labelled as being of "unsatisfactory quality".

Supplier and knitter together must decide on their priorities and establish appropriate standards and specifications. These will depend on many factors, not least of which will be the price, the end use, and the demands of the ultimate customer. It is not appropriate simply to say, for example, that all measurements must be better than the 25% level given in the Uster® Statistics. A yarn that is in the top 25% for all of its quality characteristics will seldom be encountered and must by necessity be spun from very good (i.e. expensive) raw material. If such a yarn could be obtained it probably would not be economic.

Note: Uster® Technologies AG publishes experience values for these parameters. The values are deduced from test data and information received for yarns produced by spinners throughout the world. Reference to these "Uster® Statistics" can provide invaluable information on world-wide yarn quality characteristics measured using Uster® testing equipment. The latest statistics were published in 2007. This document provides an introduction to the concept of yarn specifications, and the interpretation of yarn test values, which is very highly recommended reading.

What to Specify

The most important Yarn Quality characteristics that ideally should be discussed with the yarn supplier and considered for inclusion in the yarn specification are:

- Fibre Quality
- Yarn Type
- Yarn Count, Count Variation
- Yarn Twist, Twist Variation
- Yarn Irregularity, Imperfections
- Yarn Strength, Strength Uniformity
- Yarn Friction

Fibre Quality

Ideally the Fibre Type and Quality should form part of the yarn specification because the particular variety of cotton and its physical characteristics can have an influence, not only on the fabric appearance - for example its dyeability - but also on the Reference Dimensions of the fabric.

In practice, it is almost certainly not practical for the knitter to attempt to issue detailed specifications regarding fibre quality to the spinner. It is nonetheless a subject that can and should be discussed since many spinners are not aware that changes to the fibre mix can have a direct influence on the properties of a knitted fabric. Through discussion it should be possible to arrive at some general specifications concerning the most important fibre quality parameters. e.g. staple length and short fibre content, Micronaire etc.

The spinner should have fibre test data available - either from his own in-house testing or data, which has been supplied by the grower or the merchant with the bales. For example, all cotton purchased from the USA will have HVI test data available on each bale, since the whole of the US cotton crop is classified by HVI. Increasingly this will become true for cotton grown in other areas of the world.

Yarn Type

The type of yarn, whether it is ring spun or rotor spun, combed or carded etc. will form an important part of the specification and have a major influence on the price, as well as the knitting efficiency.

Furthermore, nominally the same yarns obtained from different suppliers should be treated as different yarn types. Obviously, differences between suppliers will be much smaller than differences between spinning systems. Nevertheless, the differences between suppliers can be large enough, for example, to change the shrinkage of dyed and finished fabric by up to three percentage points.

If a change of yarn type is contemplated for an established fabric quality, then the fabric specification may have to be changed, to accommodate the different yarn properties. If a change in yarn type or supplier is made, then the dyer and finisher must be informed to be aware that the cotton may behave differently.

Yarn Count, Yarn Count Variation

The yarn count is one of the most important quality characteristics for the knitter. It has a direct effect on fabric dimensions, weight and cost. However, it is not sufficient simply to specify the average yarn count. Variation in yarn count is of at least equal importance.

Count variation between packages of about 3% or more is likely to give rise to poor fabric appearance, including the possibility of barré effects. The biggest effects will be seen in plain fabrics dyed in dark shades. This is only one of the reasons why different yarn lots should never be mixed.

Yarn Twist, Twist Variation

The average yarn twist influences the fabric dimensions and spirality. It will also affect yarn strength, hairiness, fibre fly generation, etc. An appropriate balance of these various characteristics has to be found, depending on the required product performance.

For a given fibre quality and spinning system, lower yarn twist gives softer yarns and fabrics with lower spirality. For a given yarn count and stitch length, fabrics knitted from low twist yarns are slightly wider and longer, with a lower weight per unit area.

Yarns made from high twist yarns are generally stronger and less hairy. They also resist the development of hairiness during processing. Fabrics made from high twist yarns have high spirality and a less regular appearance.

Once the most appropriate twist factor for a particular yarn quality has been determined, this must be delivered consistently. Once again it is the variation rather than the mean level that will most often cause quality problems in the knitted fabric.

Yarn Irregularity, Imperfections

Average levels for these quality characteristics will already have been decided to a certain extent by previous decisions on yarn type, count etc. As with most other quality characteristics whether the yarn contains a low or high incidence of imperfections etc. will depend on the quality systems operational in the spinning mill and the price. For critical applications it may be more cost effective in the long run to pay slightly more for guaranteed yarn evenness and low imperfections.

In any case, yarn for knitting should have been properly cleared of major faults and preferably spliced rather than knotted.

Yarn Strength, Strength Uniformity

The average strength and breaking elongation of most good quality knitting yarns will usually be adequate for all but the most critical of end uses.

As with other yarn quality characteristics it is not sufficient simply to specify average yarn strength. The strength variation must also be considered and an appropriate level agreed.

Yarn Friction

All yarns for knitting must be waxed to ensure good knittability. The coefficient of friction against steel should be around 0.15 or below.

The quality of the wax applied and the amount and consistency of waxing are both crucial. Unwaxed or badly waxed sections within cones, or cones that have not been waxed at all, in a given lot of yarn will inevitably cause problems for the knitter.

Control of Yarn Quality

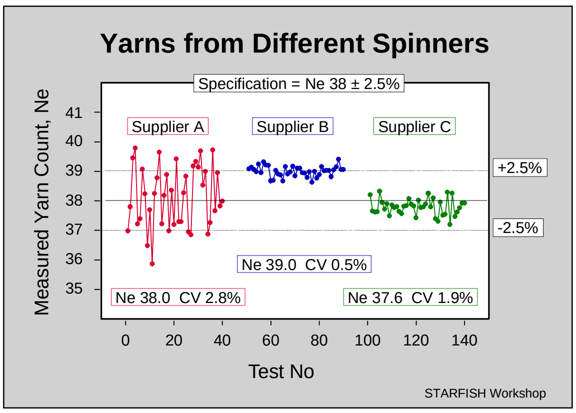
Once appropriate yarn specifications have been established with suppliers it is important that corresponding Quality Control procedures are in place in the knitting mill to check that these specifications are actually being met.

Yarn testing is both time consuming and expensive. Very few knitting mills are in a position to justify the purchase of the sophisticated yarn testing equipment that is needed to carry out all of the testing that could be considered to be important. On the other hand, the spinner needs to have this testing equipment available in the spinning mill in order to monitor and control his own production. By developing and maintaining a good working relationship with suppliers it should be possible to obtain this information from the spinner. In this way a check can be kept on all the yarn quality characteristics that have been specified.

However, it would be unwise to rely entirely on test data supplied by the spinner, therefore it is important that the knitter is equipped to make his own independent checks on certain key properties of the yarn, such as Yarn Count, Twist and Friction. This will inevitably require a certain investment in staff and testing equipment but is necessary if yarn quality is to be reliably controlled.

Variation in Yarn Count

The consistency with which a particular knitted quality can be produced depends on the reliability of all suppliers. If different lots of yarn obtained from either a single supplier or from several suppliers vary significantly then the consequences in terms of finished fabric dimensions and performance can be significant, even if the knitter has excellent control over his production.



STARFISH can be used to simulate the effect of variations in yarn deliveries on the dimensions and performance of the finished fabric knitted with exactly the same stitch length and finished to exactly the same dimensions of Courses and Width.

Fabric: Interlock 20 g 30 d 1884 n
Knitting Specification: Ne 1/ 38, SL 3.4 mm
Process: Winch-jet: Mid Tension, White
Finishing Specification: 14.5 Course/cm; 68 cm Tubular Width, 200 gsm

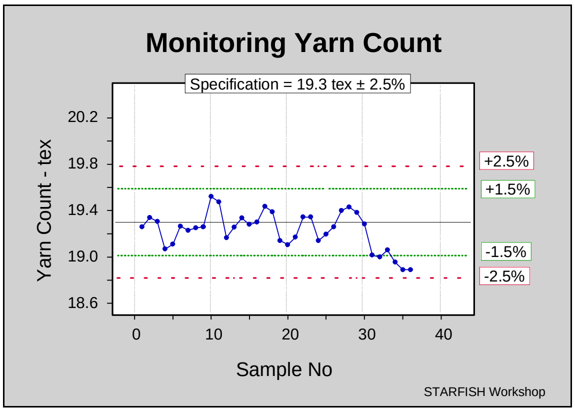
- Weight gsm 194 to 206
- Length Shrinkage % -4.6 to -5.8
- Width Shrinkage % -4.3 to -6.0

If the fabrics had been finished to exactly 200 gsm and 68 cm, then the range in Length Shrinkage increases to between -1.6% and -8.5%.

In this example the actual range in delivered Yarn Counts was between Ne 39.2 and Ne 36.89, or approximately ± 3%, a level of variation between yarn deliveries which is not unusual.

Monitoring Yarn Quality

1. Insist that each delivery or lot of yarn is accompanied by fibre and yarn test data from each supplier. Use this information to monitor each supplier's performance using Control Charts.



2. Check each delivery or lot for at least Yarn Count, Yarn Twist and Friction before the yarn is knitted. Monitor and compare the results with the agreed specifications using control charts.

   New Suppliers should get more stringent checking until their reliability is proved.

   - **Note:** It is important to remember the effect of atmospheric conditions on yarn count. Cotton is hygroscopic and absorbs moisture readily. The count of yarn, in particular is affected by the temperature and relative humidity in the room where testing is carried out. It is essential for accurate measurements that yarn testing is carried out in Standard Atmospheric Conditions.
   - The commercial weight of cotton yarn includes a standard allowance for moisture content of 8.5%.
   - Twist measurement is notoriously difficult to control. Absolute measures of twist from one laboratory to another are seldom exactly the same. However, the differences should be consistent. The standard deviation of twist measurements within a laboratory should be lower than 4% most of the time, and never greater than about 7%.

3. Establish appropriate procedures for dealing with deliveries that are out of tolerance both internally and also with suppliers.

- The procedures should be thoroughly understood by the quality personnel in the yarn store / knitting mill so that out of tolerance yarn deliveries are dealt with appropriately and not mixed with yarn that is conforming to the specifications. If out of tolerance yarn has to be used then this must be known before knitting so that appropriate action can be taken; not after the fabric has been knitted and found to be unacceptable.

4. Communicate the results obtained directly to the spinner, both to acknowledge that yarn is being delivered correctly and also to send a warning if undue variation is creeping in.

   - It is usually the case that, once yarn suppliers are made fully aware of the importance of consistent quality to their customers, and also that quality checks are being carried out on a routine basis, then they become more careful in the deliveries that they send. Doubtful lots are directed to less critical customers.
   - If a particular supplier consistently delivers out of tolerance yarn then consider looking for a new supplier.

5. Give each delivery or lot a unique identification number that is carried through onto the knitted piece card so that any problems that may be identified in the grey or finished fabric can be related back directly to the particular delivery and the individual spinner.

   - Pay attention to the condition of the yarn boxes. A damaged box may mean that the cones are damaged. Cones that have been damaged at the edges during transit or storage can cause problems in knitting. The attention paid to packaging can often be an indication of the quality consciousness of the spinner.

6. Do not mix lots from different deliveries on the knitting machine or in a single dyelot. This will lead inevitably to problems with barré or shade matching in the dyehouse and in the finished fabric.

7. Pay attention to yarn storage conditions. If the ambient temperatures are very high and combined with low relative humidity the yarn may not knit efficiently. Try to arrange yarn storage conditions so that temperature and relative humidity are maintained as constant as possible. Never store yarn in direct sunlight.

   - Yarn that has been stored for a long time is likely to give knitting and dyeing problems.
   - Complaints about weight losses during processing can often be traced back to the moisture content of the yarn. Yarn is usually bought with a standard allowance for moisture content. If the yarn is stored in very dry conditions moisture will be lost i.e. it will be lighter. Dry yarn will tend to shed more lint during knitting, and is more likely to break or cause faults.

Good Yarn Makes Good Fabric

It is important not to be complacent about yarn quality.

The ultimate quality of the knitted fabric depends on the quality of the yarn from which it is made. If the yarn is of poor or of inappropriate quality for the end product, it can not be corrected after the fabric has been knitted. For this reason, it is essential that appropriate specifications are agreed with suppliers and that deliveries are monitored to ensure conformity.

When production and commercial considerations demand that out of tolerance supplies have to be used then this should be known and the potential effect on the product down stream understood.

In certain cases, it may be possible to make adjustments to knitting and / or processing specifications to compensate for these unusual situations. Nevertheless, it is important to be aware that undue variation in the raw material can only add to variation in the final product.

Don't be tempted to buy just on price.

It is not always cheaper in the long run if the less expensive yarn causes quality problems down stream - e.g. reduced knitting efficiency, higher fault rates, dyeing problems, finished fabric properties out of specification etc. It can often be the case that the overall cost effectiveness of the knitting and dyeing operation will be improved by paying a little more for the basic yarn.

Consider the repeatability of supply.

It is the repeatability of yarn supplies that is important. Fabric quality specifications that are established on a one-off purchase will not be able to be repeated. This will lead inevitably to problems meeting specifications for finished fabric or garments laid down by customers.

The overall variation in fabric properties, appearance and production efficiency in the knitting mill depends not only on the reliability of an individual supplier but on the reliability of all suppliers. For this reason, it is often better to limit the number of suppliers to a few trusted spinners than to source from many. Although it is important to have a sufficient number of suppliers to guarantee security of supply, the more sources used the greater the potential for increased variability in overall fabric quality.

In short, the spinner is not to be treated as a source of competitive advantage in terms of price. He is to be regarded as a source of competitive advantage in quality, reliability, and manufacturing efficiency.

Knitting Specifications

The knitting specification is the primary key to the production of dyed and finished fabrics with the correct fabric properties. If the grey fabric is not correctly specified for the required fabric performance, then there is little that the dyer and finisher can do to recover the situation.

Furthermore, once the key production control parameters have been specified, they must be set up correctly and not allowed to vary outside of a known and accepted tolerance range. Variations that are allowed in the grey fabric can not be eliminated during finishing.

What to Specify

The minimum knitting specification for each fabric style or quality is the basic fabric construction plus the weight of each roll. This information must be used to develop the Production Specification for each knitting machine scheduled to produce the fabric.

The basic fabric construction is specified by the Yarn Quality to be used (supplier, type, count) and the average Stitch Length to knit.

The weight of each roll is specified by the number of courses to knit, given by the number of active feeders multiplied by the number of machine revolutions.

Each parameter in the specification must be provided with a tolerance. The tolerance applies either to purchasing (e.g. permissible Yarn Count variation) or machine set up (e.g. permissible Course Length variation). Beyond this, the specification should include only those parameters that contribute towards quality control, production control, or production efficiency. Examples of worthless parameters that are often included in a knitting specification are the grey fabric weight per unit area and the number of courses per unit length in the fabric on the knitting machine.

Yarn Quality

The Yarn Quality for each style should be identified by reference to the Yarn Specification and should include at least the following so that identification is unambiguous.

- Yarn Type,
- Yarn Count and Twist
- Supplier
- Lot Number

Yarn lots must always be identified and kept separate. Mixed lots will inevitably cause problems down stream.

Course Length is the Key Production Control Parameter

Course Length is defined as the total length of yarn consumed by one feeder during one complete revolution of the knitting machine. Stitch Length is the Course Length divided by the total number of needles knitting.

The average knitted stitch length is the single most important production control parameter for a knitted fabric. For a given yarn quality, wet process, and depth of shade it is the average knitted stitch length that determines the Reference Dimensions of the finished fabric and therefore the balance of properties that can be delivered by the finisher.

There is only one practical way to ensure that the average knitted stitch length is both correctly set-up and accurately maintained throughout production. That is by on-line monitoring of the course length on the knitting machine, using electronic length measurement devices. Yarn speed measurement can also be used but is less satisfactory.

Yarn Feed Systems

There are two basic methods for delivering or feeding yarn to the needles in a knitting machine. Yarn can be either negatively (passively) fed or positively fed (driven).

Negative Feed

As the name suggests, a negative or passive yarn feed system exerts no control over the length of yarn that is delivered or fed to the needles. It allows the machine to take in as much or as little yarn as it requires.

For certain complex constructions (e.g. Jacquard), where the number of needles knitting (and therefore the length of yarn required at each feeder) varies significantly from course to course, the use of a negative yarn feed may be necessary. This is not the case for the vast majority of basic fabric constructions, including all of the fabric types in STARFISH. For these fabric types the use of a negative yarn feed system is a severe hindrance to the production of knitted fabrics of consistent quality and dimensions.

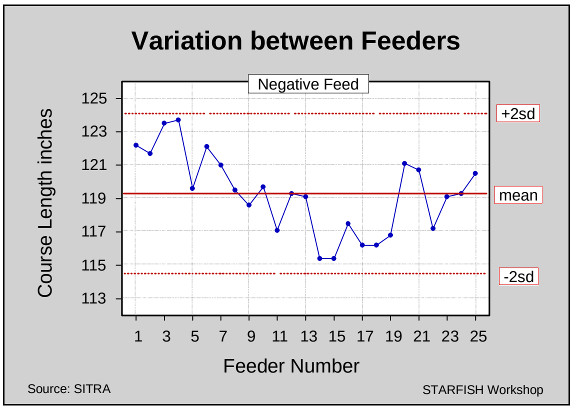
This is because when a negative feed system is used the amount of yarn that will be consumed per machine revolution (the course length) is affected by variations in the yarn input tension, the yarn friction, the yarn speed, the machine speed, the take down tension, the stitch cam settings, etc. This makes accurate control of course length practically impossible.

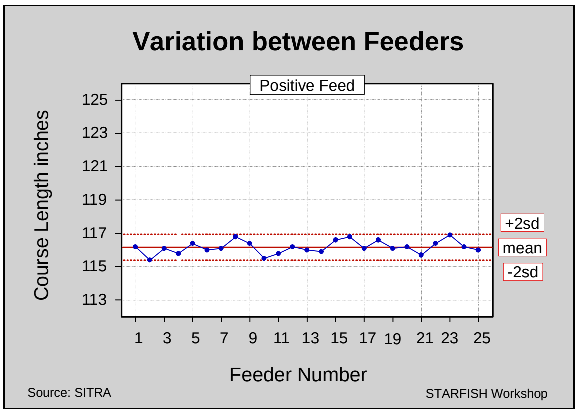
Negative feed systems are extremely uncommon in modern knitting plants.

Positive Feed

For the production of the vast majority of basic fabric constructions, the only reliable method for accurately controlling the average course length in a knitted fabric is to use a positive, or driven yarn feeding system on the knitting machine. A positive feed system consistently delivers a predetermined length of yarn to all the needles knitting in one complete revolution of the machine cylinder, without influence from such variables as the yarn input tension, the yarn friction, the yarn speed, the machine speed, the take down tension, the stitch cam settings, etc.

The dimensions of a knitted fabric can not be accurately controlled without a properly set up and well-maintained positive yarn feed system to deliver the appropriate length of yarn at each feeder. This point can be very effectively demonstrated by reference to the following two diagrams. These illustrate the effect on the course length of knitting with and without positive feed.





The results illustrated are taken from a series of experiments carried out by the Southern India Textile Research Association (SITRA) and clearly show the influence that positive feed can have on the consistency of fabric production. In this example not only are the average course lengths in the two fabrics significantly different, but also the level of variation between feeders was considerably higher when the positive feed system was not in use.

- With positive feed: Course Length = 116.2 ins, CV% 0.32
- Without positive feed: Course Length = 119.2 ins, CV% 2.0

Modern knitting machines from reputable machinery builders, almost without exception, are equipped with feeding systems that enable the length of yarn delivered to the needles to be positively controlled. This may not necessarily be the case for older machines, or for machinery that has been produced by small local factories.

Yarn Input Tension and Fabric Take Down Tension

Yarn input tension and fabric take down tension are two important knitting variables that must be properly controlled. If they are badly adjusted, or are allowed to vary by significant amounts, then they can have an influence on knitting efficiency, the frequency of faults and the appearance of the fabric.

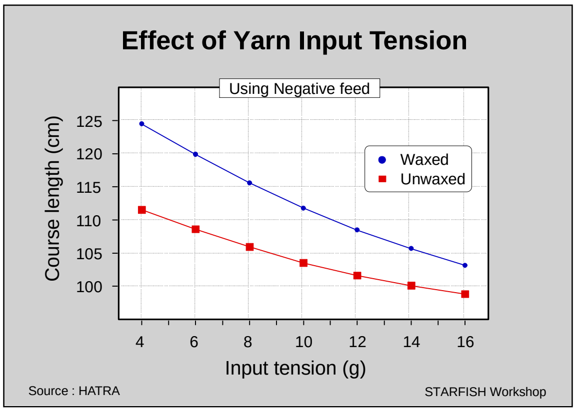
However, provided that the fabric is being produced with positive control of the course length then neither of them will have any effect upon the Reference Dimensions or shrinkage of the final finished fabric.

Yarn Input Tension

From the practical knitting point of view, attention must be paid to the setting of the yarn input tension and the levelling and setting of the individual stitch cams to ensure even stitch formation and to avoid yarn breakage caused by high tension peaks in the knitting zone. Yarn input tension is measured between the yarn feeding device and the knitting feeder.

When positive yarn feeding systems are used, yarn input tensions are adjusted by raising or lowering the stitch cams. Ideally all feeders should be adjusted to give the same tension although for some speciality fabrics, e.g. plush, different input tensions may be required on the different feeders to assist accurate plating. For most basic fabric types (single jersey, interlock, 1x1 rib) knitted from cotton yarns, input tensions within the range 3g - 5g can be considered appropriate.

Ideally the yarn tension measuring device should cause only minimum deviation to the yarn path and instruments of this type, both mechanical and electronic, are available from manufacturers throughout the world. To ensure accurate measuring and setting of course length on the knitting machine, course length measurements should only be finalised once the yarn input tension has been adjusted to the appropriate level on all feeders and the knitting machine has reached its normal operating temperature. For knitted cotton fabrics, provided that the yarn feed is being positively controlled, variations in yarn input tension (unless they become excessive) have not been found to significantly affect the knitted stitch length. Therefore, small variations in yarn input tension are unlikely to be an additional source of stitch length variation in the fabric. This is not necessarily the case for yarns spun from other fibres or when fabrics are knitted without the use of positive feed systems.



When fabric is produced without the benefit of positive feed the yarn input tension can have a very direct influence on the knitted stitch length.

High input tension will produce a smaller stitch compared to low yarn input tension.

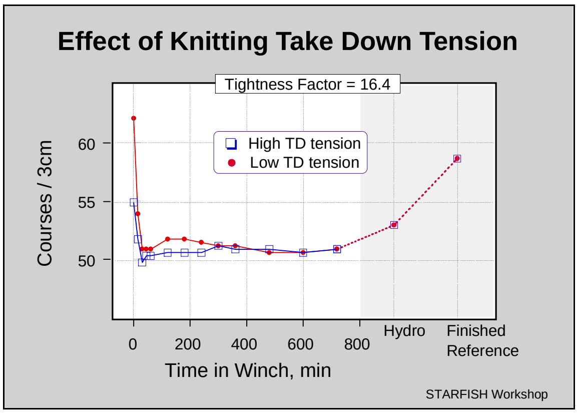
Take down Tension

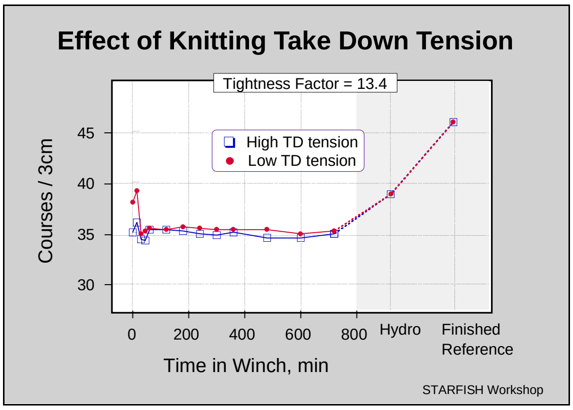
Similarly, to yarn input tension, there are sound practical reasons for ensuring that take down tensions on the knitting machine are controlled at an appropriate level to ensure efficient knitting and fabric collection. That is at a level sufficient to ensure efficient knock over of the loops but not so high that they cause distortion of the needles. Badly adjusted take down mechanisms can cause miss knitting and holes in the fabric and, in extreme cases, damage to the needles.

Provided that the course length is being positively controlled, variations in average take down tension on or between different knitting machines have not been found to have a significant effect on the average measured stitch length in a knitted cotton fabric. This is not necessarily the case for yarns spun from other fibres or when fabrics are knitted without the use of positive feed.

If fabrics are knitted without an efficient positive yarn feed, then variations in take down tension can cause variations in the knitted stitch length. With yarns spun from fibres other than cotton, very high take down tensions may stretch the yarn and distort the loops.

For cotton fabric knitted with positive feed, variation in take down tension is not however the source of variation in fabric shrinkage as is often suggested. This is primarily because the tensions that can cause distortion to the knitted fabric in the dry (as knitted) state are essentially temporary and will be removed (equalised) during wet processing.





Control of Course Length

It is not sufficient simply that a machine is equipped with positive yarn feed systems. In addition, the course length must be correctly set and regularly checked. It should be remembered that a positive yarn feed system can deliver the wrong course length just as consistently as it can deliver the correct course length. Furthermore, the positive feed system will not work properly and deliver the expected course length if it is not regularly maintained and kept free of any build up of wax or fibre fly.

When setting up the positive feed system for a new quality, it is not sufficient to rely on the markings on the drive wheels for establishing the course length. These markings are provided, by the manufacturer, as guidelines only for the initial adjustment. To ensure accuracy, the actual course length that is delivered at a particular setting must be checked by independent means. This is of particular relevance when more than one positive feed drive is in use, as is usually the case on large diameter multiple feeder machines. If different feeders are allowed to knit significantly different course lengths then not only will the dimensions of the fabric vary but the fabric appearance will suffer also.

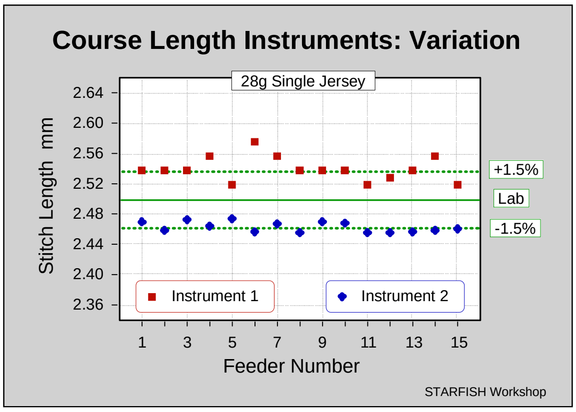
Several electronic instruments are readily available on the market that enable the actual course length delivered at each individual feeder to be measured directly with very good precision. These instruments are portable and can be moved easily between each machine in the factory.

Modern knitting machines can also be provided with a built in system that can monitor the average course length delivered to all feeders indirectly. These systems calculate the average length of yarn delivered to each feeder from measurements of the speed of the positive feed tapes.

Whichever system is adopted it is important also that the results are checked on a regular basis, with an independent laboratory measurement of stitch length in the fabric, to ensure the accuracy of the readings.

Furthermore, it should be remembered that any instrument can only operate within certain limits of accuracy - that is within the technical limitations of its manufacture - and from time to time they can go wrong.
Therefore, it is advisable to have the instruments or measuring systems independently checked and calibrated on a regular basis. This service can often be obtained from the instrument manufacturer for a small charge. Independent calibration checks are even more important if more than one instrument or measuring system is in use in the knitting mill. When this is the case, the results obtained from each instrument or measuring system should be regularly checked one with the other.

An illustration of the differences in course length / stitch length measurements that can be encountered when different instruments are used is given in the following diagram. This shows the results obtained from two different course length measuring instruments compared to those obtained from laboratory determination of the actual stitch length in the fabric.



Instrument 1 recorded a longer stitch length than was measured in the fabric and instrument 2 recorded a shorter stitch length. The results obtained from instrument 1 were also more variable.

The consequence of this observation for the knitter is that if the two instruments had been used in the same mill to establish the same course length quality on different knitting machines (or different pieces on the same machine), then the actual stitch lengths which would have been knitted would have been quite different. If these two fabrics had then been finished to meet the same targets of weight and width, then the potential shrinkage in the two fabrics would also have been different. Similar results to those illustrated have been obtained from case studies carried out within commercial knitting mills.

Course Length & Machine Needles

The fundamental control parameter on the knitting machine is the course length. The course length for each machine is calculated from the specified stitch length multiplied by the number of needles knitting.

Machine Needles

It is very important that the exact number of needles is known for each knitting machine in the mill.

Machine builders usually quote Machine Gauge and Diameter to the nearest whole number, e.g. 24 gauge, 30 inch diameter. If these measurements were precise then the exact number of needles in the cylinder could be calculated as follows: -

- Needles = Gauge * Diameter * π

However, it is often the case that, for machinery design and engineering reasons, the actual number of needles in a given machine is not the same as the theoretical number.

It is not unusual for knitters to assume that if two machines have the same nominal gauge and diameter then they will also have the same number of needles. This is not necessarily the case. Different makes and models of knitting machine can have different numbers of needles for the same nominal gauge and diameter e.g.

Single Jersey 30" Diameter, 20 Gauge

	Needles	% Diff
Theoretical	1884	0
Falmac "B" series	1848	-1.9
Monarch VXC-73S	1860	-1.3
Pai Lung FS3A/T	1872	-0.6
Vanguard 1SJ4	1920	+1.9

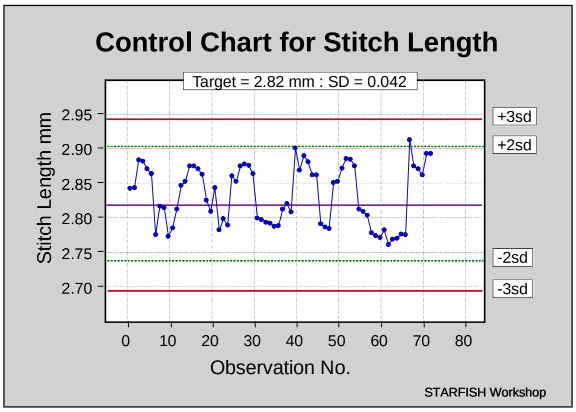
An accurate knowledge of the number of needles is vital, because for a given stitch length and yarn count the number of Needles determines the Width of the fabric. This is especially relevant for body width fabric ranges when exact Width Targets must be achieved.

Course Length should be used to set-up and control production on individual machines. For the same Quality the Course Length may be different on different machines depending on the Number of Cylinder needles.

Stitch Length should be used to specify the Quality and compare production across all machines. Recorded stitch lengths should be the same on all machines.

Variation in Stitch length

The consistency with which a particular knitted quality is produced depends on how well stitch length is measured and controlled on the knitting machine. If different pieces or different machines are set-up incorrectly then the consequences in terms of finished fabric dimensions and performance can be significant, even if the knitter has excellent control over his yarn supply.



STARFISH can be used to simulate the effect on finished fabric dimensions and performance of variations in stitch length between different fabric rolls knitted from exactly the same Yarn Count and Finished to exactly the same dimensions of Courses and Width.

Fabric: 1x1 Rib, 14 g, 20 d, 876 n
Knitting Specification: Ne 1/ 30, SL 2.82 mm
Process: Winch-jet: Mid Tension, Medium shade
Finishing Specification: 17.6 Course/cm; 41 cm Tubular Width, 200 gsm

- Weight gsm 194 to 206
- Length Shrinkage % -2.3 to -9.4
- Width Shrinkage % -3.8 to -8.4

In this example Stitch Length = 2.82 mm ± 2 * 0.042, CV 1.49%

Control of Course Length

The main objective of any Quality Control system must be to achieve the required level of control with minimum cost. Consequently, there are certain points that need to be considered when developing quality control procedures for monitoring course length.

Prevention better than Cure

Making the quality right first time is always more cost effective than making it wrong. Once a fabric has been knitted it is too late. The knitter will have to accept that the dimensions or the performance of the finished fabric will not be as intended. The finisher can do nothing to alter the situation. Therefore, it is worth devoting significant effort to making sure that each new quality is correctly set up on the knitting machine before production begins.

This means that, after all machinery adjustments have been made, the average course length established over several feeders should be checked and the results recorded.

Initially this may require evaluation trials to be carried out to establish the normal level of variation in course length measurements that can be expected between feeders and between different knitting machines. These will help to establish the minimum number of feeders that need to be monitored in order to establish that the average course length has been properly measured.

Proper recording of individual measurements and calculation of averages is an important discipline when setting up a machine. The temptation is to make "mental" averages in order to save time but this can result in additional unnecessary variation.

Making Measurements

Establish standard deviations for the manufacturing process.
Once the knitting quality has been confirmed and passed for production, a system of regular checking should be established to ensure that the specified quality is being maintained consistently over the course of the production run.

For each machine and fabric quality the measurements of course length should be recorded in such a way that the average measurements and the variability in measurements can be easily monitored. Ideally, the same number of feeders should be checked each time (though not the same actual feeders). If more than one positive feed system is in use, then each system should be checked and recorded independently.

It is important to establish what is the standard deviation of the measured mean values. The standard deviation of the sample means should be established for different qualities, for different machines, and for different yarn lots.

In principle, there should be no differences between them, so any significant differences that are found may be pointers to possible problems. If it can be proved that there are no differences, then the data can be combined to give global standard deviations for certain groups of qualities, or groups of machines, or even the entire operation. These standard deviations will be used to set up an objective process control system.

Frequency of Checking

The need to establish standard deviations may require a more intense level of checking when the system is first introduced than may eventually be necessary. Increased frequency is also needed when new positive feed systems are purchased, or after a full service and maintenance has been carried out, in order to establish (or reconfirm) the efficiency and consistency of the positive feed systems in use.

Checking the standard deviations will allow detection of any deterioration in the performance of the positive feed systems. Their long-term efficiency will depend on regular maintenance and cleaning. Maintenance schedules should be timed so that systems are cleaned and serviced before any deterioration in performance can begin.

For a new quality, or a new (or refurbished) feeder system, one might start by checking the course length at the beginning of each new piece. If it becomes clear that feeder consistency is being maintained throughout the shift, then the frequency can be reduced to once per shift. As soon as shift to shift consistency is proved, then daily monitoring can be introduced. Further reductions in frequency require very clear proof that feeder efficiency can really be maintained over long periods.

Obviously, the more often checks are made, the quicker will a drift in performance of the feeder system be detected, but the more expensive is the monitoring operation. When measurements are made and recorded properly, and when good records are kept and analysed appropriately, then cost effective decisions about the required frequency of checking can be made on the basis of statistical probabilities.

If there is a major knitting failure such as a cast off, or if a new yarn delivery is introduced, then the course length should be re-checked before continuing production.

Tolerances and Control Limits

Tolerances are related to Standard Deviations.

Tolerances have to be established, so that an objective decision can be made whether or not the feeder system needs to be adjusted after a particular set of measurements has been made.

Obviously the closer the tolerances are to the Target Value the more chance there is that production will have to be stopped frequently for adjustments to be made to the course length. The optimum levels to ensure the minimum acceptable variation with the minimum acceptable disruption to production should therefore be established only after a fairly intensive evaluation period and they should be regularly reviewed to ensure that the level of monitoring is at its most efficient.

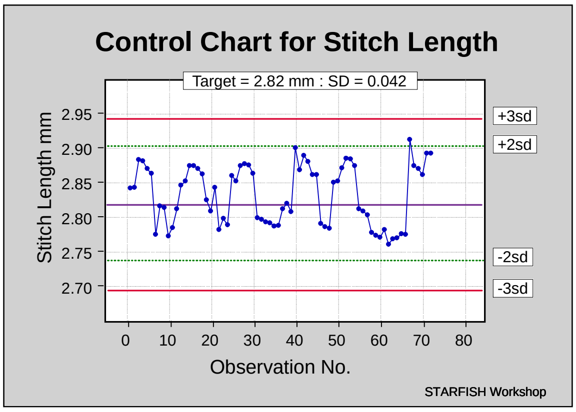
Tolerances on Course Length Targets should be set at a level that is both realistic and achievable within the context of the manufacturing environment. For example, there is little point insisting that the feeder system must be adjusted whenever the measurement is more than 0.5% away from the Target, if the normal variation between measurements is ± 1% or if the accuracy of the measuring device is ± 2%. This is why it is important to establish the standard deviations for each quality and machine. Two sets of Tolerances should be calculated, namely the Normal Tolerance and the Action Tolerance.

The Normal Tolerances will be two standard deviations. 95 out of every 100 measurements should lie within two standard deviations of the Target. The Action

Tolerances will be three standard deviations. 99 out of every 100 measurements should be within three standard deviations of the Target.

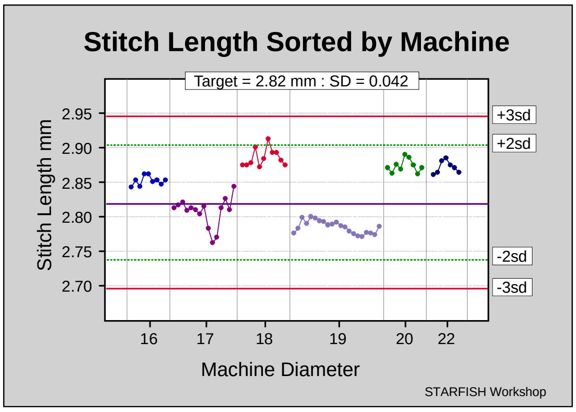
It is important to distinguish between the practical, Control Tolerances, and the most desirable tolerances. The practical tolerances, which must be used for routine process control, are an objective reflection of the current capabilities of the manufacturing operation. If the current standard is lower than what is desirable, it makes no sense simply to adopt tighter tolerances for production control purposes; this is an exercise in self-delusion.

The standard deviation between successive measurements reflects all of the normal variations in current production practices, including yarn purchasing decisions, operator skills, and machinery capability. If the standard deviation is so high that unacceptable variation in fabric properties will result, then efforts must be made to bring it down, by reviewing yarn purchasing practices, and by upgrading the training of operatives and the mechanical condition of the machinery. Only after the current standard deviations have been successfully reduced can new and tighter Control Tolerances be set, reflecting the new manufacturing situation.



Some of these points can be illustrated using the results obtained from an industrial case study that examined fabrics obtained from a manufacturer of body size fabrics.

The chart illustrates the actual variation in stitch length that was found in the sampled fabrics.



Closer examination of the data revealed that the main reason for the overall level in stitch length variation was that different machines had been set-up to knit at different levels.

Within an individual machine stitch length could be controlled very accurately.

STITCH LENGTH SORTED BY MACHINE

Diam.	S.L. mm	S.D.	CV %
16	2.850	0.007	0.25
17	2.806	0.021	0.76
18	2.884	0.013	0.45
19	2.785	0.010	0.35
20	2.873	0.011	0.39
22	2.785	0.009	0.31
All data	**2.832**	**0.042**	**1.49**

The overall level of variation found is in fact not particularly high. Yet, as was illustrated by the results of the STARFISH simulation presented in the earlier section, even with this level of control the potential variation in finished fabric properties is significant. Had the manufacturer been monitoring his production effectively, the variation in stitch length within and between machines would have been noticed very quickly and corrective action could have been taken. Thus, helping to reduce the overall variability in his production and improve the consistency of the finished fabrics.

Use STARFISH to Check Control Tolerances

The practical consequences of specific levels of Knitting Control Tolerances for the performance of the dyed and finished fabric can be checked by running the STARFISH software for three fabric qualities, one having the Target Stitch Length, one having the Target plus three standard deviations, and one having the Target minus three standard deviations. The model should be run with fixed Finishing Targets. These Targets should be the number of Courses and the Width which result in the correct Weight for the quality having the Target Stitch Length (and Target Yarn Count). The qualities that have stitch lengths at the maximum and minimum tolerance levels will perform differently from the Target quality. From these results, it can be judged whether the differences are acceptable. Tolerances for the Yarn Count can be investigated in a similar way.

Experience has shown that, with appropriate instrumentation and monitoring, it is not difficult to contain variation in Course Length between pieces of the same quality to within ± 1.5%. In fact, variations of less than 1% have been consistently recorded in some commercial case studies.

Control Procedure

Set up Quality Control Charts

After each measurement, the results for each feeder system should be compared to the established Tolerances for that quality. If the average measurement falls within the Normal Tolerance band, then the fabric is being produced according to specification and no further action is required, except that the result has to be properly recorded. If the result falls outside the Action Tolerance then there is a strong probability that something is wrong and that corrective action is needed.

The first action is that the set of measurements must be repeated to confirm the result. If it is confirmed, then the machine must be stopped and the feed systems checked to make sure there is no problem, e.g. with contamination. Finally, the feed system has to be re-adjusted so that the correct course length is being delivered before production continues. This machine is then marked down for more frequent checking until it is clear either that the feeding systems are working correctly, or that maintenance is required.

For measurements which fall between the Normal and the Action Tolerances, a quick check can be made to see if there is any obvious problem, such as contamination of the feeder system, and the machine should be marked down for more frequent checking. More positive action should be taken only if the result is repeated on several occasions. A result in this intermediate band is expected once every 20 measurements. Single results are not significant unless they can be related to a specific problem with the feeder system.

A simple method of monitoring long-term trends is by the use of Control Charts, that clearly show the average target course length for the machine and quality being produced, and the allowed Normal Tolerances and Action Tolerances. Each new measurement is plotted on the Control Chart. The level of control being achieved is easily seen and any long-term trends become obvious.

Consistency of Operations

Maintain a consistent standard

It may be thought that, if the fabric is being produced for an uncritical customer, or an undemanding end use, then fewer checks or wider tolerances may be allowable than when the fabric is being produced for a critical end use or customer. This is dangerous thinking. Double quality standards should not be tolerated. They will inevitably lead to a drop in overall standards.

The results obtained from the on-line course length instruments should be checked on a regular basis (e.g. once a month) with a laboratory measurement for stitch length and the two results compared. Here again, the average performance of instruments, and long-term trends can be monitored quite easily using the Control Chart system.

In addition, tolerances that reflect the accuracy of the two measuring methods should be established so that action limits can be devised. On average both sets of measurements should be the same. If one measurement is continually falling above or below the other then an investigation into the reasons can be launched. If more than one on-line instrument is being used then each instrument must be independently checked against the laboratory method.

As an added precaution the on-line instruments themselves should probably be externally checked for calibration on a regular basis (e.g. once a year).

Modern computer software packages are ideal for recording, storing and analysing quality control data. However, the use of Quality Control Charts provides an immediate visual check on production quality. The charts are easily understood by all personnel and enable everyone (without computer or mathematical skills) to become fully involved in keeping an eye on quality. It is often recommended that the charts should be displayed in an area where all operatives can see them. Advanced statistical analysis can still be carried out for in depth management reporting by the appropriate department if this is considered appropriate.

The effective implementation of Quality Assurance systems and Quality Control procedures within a mill requires that everyone involved in the production process is fully informed about and fully committed to the Quality Policy of the company. All staff should be encouraged to look for ways of improving quality and to communicate and discuss their ideas to the person with overall responsibility for quality management within the mill. From time to time, the control system itself should be audited, to make sure it is still operating effectively and at an appropriate level of investment.

It is also important that those responsible for monitoring course length fully understand the importance of accurate measurements. It is not uncommon for staff, working under intense production pressures, to record the figure which is expected rather than that which is actually measured, particularly if they are not fully aware of the consequences. For this reason, it has become the policy in some companies to use persons independent of production to make these vital routine quality checks. They are fully trained in how to make the measurements and have the authority to stop production if a machine is out of specification, but they are not involved directly in production and are not allowed to make adjustments to the knitting machines themselves.

Roll Weight & Roll Length

Control of Roll Weight (piece weight) is important for many practical reasons. Standardised roll weights allow for easy planning, monitoring and control of production rates and production capacities, uniform stacking and handling of rolls, and easy composition of dyelots.

However, accurate knowledge of the roll weight, together with the use of the STARFISH software allows the knitter to predict what will be the length of the finished piece (neglecting fabric waste). With this knowledge, the roll weight can be so managed as to allow optimum finished piece lengths for the cutting-room table.

Roll Weight

Provided that the exact Yarn Count is known, and the specified Course Length in the fabric is accurately set up on the knitting machine, then the weight of each knitted piece can be quite closely controlled by specifying the number of machine revolutions.

$$\text{Roll Weight (kg)} = \text{tex} * \text{CL (cm)} * \text{feeders} * \text{revs} * 10^{-8}$$

Conversely, after the actual roll has been weighed, the Yarn Count can be back calculated from the roll weight and a knowledge of the total length of yarn in each piece.

$$\text{tex} = \frac{\text{roll weight (kg)} * 10^{8}}{\text{CL (cm)} * \text{feeders} * \text{revs}}$$

$$\text{Ne} = \frac{590.54}{\text{tex}}$$

This can be used to provide a check on apparent weight losses during knitting. When the normal weight losses are known, target roll weights can be adjusted accordingly, to allow for the expected losses, thus maintaining the lengths of the final finished fabric pieces.

Note: It is important to remember that the moisture content in the fabric will influence the roll weight. The ambient conditions in the knitting room, (temperature and relative humidity) and the temperature of the knitting machine will both have an influence. Variation in moisture content between grey knitted pieces and the grey yarn can often be identified as the main reason for apparent excessive knitting losses. Some knitting factories, especially those working on a commission basis, have found it extremely useful to invest in portable moisture meters which allow the moisture content of the grey yarn and the grey knitted pieces to be checked, before these types of calculations are made.

Roll Length

The Length of each piece is given by the Total Number of Courses divided by the Course Density.

$$\text{Total Number of Courses} = \text{Feeders} * \text{Revolutions}$$

For the grey fabric, this fact is of no value because it makes no sense to attempt to control the course density during knitting. However, the Course Density in the dyed and finished fabric should be known from the Finishing Control Targets. Therefore, the length of the finished piece can easily be calculated and used to specify a number of machine revolutions that results in a desirable nominal finished piece length.

Quality Checks on Grey Fabric

In many knitting mills, where the fundamental importance of the accurate control and monitoring of stitch length is not properly appreciated, significant effort and resources are devoted to checking the quality of the grey fabric by counting courses and wales and measuring area weight on the grey machine state fabric. In some cases grey fabric shrinkage is also measured.

These measurements are of doubtful benefit and in our opinion can be considered to be a complete waste of time and fabric.

Variations in take down tension do not affect the Reference Dimensions of a fabric that is knitted with positive course length control. They do, however, influence the dimensions of fabrics as they are delivered from the knitting machine. Different pieces can be quite different and these differences will be affected by the settings of the take up rollers and the stretcher board.

For example, a high take down tension will stretch the fabric in the length direction resulting in a longer fabric with fewer courses per unit length. A wide stretcher board setting combined with low take down tension will stretch the fabric in the width direction producing a wider fabric with fewer wales per unit width and more courses per unit length.

This means that the area weight of the grey, as knitted, fabric can often vary significantly between different pieces which are knitted with different levels of take down tension and / or stretcher board settings. Similarly, the number of courses and wales per unit length that will be measured in the grey fabric can also be significantly different.

Thus, even when the yarn count and stitch length have been accurately measured and consistently maintained, small variations in the take down tension or the stretcher board settings between machines or between different pieces will change the grey dimensions and the weight of the machine state fabric.

Regardless of by how much the grey dimensions may vary, provided that the yarn count and stitch length have been correctly specified, accurately controlled and consistently maintained the Reference Dimensions of the finished fabric will not be affected.

Specification and Control

The development of appropriate specifications together with effective monitoring and control of the knitting operation can provide the following benefits

- improved product control and consistency,

⇒ reduced grey fabric testing,

- improved yarn utilisation,

⇒ reduced production costs,

- improved production efficiency and planning,

⇒ reduced waste,

- improved competitiveness and customer relations.