Low Shrinkage by Design

STARFISH Technology for Cotton Circular Knitgoods

Introduction

Manufacturers of cotton circular knitted fabrics are faced with constantly increasing global competition and ever-rising demands for better quality and reliability. One of the key demands is for fabrics and garments having consistently low levels of potential shrinkage. Achieving a low level of shrinkage in these fabrics may not always be easy, but it is no longer the difficult problem that it once was - thanks to the developments of the machinery builders. The main problem is that, for any particular fabric quality, the required low levels of shrinkage have to be delivered in conjunction with a specific weight per unit area and a specific fabric width.

A largely unrecognised, but very serious consequence of lowered maximum shrinkage levels is that there is now a drastically reduced margin for error in the design engineering of fabrics.

Consider the simplified case where, with a given fabric style, a dyer and finisher has the equipment and techniques available that allow him to deliver the fabric with 3% length shrinkage. If the customer demands a fixed width and a fixed weight then, in effect, he is also demanding a fixed fabric length and a consequent fixed value for the length shrinkage. Let us call this value the Target Length Shrinkage and identify it with TLS. Now, if the customer allows the maximum length shrinkage to be 10% then there is a good chance that TLS will be found between 3 and 10%, and the finisher's job is relatively easy, provided that the fabric has been engineered only approximately correctly. However, if the customer demands that the maximum length shrinkage shall be only 5%, then there is a much smaller probability that TLS will be found between 3 and 5%. In this case, the fabric will have to be very precisely engineered if the finisher is to be able to deliver the correct weight and width together with an acceptable level of shrinkage.

Traditionally, cotton circular knitted products have been developed and optimised largely by trial and error methods but these methods will not be good enough for the future because they are too costly and not sufficiently accurate.

A modern quality assurance system requires

- firstly, that product performance can be designed in advance by (sufficiently) accurate calculations and,
- secondly, that processing machinery can be regulated by reference to predetermined target levels of key product properties which can be measured continuously on-line, and used in feed-back loops to control some aspect of machinery settings.

Shrinkage and Fabric Dimensions

Shrinkage is simply the difference in the length and width of a fabric sample before and after a specified relaxation procedure, such as household laundering, expressed as a percentage.

$$\text{Length Shrinkage} = 100\,(Lo - Lr)\,/\,Lo$$
$$\text{Width Shrinkage} = 100\,(Xo - Xr)\,/\,Xo$$

Where Lo and Xo are the original length and width of the sample, and Lr and Xr are the corresponding dimensions after relaxation.

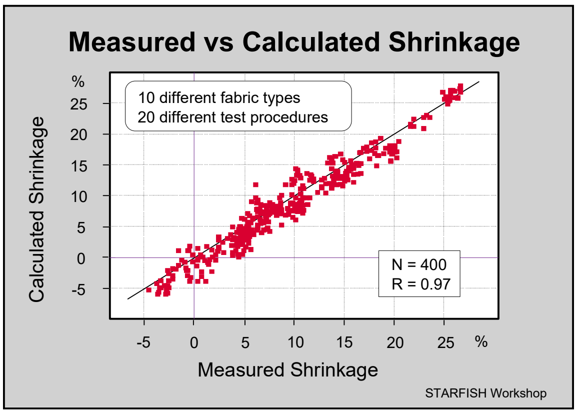
Shrinkage is an important property of the fabric and the customer will specify it as a key Performance Target. However, shrinkage is not a very useful property in terms of controlling production. Even the most abbreviated of shrinkage tests take quite a long time to perform compared to the production rate of a fabric dryer or compactor. Many customers will specify shrinkages according to a test that involves several cycles of washing and tumble drying. A large quantity of fabric can have been processed before the shrinkage result is available to say whether the performance was acceptable. For process control, we need a fabric property that can be determined rather quickly - preferably one that can be monitored continuously, on-line.

For a given fabric style, shrinkage depends directly on the length and the width of the fabric. If we pull the fabric out to a wider width, then the width shrinkage is increased proportionately. Likewise, the length shrinkage will be directly proportional to the amount by which the fabric has been stretched during processing.

The length and width of a given sample of fabric are inversely proportional to the density of courses and wales. It follows that shrinkage can be calculated from the Courses and Wales per cm (or per inch) in the fabric sample before and after relaxation.

$$\text{Length Shrinkage} = 100\,(Cr - Co)\,/\,Cr$$
$$\text{Width Shrinkage} = 100\,(Wr - Wo)\,/\,Wr$$

Where Co and Wo are the course and wale densities in the original sample, and Cr and Wr are the corresponding values after relaxation.



Large numbers of experiments, and case studies involving serial sampling from industrial production, have shown that shrinkage values calculated from the measurements of courses and wales are at least as precise as the directly measured shrinkages. The diagram shows the results of only one such experiment where shrinkage values returned by different test procedures were being evaluated, whilst at the same time the course and wale densities were also measured. When it is considered that the scatter in the graph is contributed by variation from both methods of estimating shrinkage, and that direct measurement of shrinkage has an average standard deviation of about one to two percentage points, then the level of agreement between the two methods is excellent.

This knowledge of itself does not allow any reduction in the time required for determining whether the shrinkage of a particular sample is acceptable. We still have to carry out the shrinkage test to be able to count the courses and wales in the relaxed fabric. However, what if we already know the values for course and wale density in the relaxed fabric? In that case we would need only to count the courses and wales in the original sample (i.e. the delivered fabric) to be able to calculate the expected shrinkage. There would be no need to carry out the actual shrinkage test.

Furthermore, if we know the number of courses in the relaxed fabric then we can easily calculate what should be the course density in the delivered fabric, in order to guarantee a certain level of length shrinkage. This value can then be used for process control, to make sure that the same style of fabric is always being delivered at the same length.

Course and wale densities are useful also in connection with our other two major performance targets, namely width and weight per unit area.

Width = Needles / Wales
Weight = Courses * Wales * tex * Stitch Length

Because we are required to deliver a fixed fabric width, it follows that the wale density is also fixed. Because we are also required to deliver a fixed area weight, it follows that the course density is fixed.

The conclusion is that, for a given fabric type and construction (yarn count and stitch length) a fixed set of Performance Targets implies fixed values for the course and wale densities, both in the delivered and in the relaxed fabric.

The obvious corollary, instinctively understood by all finishers, is that the delivered fabric dimensions can be held constant by holding to constant values for course and wale densities. Wale density is easily controlled through the delivered fabric width. Course density must be controlled either by manual counting or, preferably, by installing electronic sensors at the final drying or compacting machine. Even manual counting of courses is quicker than a shrinkage test. Electronic course density sensors allow true on-line control.

All that remains is

- To ensure that the basic fabric construction is engineered in such a way that, when the correct weight and width is delivered, the shrinkages will also be on target.
- To determine the target value for the course density which guarantees the correct weight in the delivered fabric, at the target width.

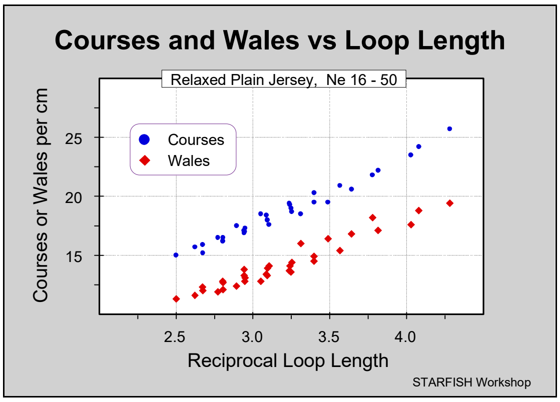
Engineering the Fabric

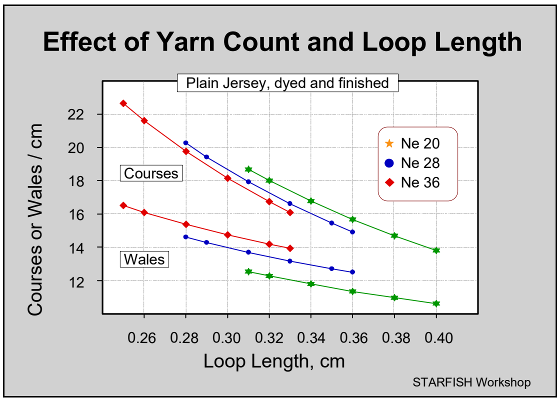
Fabric engineering in the modern sense implies that equations have to be available which can be used to calculate the fabric properties of interest, starting from the known manufacturing and processing conditions.

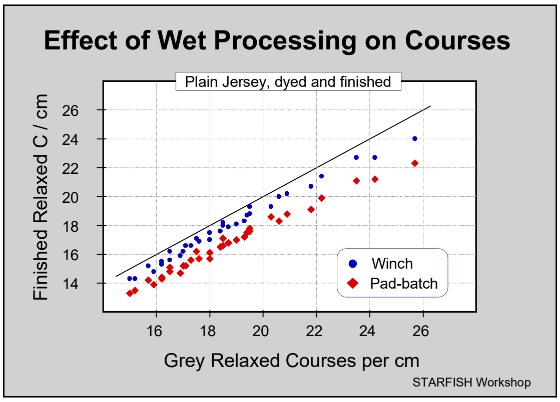
The known manufacturing and processing conditions comprise:

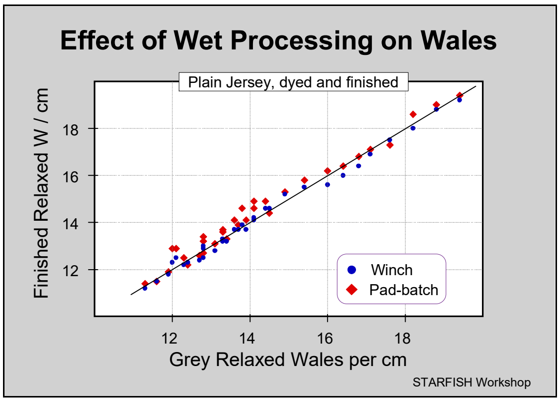
- The yarn (or selection of yarns) available for knitting.
- The knitting machinery characteristics (essentially, the number of needles).
- The knitting specification (essentially, the length of yarn fed for each revolution of the machine).
- The wet processing and finishing machinery characteristics.

The fabric properties of interest are the course and wale densities in the fabric after relaxation. As we have seen, once we know the course and wale densities that are to be expected in the relaxed fabric, then we can easily calculate everything that we need to know about the fabric performance and the process control targets. A large programme of research has been carried out to discover the basic equations relating the manufacturing and processing conditions to the relaxed courses and wales for a wide range of yarn and fabric types. Typical results are illustrated in the following four graphs.









The equations, which have resulted from this research, have formed the backbone for the STARFISH computer prediction program for cotton knitted fabric engineering and process control.

Low Shrinkage by Design

For cotton circular knitted fabrics, there are three major requirements for achieving "low shrinkage by design".

1. The fabric has to be correctly engineered for the required performance (appropriate choice of yarn and knitting conditions).
2. Appropriate values have to be specified for the key fabric properties that will be used for process control (knitting and finishing targets).
3. The knitting and finishing machinery has to be provided with appropriate sensors and regulators, so that the chosen control targets can be accurately maintained.

If the fabric has not been appropriately engineered, then there is no way that the dyer and finisher will be able to meet all of the performance requirements. He may choose to deliver the correct weight and width, or he may choose to deliver the correct shrinkages, or he may elect to compromise on some or all of the four targets: he can not achieve them all at the same time.

What the finisher can and must do is to control the width and the course density accurately and consistently. It is the responsibility of the knitter to ensure that the basic fabric construction is specified and manufactured so that when the finisher successfully delivers the correct target courses and width, then the weight and shrinkages will also be correct.

It is their joint responsibility to agree on the actual values for the correct process control targets of delivered course density and width.

The discovery of the proper knitting specification and the calculation of the correct process control targets are best achieved by use of the STARFISH computer program.

The STARFISH Computer Program

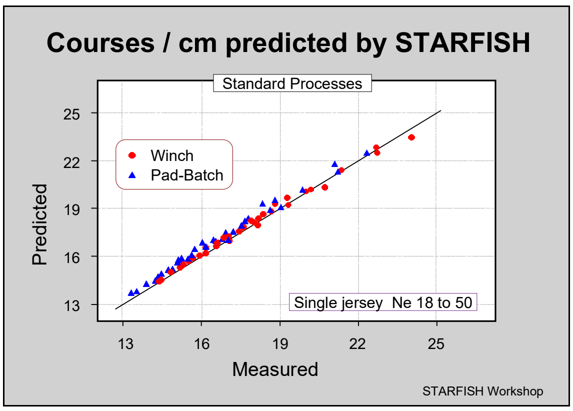
The STARFISH computer program is founded on a database which, at the time of writing, comprises test data on more than 5000 separate fabric qualities, and is still growing year by year. Almost all of the data come from fabrics, which have been manufactured and processed at full scale. These data are mainly of two types. Firstly, there are the systematic series of fabric qualities that enable the basic mathematical analysis to develop the underlying equations. Secondly, there are the results from sets of serial samplings of individual qualities, taken over a period of weeks or months in dyeing and finishing plants. These serve to validate the predictions of the current program and also to establish the normal variation that can be seen in commercial production.

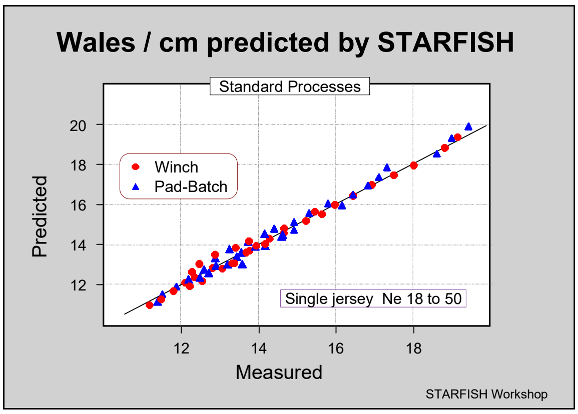
Using these data, we are able to model (amongst others) the average influence of different types of yarns and different wet processing regimes, so that these average effects are already built into the model.

Thus, with the STARFISH computer program, the average values for courses and wales, weight and width of an extremely wide range of dyed and finished fabrics can be estimated very rapidly and pretty accurately without the need for any physical knitting or finishing trials. The program will also calculate finishing control targets for any desired level of shrinkage or any requested weight and width. It will also show whether a given set of customer demands can actually be met, in principle, using the yarns, knitting machines, and wet processing machinery which are actually available.

To get started with a basic simulation model, the user can select from a list of four standard yarn types, ten standard processes and eight depths of shade. Up to nine different yarn count values can be specified, as well as nine different knitting machines (to simulate a body-width range).

The next two graphs illustrate the accuracy of the program in calculating courses and wales for a wide range of single jersey fabrics, compared to those actually measured, using the appropriate STARFISH standard wet process. Clearly, the standard average STARFISH equations are doing a pretty good job of modelling both the knitting and the wet processing variables.

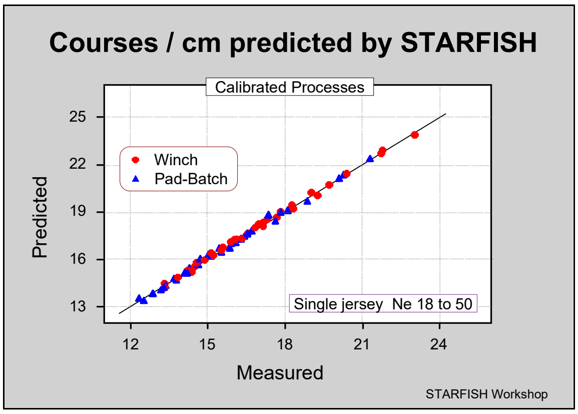


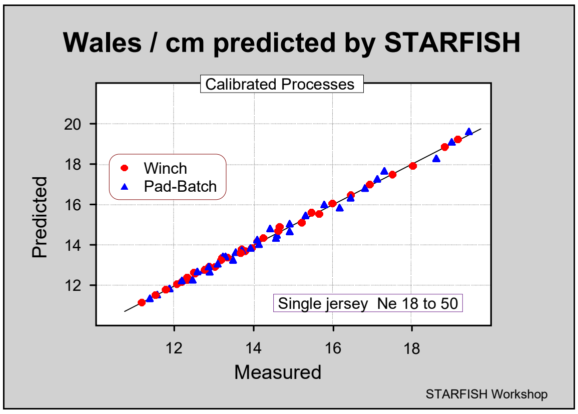


Most of the time, the predictions provided by the standard average models will be sufficiently accurate. However, it has been recognised that not all plants have equipment that performs close to the average, so the STARFISH program is provided with a customising facility.

The user can enter his actual measured values for courses and wales, which the program will then use to develop a calibration. This calibration can be saved to a file and used as a standard model whenever such conditions pertain again in the future. The effect of different yarn specifications can be allowed for as well as the wet process and the depth of shade.

The next two graphs show the improvement that was achieved when the program was calibrated using the measured data from one of the fabric data sets for each yarn type and wet process, and then applied to them all. The agreement is now almost perfect. One could speculate that the scatter that remains must be due mainly to small "random errors" in the measured values.





In addition to fabric dimensions and shrinkages, the expected net weight loss due to wet processing, and the length and weight of the finished roll (based on a given grey roll weight) are calculated.

STARFISH Technology

With the STARFISH computer program available, the central problem of defining a proper production specification to achieve particular performance targets has been solved in a very effective and satisfying manner, for plain jersey, single, double and six-thread piqué, 1x1 and 2x2 rib, interlock and two-thread fleece fabrics. However, this facility alone is not sufficient to guarantee consistent performance levels for two reasons.

The first reason is that the STARFISH predictions refer to *average* performance values and they assume that the specified production conditions are being strictly maintained. In practice, there is always some variation in control of production conditions and this means that there will be variation in performance. Therefore, the first essential requirement for the introduction of the STARFISH system into any manufacturing regime must be an increased awareness of quality assurance and process control, plus a much closer attention to the key factors in production which lead to avoidable variations in the product. This aspect of the STARFISH system is dealt with in the online Help system, which accompanies the software, and is also covered in greater depth and detail in this special STARFISH WORKSHOP.

The second reason is that, although the computer programme is able to help in the setting of proper control targets for the finisher - for example in terms of the courses and width which must be delivered in order to achieve specified performance targets - it does not tell the finisher how to achieve these targets in practice. Therefore, the second essential requirement for the introduction of the STARFISH system is the acquisition of the latest finishing technology and application know-how. If a really good performance (i.e. low shrinkage) is required, then it will be found that traditional finishing technology is not good enough - especially for some of the more difficult fabrics such as interlock, fleece, and crosstuck (piqué). It goes without saying, of course, that additional attention to certain aspects of process control is also necessary in the finishing plant. The question of finishing technology, as well as quality control in the finishing plant is also covered in the online Help system and in this WORKSHOP.

Thus we see that upgrading the performance of cotton circular knitgoods in general requires three main elements, each of which is dependent upon the other.

- A rational system of fabric engineering based on the ability to predict the dimensions of the fabric in its fully relaxed state.
- The installation of Quality Assurance and Quality Control systems that are carefully focused on the key production control variables.
- The installation of the latest wet processing technology and the application of the corresponding technical know-how.