THE EFFECT OF OPEN-END ROTOR YARN QUALITY ON DIMENSIONS AND SHRINKAGE OF COTTON INTERLOCK FABRICS

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INTRODUCTION

Two of the important new concepts of recent years are those of "Quick Response" and "Total Quality Management". These are both large and complex subjects which, for practical implementation in a knitting factory, require the adoption of many new technical and organisational procedures and, perhaps more importantly, some fundamental changes in attitudes. Among these new procedures and attitudes are :

- The ability to develop new products, or improve the performance of existing products very rapidly and **according to the specific requirements of the customer** (rather than according to what we have always made before).

- The ability to **predetermine product quality and reliability** through the identification and continuous positive control of key raw material and process parameters (rather than by trial and error processing) so that product quality is guaranteed by making it "right first time and every time".

A feature of modern quality assurance systems is that they rely to a large extent on more or less exact numerical solutions to development and control problems, rather than trial and error solutions based on past experience plus manual tuning. In modern production situations, trial and error development and control systems are simply too expensive and too unreliable. In other words, when we want to develop a new product, we have to be able to calculate exactly what are the raw materials which must be used and the control settings of the key machines which must be maintained.

Probably the most obvious and widespread example of this approach is computer-based dye recipe selection combined with automated dyebath preparation and metering (together with strict quality control of water and chemicals) to allow one-shot dyeing for the majority of dyelots with no need for shading additions. Although the cost of such equipment is very high, it can easily be justified in terms of savings in time, reductions in reprocessing, and improvements in quality and reliability.

A further example, in the field of circular knitted cotton fabrics, is the need to guarantee that the weight per unit area and especially the shrinkage of the fabric shall conform to particular customer requirements reliably and consistently. In this case, the computer software which models the fabric manufacturing, dyeing, and finishing processes is the **STARFISH** system and the raw material which has to be closely controlled is the yarn. The main yarn quality parameters which affect the weight and shrinkage of knitted fabrics are the yarn type (ring, rotor, carded, combed), the yarn count (yarn weight and diameter), the yarn twist, and the basic fibre quality (especially fibre fineness and maturity). Other yarn properties are of course important for manufacturing efficiency and fabric appearance but they do not affect the weight and shrinkage.

In the **STARFISH** software, the separate effects of these four different aspects of yarn quality are modelled by only two parameters, namely the yarn type and the yarn count. This is partly because of the enormous time and expense which would be required to develop a comprehensive data base to properly take account of variations in twist and fibre quality. However, it is also the case that, in practice, only a narrow range of twist factors is actually used for knitting yarns and, moreover, the quality of fibre used tends to be related to the yarn type and the yarn count. Therefore, the practical range of influence of twist and fibre quality is much less than the potential range.

In spite of this reasoning, it is fairly important for the knitter to monitor the twist of his yarns and to ensure that the fibre quality stays more or less the same from lot to lot if he wants to guarantee a consistent product. In addition, we would like eventually to be able to include the yarn twist as a separate input parameter in the **STARFISH** computer software because twist is important in determining the spirality of plain jersey fabrics. Spirality is a fabric performance property that we have studied extensively and that we would like to be able to predict in a future version of the **STARFISH** software.

Therefore, from time to time, we do carry out studies of the effect of twist and fibre quality on the dimensions and shrinkage of circular knitted cotton fabrics. This report summarises a part of the results from some experimental work which was carried out on interlock fabrics made from open-end rotor yarn fabrics made from two different cotton fibre qualities spun to different yarn counts at different twist levels.

EXPERIMENTAL

Bales of cotton from two separate origins were available. The main fibre quality parameters were as follows.

Origin	West Texas	California
Staple Length, mm	25.9	27.9
Micronaire value	4.0	4.3
Tenacity, g/tex	22.4	27.1

The bales were prepared over a hopper feeder, step cleaner, chute feed, card at 25 Kg/hour, followed by two passages drawing to 3.9 Ktex sliver. Spinning was on a Schlafhorst Autocoro rotor frame fitted with a G33D rotor running at 90,000 rpm. and a KN4 navel with twist-stop device. From each cotton type, three yarn counts were spun, each at three twist levels, as follows.

Yarn Count, Ne	22	26	30
Twist Multiple	3.50	3.75	3.97
Twist Multiple	4.01	4.27	4.50
Twist Multiple	4.51	4.74	5.00

Each of the yarns was knitted into interlock fabrics, on a 30" diameter, 18g Mayer machine, at three separate levels of tightness factor, namely 11.0, 12.0 and 13.0. Tightness factor is the square root of the yarn count (tex) divided by the stitch length (cm). Fabrics were alkali scoured and peroxide bleached in several lots in a Burlington winch beck, then hydroextracted by centrifuge and dried in a Huebsch tumble drier.

The finished fabrics were all tested using standard methods for the main parameters, namely yarn count, stitch length, course density, wale density and unit weight. Fabrics were tested both dry relaxed and also after the **STARFISH** Reference Relaxation procedure (five cycles of washing and tumble drying in automatic domestic laundering equipment).

RESULTS

Preliminary Considerations

It is an unfortunate fact of knitted fabric geometry that one can learn little or nothing about the effect of variation in yarn quality (or any other manufacturing variable) upon the shrinkage performance of circular knitted cotton fabrics merely by measuring shrinkages. Shrinkage for a given fabric quality can take on a wide range of values depending on the tensions which have been applied to the fabric during processing. Furthermore, shrinkage is a very unreliable test parameter so that its results can be quite different from day to day and especially from laboratory to laboratory. In fact, it is our opinion that knitters and finishers spend altogether too much time and money measuring shrinkage which is an almost worthless parameter for purposes of product design and quality assurance.

The only fixed reference points are the number of courses and wales in the fabric **after all shrinkage has been removed** and, in general, the results of our research and development trials can only be interpreted rationally by considering the fully relaxed (Reference) dimensions of the fabrics. For the present case, therefore, we are interested in the effect of the yarn quality parameters upon the level of courses and wales measured in the fully relaxed (Reference State) finished fabrics.

The effect of variation in stitch length is well known. *Figure 1* shows the graph of courses and wales plotted against the reciprocal of stitch length for all of the 54 fabrics. Apart from experimental error, the scatter in this graph is due mainly to the variations in yarn count, twist multiple and fibre type.

To separate the independent effects of these yarn quality variables, it is first necessary to manipulate the data in such a way that the dominant influence of the stitch length is removed. This can be done by reference to the fact that, for a given yarn quality, there is a close straight-line relationship between the Reference State courses or wales per cm and the reciprocal of the stitch length. The difference between the different yarns is the intercept that this straight line makes with the axis of courses or wales. If these intercepts are different, then the number of courses and wales in the Reference State will be different and, hence (for a given target finishing specification) the shrinkages of fabrics, as delivered to the garment maker, will also be different in the same proportions.

Figure 2 shows the effect of the yarn count and twist multiple on the reference courses and wales, for each yarn count, averaged over the two cotton types and independent of the stitch length. The ordinate for this graph is the absolute value of the (normalised) intercept of the straight-line relationships between courses or wales per cm and reciprocal stitch length. They are in units of courses and wales. Absolute values are shown because the intercept for courses is actually negative. For a given yarn count and stitch length, increasing the yarn twist will increase the number of both courses and wales in the Reference State, though the effect on the level of courses is apparently much greater than on the wales. From these data it is possible to develop regression equations which predict the independent effect of twist multiple on the courses and wales. Correlation coefficients for such regressions are generally better than $R = 0.98$.

Effect of Twist level

From these regression equations we can easily calculate the effect of twist multiple on fabric shrinkage by comparing the differences to the average values of Reference courses and wales at some arbitrary base level of twist multiple for each yarn count. The result is shown in *Figure 3,* where the base value for the twist multiple is taken as 3.6.

The additional shrinkage caused by increasing twist multiple, over the range 3.6 to 4.4, is about three percentage points for the length and about one-and-a-half percentage points for the width. This is, of course, a much wider range of twist multiples than would normally be allowed by knitters so the practical consequences of twist variation in yarn supplies are likely to be less than half of the effect shown here.

Effect of Fibre Quality

In general, cottons from California tend to be longer, finer, stronger, and more mature than those from Texas. The fibre test data given earlier are consistent with this expectation. Since the yarns from the two different fibre types were spun under the same conditions, to the same nominal counts and twist multiples, and were knitted at the same nominal tightness factors, we can deduce the average effect of fibre quality from the Reference State courses and wales after averaging over twist and stitch length, within yarn counts. These data are shown in *Table 1.*

The differences are not large but, nevertheless, they imply that if a yarn which was normally made from this particular Californian cotton were to be substituted by one made from the Texas cotton, and the fabric was delivered with exactly the same unit weight and width, then the length shrinkage would be about two percentage points greater and the width shrinkage would be about two percentage points less. Among the world's cotton varieties and origins there are larger differences in basic fibre quality than those which have been investigated here.

Comparison with Typical Ring-Yarn Fabrics

We can make a rough comparison by establishing the level of courses and wales which would be expected for a typical combed ring yarn of the same average yarn count and knitted stitch length, by reference to the output of the **STARFISH** computer prediction program. These data are shown in *Table 2.* They refer to ring yarns with twist factors of about 3.6 and a typical winch bleaching process. The rotor yarns in the table are the ones of this experiment, averaged over stitch length and twist factor within yarn counts. The average twist factors of the rotor yarns are significantly higher than those of the ring yarns and, moreover, the wet processing was also somewhat different. Both of these facts are reflected in the differences which are found in the fully relaxed courses and wales for the two types of fabric.

For a given yarn count and stitch length, the differences in the levels of courses and wales in the Reference State do not look very large but they can have serious consequences for the shrinkages of the corresponding fabrics. The figures in the last two columns show that, if these particular rotor-yarn fabrics were to be delivered by the finisher at the same weight and width as the typical ring-yarn fabrics then, on the average, their length shrinkages would be five to nine percent greater and their width shrinkages would be three to four percent less.

CONCLUSIONS

In addition to the yarn count, it seems that cotton fibre type and yarn twist multiple probably have a significant effect on the fully relaxed dimensions of interlock fabrics made from open-end rotor spun yarns.

This means that, for a given nominal quality of fabric (made from a given yarn count, knitted to a given stitch length, dyed and finished in a given way to fixed targets of unit weight and width), if significant variations are allowed in the fibre quality and the yarn twist multiple, then there will be corresponding variations in the average levels of length and width shrinkage.

For the yarns and fabrics of this investigation, it was found that an increase in the yarn twist multiple from 3.6 to 4.0 would cause the average shrinkage to increase by about one and a half percentage points in the length and by about one percentage point in the width.

Independently of the effect of twist, substitution of a different cotton fibre type could cause length and width shrinkages to change by about two percentage points each, but in opposite directions.

The results presented here refer to a specific set of fibres, yarns, fabrics, and processing conditions. Therefore the absolute differences found for the effects of yarn quality on fabric shrinkages can not necessarily be taken as typical. Nevertheless, it seems reasonable to suppose that similar trends will exist for the generality of interlock fabrics. In fact we have previously found similar trends in two separate series of experiments with interlock fabrics made from ring yarns.

Although the range of yarn twist and fibre quality found in practice should not be as wide as that presented here, it is clear that knitters should keep a careful watch on the average level and the consistency of yarn quality. Most knitters do not routinely monitor the twist of the yarns that they buy and have only a vague idea of the fibre quality that is used to spin them.

TABLES & FIGURES

Table 1

Reference State Courses and Wales per cm, for 54 Rotor Yarn Fabrics averaged over Twist Multiple and Stitch Length, within Fibre Origin and Yarn Count.

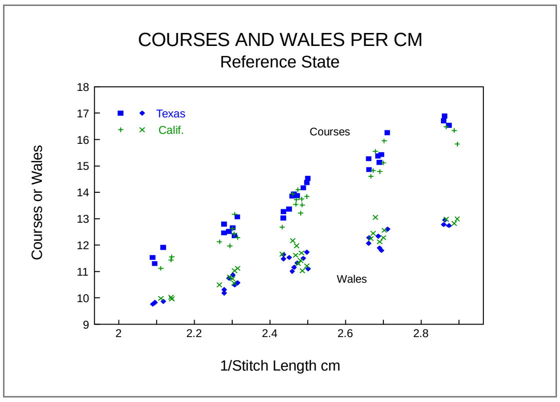
Count	Origin	Courses	Wales	Weight
Ne 22	**Texas**	12.82	10.42	310.7
	California	12.59	10.62	304.6
	Difference %	1.8	-1.9	2.0
Ne 26	**Texas**	14.09	11.44	284.8
	California	13.69	11.59	280.1
	Difference %	2.8	-1.3	1.6
Ne 30	**Texas**	15.03	12.20	264.6
	California	14.88	12.48	262.7
	Difference %	1.0	-2.3	0.7
	Mean Difference %	1.9	-1.8	1.4

Table 2

Reference State Courses and Wales for 54 Rotor Yarn Fabrics, averaged over Fibre Origin, Twist Multiple and Stitch Length within Yarn Counts, compared to the output of the STARFISH model for Ring Yarns.

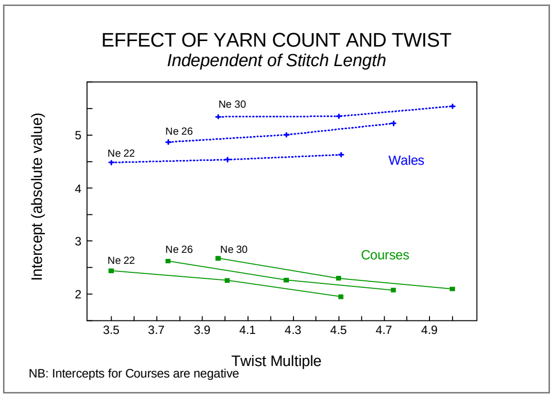
As Knitted		Finished Reference State								
		Ring Yarns			Rotor Yarns				Difference	
Ne	**SL mm**	**C/cm**	**W/cm**	**gsm**	**TM**	**C/cm**	**W/cm**	**gsm**	**Len%**	**Wid%**
21.9	4.43	12.0	10.8	295	4.01	12.7	10.5	307	5.5	-2.8
25.8	4.08	13.0	11.9	272	4.25	13.9	11.5	283	6.5	-3.4
29.8	3.82	13.7	12.8	252	4.49	15.0	12.3	264	8.7	-3.9

Figure1:



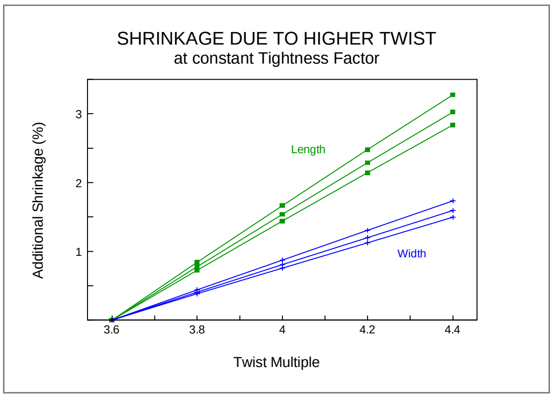
Effect of Stitch Length on Reference State Courses and Wales

Figure 2:



Effect of Yarn Count and Twist Multiple independent of Stitch length on Reference State Courses and Wales

Figure 3:



Effect of Twist Multiple on Fabric Shrinkage at constant Tightness Factor

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