SHRINKAGE
YOU DON'T NEED TO MEASURE IT TO BE ABLE TO CONTROL IT

S. Allan Heap & Jill C Stevens, Cotton Technology International, Stockport, U.K.

Presented at the 36th Congress of the IFKT, Ghent, Belgium, September 1994

INTRODUCTION

Cotton knitters and finishers are faced with constantly-increasing global competition and ever-rising demands for better quality and reliability. One of the key demands is for circular knitted fabrics and garments having consistently low levels of potential shrinkage. Therefore, a great deal of time and money is expended, especially by the finishers and garment retailers, in making routine tests for shrinkage. Unfortunately, the shrinkage test often is not very reliable (*Figure 1*) but, what is worse, it is not very informative.

For a large garment retailer, a shrinkage test may be a reasonable pass/fail criterion because, provided that he has been keeping good records (and provided that his testing is consistent), he can obtain some idea of the level of complaints that he may expect from his customers as a function of the average level of shrinkage in the products that he offers.

For the fabric manufacturer and finisher, the shrinkage test is of very limited value. A poor shrinkage result will indicate that something about the fabric is not right but it gives no information about where the fault lies. There are (at least) three major reasons why a given fabric may exhibit unacceptably high shrinkage.

1. The fabric was not properly engineered for the required performance (inappropriate choice of knitting conditions).

2. The finishing targets were inappropriate (incompatible values for weight, width, and shrinkage).

3. The finisher has failed to hit the finishing targets.

Thus the shrinkage test has little or no diagnostic value for the manufacturer **-** it can not tell him how to improve the product, merely that improvement is needed. Furthermore, the shrinkage has no value as a production control parameter. Its result is available only after the fabric has been finished so it can not be utilised to make short-term adjustments to production conditions.
In passing, it may be noted that the shrinkage measured on a fabric (using the usual routine test methods) is not a very reliable guide to the shrinkage which will be measured in a garment made from that fabric - still less to the shrinkage which will be experienced by the ultimate purchaser of that garment after it has been worn and laundered several times (Figure 2).

In fact it is our impression that there are two main reasons why finishers test for shrinkage. Firstly because their customers demand a certain (maximum) level of shrinkage and secondly because they are not able confidently to predict what will be the actual level of shrinkage in a given fabric on a given day. In short, they need to know the level of shrinkage in their fabrics and the only way that they can know it is to measure it.

AN ALTERNATIVE SYSTEM

Shrinkage is a measure of distortion in a fabric. Shrinkage is the result of relaxation of manufacturing and processing strains. It is defined as the difference in dimensions between the fabric as delivered and the fabric after some relaxation process. The amount of shrinkage that will be measured in a given fabric depends firstly on by how much it had previously been distorted and secondly on how efficiently it is relaxed during the shrinkage test. Different shrinkage test methods (and different aftercare regimes by consumers) involve different relaxation treatments and therefore deliver different results.

The reason that we can not predict shrinkage is that we can not predict the effect of the relaxation treatment. After all, we always know what are the dimensions of the as-delivered fabric before we carry out a shrinkage test (or the dimensions of a garment at the point of sale). What we do not know is what will be the dimensions of the fabric (or garment) after the test (or after the consumer has worn and laundered the garment several times).

If we could predict what would be the dimensions of a given fabric after the shrinkage test, then we would not need to measure shrinkage because we could calculate it easily from the known as-delivered dimensions. What is more important, we would also be able to calculate what should be the as-delivered dimensions in order to have a certain level of shrinkage. This would then have a very important consequence. Once we are able to calculate the required as-delivered dimensions for a given level of performance, then we have a vital process control tool which can be used to adjust the processing conditions, on a short term basis, to guarantee the required level of potential shrinkage in the as-delivered fabric.

Shrinkage can be calculated about as reliably as it can be measured from the density of courses and wales in the fabric, before and after relaxation (*Figures 3 and 4*).

Thus:

Length Shrinkage = 100 (CA - CB) / CA

Width Shrinkage = 100 (WA - WB) / WA

Where:

CB, WB are the courses and wales per unit distance, before relaxation,

CA, WA are the courses and wales per unit distance, after relaxation.

Therefore, provided that we can define a reliable and reproducible relaxation process, and provided that we can predict the number of courses and wales that the fabric will attain after such relaxation process, then we will be able to use the courses and wales, measured in the as-delivered fabric both to calculate potential shrinkage and to use as process control parameters. It is an advantage if the relaxation treatment is one that produces (close to) the maximum possible relaxation.

It is relatively easy to define a standard relaxation process. The one that we (and others) have used consists of five cycles of washing and tumble drying, followed by conditioning. To obtain the best reproducibility, the detailed relaxation conditions (especially of tumble drying) have to be rigidly standardised. To distinguish our particular set of conditions we have named our relaxation treatment the "Reference Relaxation Procedure". Fabrics which have been subjected to this treatment are said to be in their "Reference State". In the two equations above, we would substitute the "Reference courses" and the "Reference wales" for CA and WA.

For any given fabric, which is available to the finisher on a regular basis, it is relatively easy to establish what are the Reference courses and wales. All that is necessary is to sample the finished fabric on several different occasions, subject the samples to the Reference Relaxation Procedure, and count the courses and wales in the Reference State. If the fabric is being knitted consistently, from piece to piece, from machine to machine, and from day to day, then only five to ten separate determinations of Reference State dimensions will be needed to establish a good average.

If the fabric is not being knitted consistently, then serial measurements of the Reference courses and wales will reveal this important fact. This is a matter for serious discussion between knitter and finisher because the finisher has no chance of producing a reliable *finished fabric from unreliable grey goods (though he will probably take the blame from the customer). It can be argued that, especially for commission finishers, this aspect alone will justify significant investment in monitoring Reference courses and wales.*

Once the average Reference State courses and wales are known, then it is a simple matter to calculate what should be the as-delivered courses and wales in order to have the required level of shrinkage. These values can then be used as finishing targets for process control purposes. Provided that the finisher can hit the targets, and provided that the knitting conditions remain constant, then the desired (average) level of shrinkage is guaranteed. It does not change merely by being measured.

The same principle can be applied to any new fabric that is supplied to a finisher. For such an unknown product, the finisher must first take the fabric through the preparation and dyeing process. He then samples the fabric before the final drying and calendering or compacting operation to determine the Reference courses and wales. Once these are known, then targets for courses and width can be calculated for the final finished fabric, as delivered to the garment maker. The main difficulty here is the amount of time it takes to carry out five cycles of washing and tumble-drying. In practice, a decision will be made based on only one cycle - though the full five cycles should ideally be carried out and the result filed for future reference.

The careful commission finisher will carry out this procedure in any case for any new quality. Not only does it allow him to determine the correct finishing targets for a given level of shrinkage but also it allows him to check whether the weight and width specifications he has been given by the customer are actually achievable at the desired level of shrinkage. If not, then the customer can be advised of the findings, warned that the fabric has not been correctly engineered for the stated performance requirements, and asked to choose whether he prefers the target weight and width or the target shrinkages.

PRODUCT DEVELOPMENT

Of course, this approach only works really well when we have a standard, long-running, and basically satisfactory product. What is more important, it also works only if the calculated finishing targets produce not only the desired level of shrinkage but also the weight and width, which are requested by the customer.

The real difficulty comes when we are faced with a product which is too heavy and too narrow when the shrinkage is correct, but shrinks excessively when delivered at the target weight and width; in other words, a product which has not been correctly designed for the end-use requirements. Such products are very common. They are an inevitable by-product of the demand for improved performance from our customers; they are a consequence of a change in end-use requirements.

In such cases, we need to know more about how to re-engineer the fabric so that all of the desired finishing targets are mutually compatible. In brief, we need to be able to predict the Reference courses and wales of an unknown fabric.

It is already well known that the fully-relaxed courses and wales of grey circular knitted fabrics are determined only by the knitting variables - especially the knitted stitch length but also the yarn count and the yarn construction. However, it is another matter actually to calculate Reference courses and wales of grey fabrics accurately from information available in the literature and, moreover, the properties of the grey fabrics are not a sufficient guide. The Reference courses and wales are significantly different in the finished fabric from those in the grey. Furthermore, the effect of preparation, dyeing and finishing upon the Reference Dimensions depends on the type of wet processing to be used (*Figures 5 and 6*).

In general, wet processing will usually cause a permanent lengthening of the fabric (fewer courses per cm in the Reference State). Wet processes, which embody very high tensions (e.g. continuous rope preparation), cause greater permanent elongation than those that have low tensions (e.g. overflow jets). High processing tensions also will tend to cause a permanent narrowing of the width (more wales per cm in the Reference State). However, at the same time there is a countervailing tendency in the width direction, due to a reduction in yarn twist liveliness and an increase in yarn specific volume, both of which can cause growth in the width. Processes which result in greater yarn bulking, such as long dyeing cycles in high-impulse jet machines will give greater gains (or smaller losses) in width. Processes, which tend to preserve the integrity of the yarn structure, such as pad-batch preparation and dyeing, may result in significant width reductions. In the length direction, the reduction in twist liveliness works to reduce the number of courses in the Reference State. This can reinforce any tension effects.

Because of the countervailing effects in the width and reinforcing effects in the length, net permanent changes in the width direction as a result of different wet process routes are generally of smaller magnitude than changes in the length. A notable exception is certain types of tubular mercerising process which can cause large reductions in the Reference width. For an old-fashioned winch prepare and dye process, the Reference width in the finished fabric is usually not much different from that in the grey. This may be one reason why the grey width was traditionally used as a guide to finished width with reasonable success. Unfortunately, with modern processing equipment (which may differ in different finishing plants), and with modern demands for lower levels of shrinkage, the old guide-lines are no longer good enough.

Nevertheless, for given types of fabric, within a narrow range of qualities and processed over a standard wet processing line, there will tend to be a more or less constant relationship between the Reference courses and wales in the grey fabric and those which will be found after finishing. It follows that there also will be a more or less constant relationship between two different types of wet processing (*Figures 7 and 8*).

For those knitters and finishers who are still using the trial and error system of fabric development this knowledge allows a considerable saving in time and cost. If the relationship between grey and finished (Reference State) fabrics can be established empirically, then it is not necessary actually to dye and finish the fabric in order to know what will be the (approximate) values of Reference courses and wales after dyeing and finishing, and hence to determine whether the result of a given knitting trial is likely to yield a satisfactory finished fabric.

THE STARFISH APPROACH

With the STARFISH computer program, the average values for Reference courses and wales of a very wide range of dyed and finished fabrics can be estimated fairly 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.

From the description of the effect of wet processing given above, it will be appreciated that, within certain limits, a pretty wide range of effects can be found in practice. In other words, for a given grey fabric construction, the Reference courses and wales in the finished fabric may be found at any point within the range which represents the total spread of possible results for different types of wet process. For a single process type (e.g. overflow jets), this range is actually quite narrow but, even so, it can represent differences in calculated shrinkage values of the order of several percentage points. Particular combinations of wet processing conditions might extend the range even further.

In the early version of the STARFISH program, the choice of wet processing options that could be simulated was rather limited, and was restricted to specific types of machinery. The user was obliged to select the process which most closely matched his own and to observe the systematic offsets in the predicted performance, compared to that actually achieved. Once the offsets were established, then they could be accommodated in the (re-calculated) finishing targets.

In the latest version of the program (Version 5), two changes have been introduced. These were made possible by a significant broadening of the STARFISH database, followed by a complete new mathematical analysis.

Firstly, instead of specific machinery, *average process types* have been defined. In the data base, all of the process lines of the same general type - e.g. winches, jets, continuous prepare, etc. - were grouped and their average effect was established. This means that when, for example a winch type process is selected, the STARFISH predictions will be based on the average effect of such processes. In other words, the predictions will tend to lie close to the centre of the natural spread of results that will be found for winch type processes; the different effects of different designs of winch and different methods of operation will tend to cluster around the STARFISH prediction. Note that many modern jet-dyeing machines are very similar in their basic operating characteristics to modern winches.

Secondly, a so-called process calibration routine has been included. If a finisher can establish the true Reference courses and wales for one standard quality, processed through his standard wet process route(s), then these can be used to modify the output of the STARFISH program so that all qualities of the same fabric type can henceforth be predicted more accurately. Thus, for example, the average STARFISH winch process can be made to conform to the specific conditions of a particular dyeing and finishing plant, (which actually may include overflow jets) thereby improving the accuracy of its predictions.

SUMMARY AND CONCLUSIONS

1. The measurement of shrinkage may serve as a (very) rough guide to retailers to establish the approximate performance of a given product in the consumer market, but it is of very limited help to a knitter or finisher. In particular, a shrinkage value has no diagnostic power and can not be utilised as a process control parameter or a tool for product development.

2. There is no need to measure shrinkage if it can be calculated.

3. Calculation becomes possible once we can predict what will be the average values for the courses and wales per cm for any given finished fabric in its Reference State. These are determined primarily by the knitting conditions (yarn and stitch length) but also are significantly affected by the type of wet processing used in preparation and dyeing, and the processing conditions.

4. Once the Reference courses and wales are known, they can be used for process control to deliver fabrics with predictable levels of weight, width and shrinkage.

5. For individual, established, reliable, long-running products, the average values for Reference courses and wales can be determined easily enough by measurements made on a series of deliveries of the finished fabrics. For a standard wet process, they can also be estimated approximately from the values determined on grey fabrics, provided that the effect of the wet process has been established carefully in advance, and a reliable sample of the grey fabric is available.

6. For new product development it is necessary (and highly cost-effective) to use the STARFISH computer program to estimate the Reference values of courses and wales for candidate development fabrics in advance of any knitting and finishing trials.

7. STARFISH predictions of Reference courses and wales refer to averages for given types of wet process. These predictions will generally be pretty close to the values which will be found in practice, but the finisher has the facility to "calibrate" his wet process, and hence to modify the output of the computer program so that it refers not to the average process but to his own specific situation.

POSTSCRIPT

We have pointed out, both here and elsewhere, that the average Reference values for courses and wales are fixed primarily by the knitting variables and that, for a constant wet processing route, the effect of the wet process on the average Reference dimensions is also constant. It follows that ***for a constant wet process***, the Reference courses and wales in the finished fabric are fixed by the knitter.

In many if not most cases, the final as-delivered dimensions of the finished fabric are also fixed (within certain tolerances), by the customer in terms of his specifications for the weight and width which must be delivered by the finisher.

Since the Reference dimensions are fixed by the knitter, and the as-delivered dimensions are fixed by the customer, and since the difference between the two is the shrinkage, it follows that, in principle, the finisher who succeeds in delivering exactly the required weight and width has no control over shrinkage.

This fact has been taken by some finishers to mean that, provided they meet the customer's specifications for weight and width, then they have no responsibility for the level of shrinkage that they are constrained to deliver.

Whilst this is a reasonable and understandable (and often a true) interpretation, it is justified only when the finisher is really able to guarantee a truly constant wet process. Such perfection must be rare (probably about as rare as a knitter who is able to guarantee truly constant knitting conditions). In particular, we have seen examples of nominally identical finishing plants (sometimes side-by-side in the same factory) where small, but nevertheless significantly different results are obtained.

The fact is that machinery and operating conditions are seldom absolutely constant. Machinery builders are always improving (changing) the detail of their designs and some of these changes are bound to affect tension and other conditions during processing. Preparation conditions, dye recipes and dyeing cycles are seldom identical from batch to batch. Maybe one day, when automatic controls for machinery and chemical recipes are fully developed, standardised, and universally installed, then finishers will run their processes identically from batch to batch and from month to month: but that day has not yet arrived.

Therefore, it is important that finishers should not be complacent about their apparent lack of influence on shrinkage. They should constantly be monitoring the effect of their particular processes upon the Reference Dimensions so that they are aware of the average effect, the variations in the effect, and any drifts, which may be occurring.

This mild warning to finishers does not invalidate the basic conclusion of the general argument, of course, which is that a modern, reliable, reproducible product, conforming to the customer's demands and expectations can scarcely, if ever be developed without the active, close, and informed participation of all three parties, knitter, finisher, and customer, to the product design exercise. In our view, ***informed*** implies having access to the STARFISH system of product design and process control.

FIGURES

Figure 1

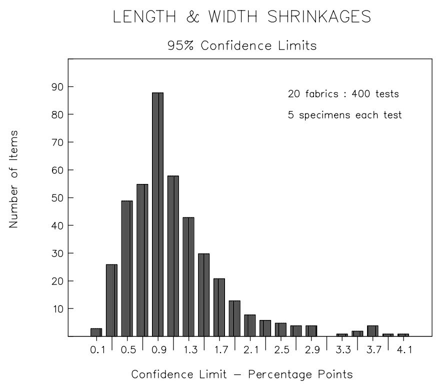


Figure 2

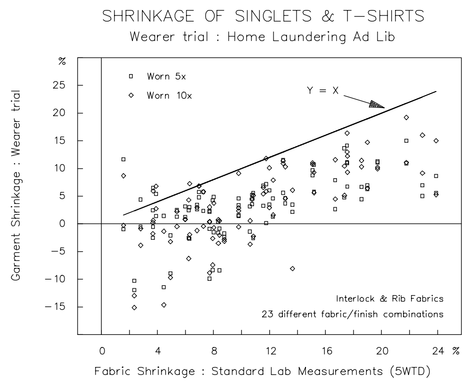


Figure 3

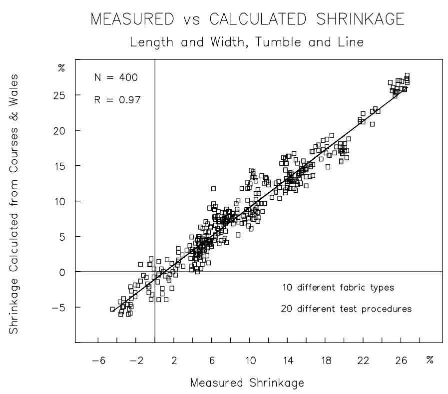


Figure 4

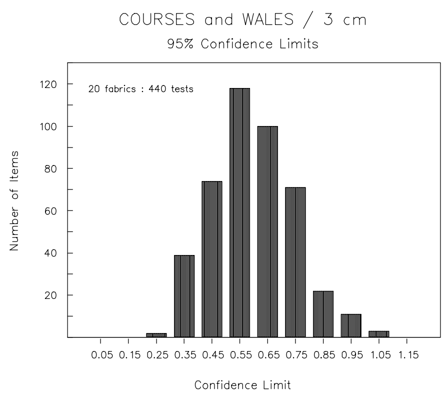


Figure 5

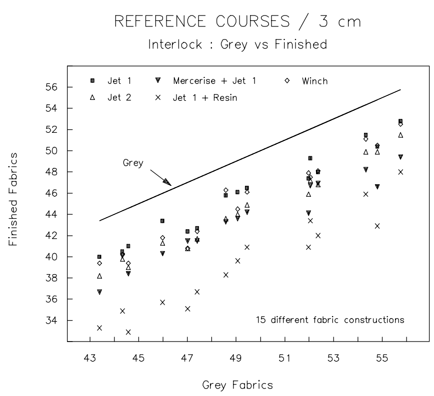


Figure 6

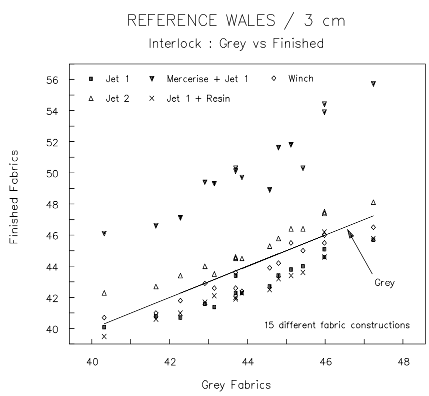


Figure 7

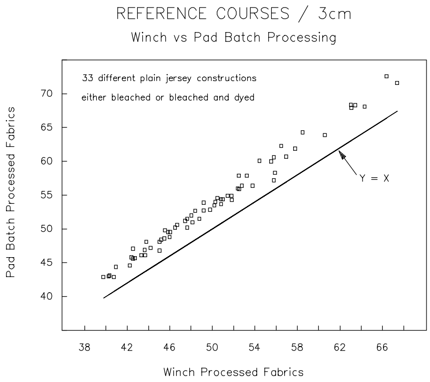
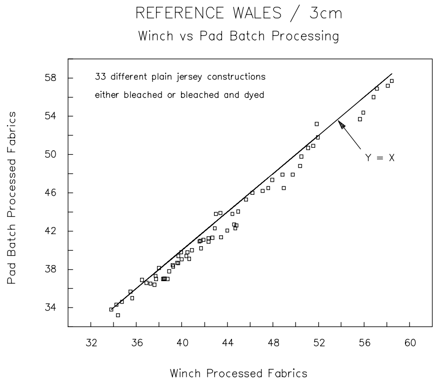


Figure 8



For more information, please contact:

Cotton Technology International
27 Winnington Road, Marple, Stockport SK6 6PD, UK

Phone: +44 (0) 161 449 5593 : Fax: +44 (0) 161 449 5594 : email: cotton.tech@virgin.net