LOW SHRINKAGE BY DESIGN
The New STARFISH Software for Cotton Circular Knits

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INTRODUCTION

Knitters, dyers and finishers 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.

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 too uncertain.

A modern quality assurance system requires firstly that product performance can be designed in advance by (more or less) exact 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.

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 which will be used for process control (finishing targets).
3. The finishing machinery has to be provided with appropriate sensors and regulators.

This paper will discuss mainly the first two requirements from the point of view of the dyer and finisher, although the implications for knitters will be obvious.

In connection with item 3, it should be noted that appropriate sensors and regulators are now on the market, e.g. from Automation Partners (California) and Erhardt & Leimer (Germany). At the last ITMA such devices were being offered as options on a significant proportion of stenters and compactors.

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.

CHECKING THE SPECIFICATION

Normally, the dyer and finisher does not participate in the fabric design and specification exercise. He has to accept whatever fabric is supplied, and he will usually be required to deliver the dyed and finished fabric at a certain weight and width and with certain maximum levels of shrinkage.

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 these requirements. Therefore, it is absolutely essential that the dyer and finisher should be able to check whether the fabric is correctly engineered before he puts it into work. If the dyer and finisher has access to the equations which are used for fabric engineering, then he is able to make such checks.

There are two sources for such equations.

- The so-called K values
- The STARFISH computer program

Calculations Based on K values

The K values were derived from observations made by research workers of more than two decades ago that there is a strong relationship between the number of courses and wales per cm in a relaxed cotton knitted fabric and the reciprocal of the loop length used in knitting (*Figure 1*). Relaxed means after the fabric has been subjected to an appropriate wetting and drying procedure (e.g. a shrinkage test). Loop length is the average length of yarn in each knitted loop. It is given by the length of yarn fed to the knitting machine per revolution (or per pattern repeat) divided by the number of needles which are knitting.

The two basic equations are:

Courses per cm = Kc / loop length in cm [1]

Wales per cm = Kw / loop length in cm [2]

It was said that Kc and Kw were constants for a given fabric construction and fibre type, and that these K values could be used to calculate the course and wale densities in any fabric, provided only that the knitted loop length is known.

Once we have found the course and wale densities for the relaxed fabric, then these can be used together with the yarn count, the knitted loop length, and the number of needles in the knitting machine to calculate the relaxed fabric weight and width.

Wt = tex * loop length * courses * wales * F1 [3]

Width = Number of needles / wales * F2 [4]

Where

F1 and F2 are scaling factors, depending on the units of measurement.

Courses and wales, weight and width in the unrelaxed fabric (i.e. as delivered to the customer) can then be derived by proportional scaling, according to the appropriate level of shrinkage.

Length Shrinkage = (Cr - Cd) / Cr [5]

Width Shrinkage = (Wr - Wd) / Wr [6]

Where

Cr and Wr are the relaxed courses and wales, Cd and Wd are the as-delivered values.

If the calculated as-delivered weight and width values do not coincide with what the customer has specified, then the fabric has not been correctly engineered, and this is a matter for serious discussion between the dyer and finisher and the customer.

If the calculated weight and width do coincide with the customer's requirements, then the calculated values for as-delivered courses and wales provide the dyer and finisher with his primary finishing targets. If he can hit these values in the delivered fabric, then the calculated weight and width, and the shrinkage values used in the calculation are guaranteed.

The finishing targets can be used as the basis for setting and operating control systems on stenters and compactors, which will aid the finisher in achieving his targets, and thus the required fabric performance. In practice the width will be used in preference to the number of wales per cm for control purposes, but there is no satisfactory substitute for courses per cm as the primary length control parameter.

Since the yarn count and loop length should be known from the knitting specification, it would seem to be a simple task for the dyer and finisher to check that a given grey fabric has been correctly engineered so that the weight, width and shrinkages required by the customer can actually be delivered. Kc and Kw values can easily be picked up from the literature, or can be determined on the grey fabric already to hand.

Limitations of K values

Unfortunately, it is now known that Kc and Kw are actually not constants. They are affected quite significantly by several factors including especially certain aspects of the yarn specification, and any wet processing which may have been carried out on the fabric. For example, K values for plain jersey fabrics which have appeared in the literature over the last two decades range from 5.1 to 5.8 for Kc and 4.1 to 4.95 for Kw. This range of variation is not some kind of experimental error. It is a reflection of real differences in K values, due to differences in the experimental conditions used by the various workers. It also represents approximately the range of K values which we have found in our own experimental work.

Some of these effects are illustrated by *Figures 2 and 3* which show the influence of the knitted Tightness Factor and wet processing on the values of Kc and Kw for a wide range of plain jersey fabrics, knitted from seven different yarns. Tightness Factor is given by the square root of the yarn count in tex divided by the Loop Length in cm. There are relatively large differences between the K values for grey fabric and those for the two sets of finished fabrics, and the wide scatter in the data, within a given wet process, is a reflection of the influence of the yarn properties upon the K values. In this context, it should be noted that a difference of only 0.1 unit in Kc represents a difference in length shrinkage of about two percentage points; a similar difference in Kw represents two and a half percentage points of width shrinkage.

Therefore, a dyer and finisher who wants to make use of simple K values to check for correct fabric design, or to develop finishing targets, should take care to use the appropriate values. Because the K values are affected by the wet process, he would be well advised to carry out determinations of courses and wales on his own finished fabrics. It is definitely not the case that he can determine K values on the grey fabrics and use these for making calculations. Indeed, the only value for the dyer and finisher in making measurements on grey fabrics is to ensure that the yarn count and loop length are exactly as specified.

Figures 4 and 5 show the dangers of using inappropriate K values for such calculations. The data behind these graphs comes from one of many STARFISH data base projects. In this case, six different yarns were each knitted at five different loop lengths, covering the normal commercial range of tightness factors, and a seventh yarn was knitted at three different loop lengths. Several rolls of all 33 qualities were produced, and the fabrics were processed, full scale, at several different dyeing and finishing plants. In other words, these are not small-scale laboratory trials, they are fully representative of commercial conditions. Results from only two of the wet processing routes are shown.

Kc and Kw were determined on the grey fabrics and their averages were computed. These averages were then used to calculate courses and wales for the dyed and finished fabrics using equations [1] and [2]. The graphs compare the calculated values with those actually measured on the finished fabrics. This is approximately what would happen if K values were taken from the literature or if they were determined on the grey fabric before putting it into work. The straight line on these graphs shows where Y = X, i.e. where calculated = measured and the error is zero.
It is clear that this is an unsatisfactory way to check a fabric specification, or to determine the correct finishing targets. Errors in estimation of more than ten percent are apparent. Since the dyer and finisher will be asked to deliver fabric with a shrinkage of less than about five percent, a potential error of ten percent is quite intolerable.

Figures 6 and 7 show the considerable improvement that can be gained by using Kc and Kw values which were determined on the finished fabrics rather than the grey. Separate estimations of Kc and Kw were made for each of the two different wet processing regimes. This amounts to a kind of calibration of the K values, so that they are representative of the dyer and finisher's own particular situation. However, even in this case there is still a fair amount of scatter in the data. Part of this will be due to measuring errors but still there is cause for concern, particularly in the case of the wales where errors of more than five percent are frequent.

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 5,000 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, such as those reported here, which allow us to perform 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 which 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 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.

It should be emphasised that the equations used by STARFISH are not dependent in any way on K values. They include additional terms which allow for the yarn type, the yarn count, the wet process, and the depth of shade.

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). *Figures 8 and 9* show the result of selecting the appropriate standard wet process on the calculated values of courses and wales, compared to those actually measured, for the same series of fabrics as in *Figures 6 and 7*. Clearly, the standard STARFISH equations are better able to cope with those additional effects which can not be allowed for by using K values.

However, just as the K values can be calibrated by making adjustments in the light of actual measurements, so too the STARFISH program provides a calibration facility. The user can enter his actual measured values which the program will then use to develop a calibration. This calibration can be saved to a file and used either as a standard model or 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.

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.

Figures 10 and 11 show the effect of calibrating the STARFISH model for the same yarns and finishes reported above. The agreement is now almost perfect. One could speculate that the scatter that remains must be due mainly to small "errors" in the measured values.

SUMMARY AND CONCLUSIONS

Demands on dyers and finishers to deliver low shrinkage on cotton circular knits will only grow more intense in an ever more competitive environment.

It is impossible for the dyer and finisher to deliver accurately to a given specification of weight, width and shrinkage if the basic fabric has not been correctly engineered.

Therefore, the dyer and finisher needs to be able to check that the fabric he has been given has been correctly designed for the performance he is expected to deliver. He also needs to be able to calculate the correct finishing targets, in terms of the courses and wales which he must strive to obtain in the delivered fabric.

The most effective means of checking performance specifications and developing correct finishing targets is by use of the STARFISH computer program, which can easily be calibrated to reflect actual commercial conditions within a given dyeing and finishing enterprise.

Figures

Figure 1

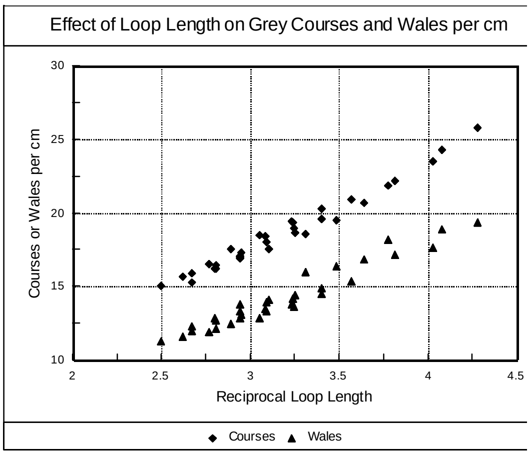


Figure 2

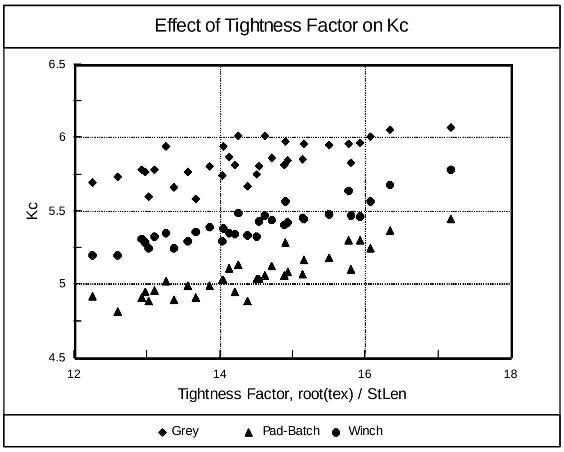


Figure 3

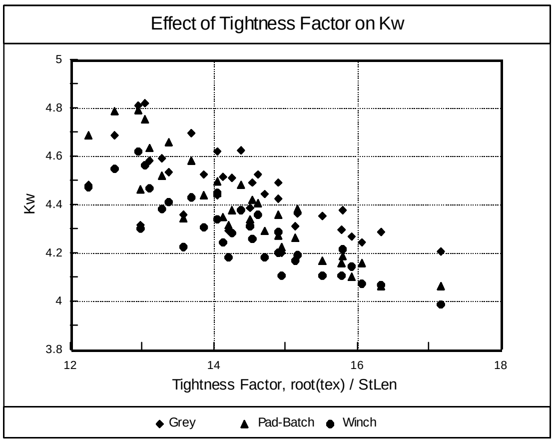


Figure 4

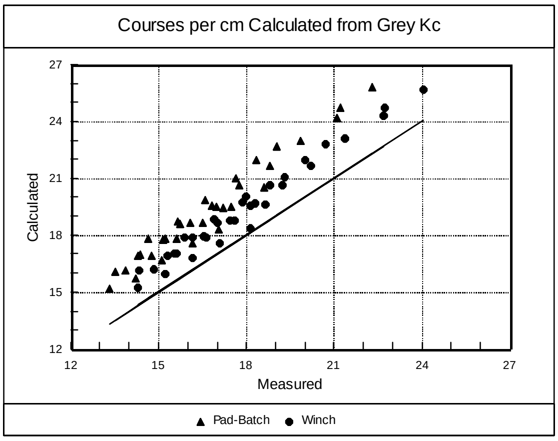


Figure 5

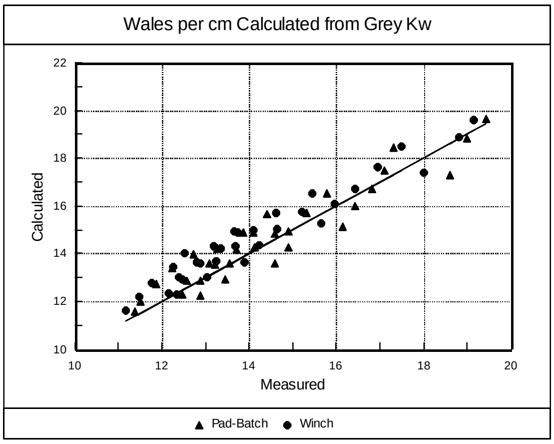


Figure 6

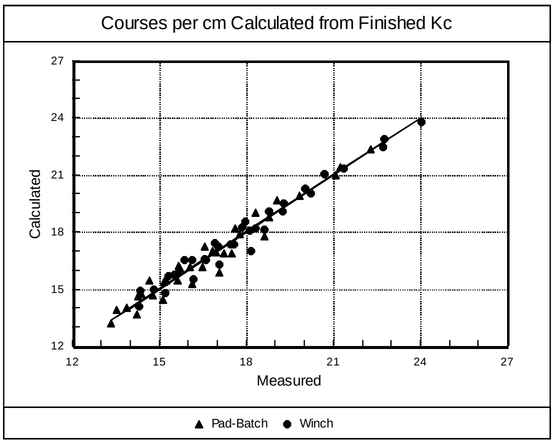


Figure 7

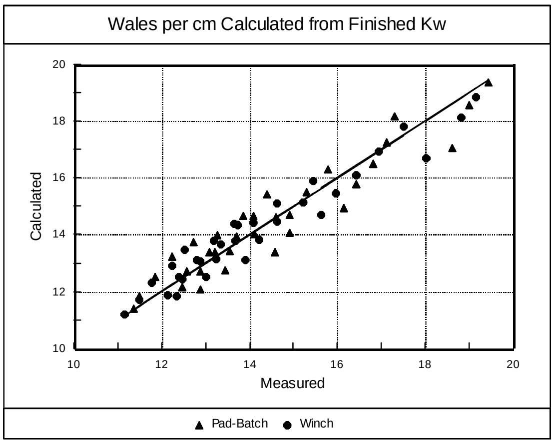


Figure 8

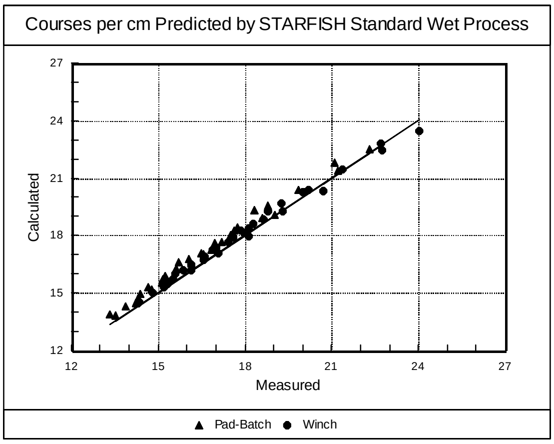


Figure 9

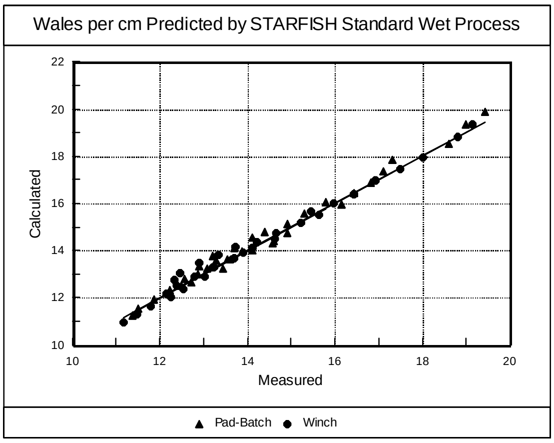


Figure 10

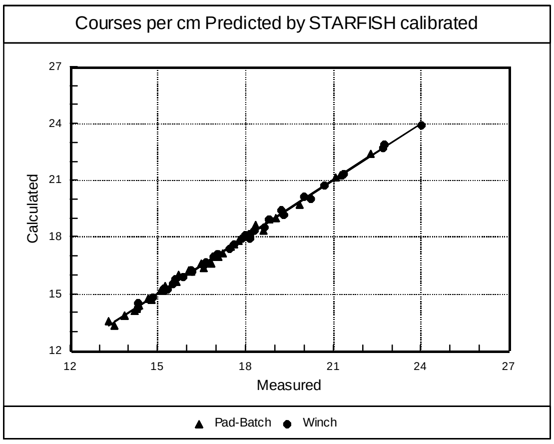
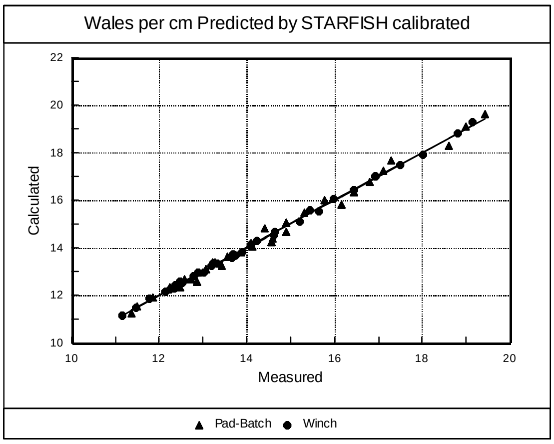


Figure 11



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