DIMENSIONAL PROPERTIES OF COTTON FLEECE FABRICS

S. Allan Heap and Jill C. Stevens
Cotton Technology International
Hazel Grove, Stockport, UK
Don Bailey and Jim Grow
Cotton Incorporated
Raleigh, NC

Abstract

To enable rational fabric engineering for end-use performance, and to allow focused process control, it is necessary to be able to predict fabric dimensions as a function of knitting and wet processing input variables. In particular it is necessary to predict the course and wale densities of the dyed and finished fabric in its Reference State of Relaxation. A wide range of two-thread cotton fleece fabrics, together with the corresponding plain jersey controls, has been knitted, processed, sampled and tested. The results have been analysed to derive the necessary prediction equations. The equations have been included in a new version of the STARFISH computer program for simulating the manufacture and processing, and for predicting the end-use performance of cotton circular knits.

Introduction

One of the fundamental tasks of a manufacturer of cotton circular-knitted fabrics is to provide materials having specified values of weight per unit area and width, together with minimal levels of potential shrinkage, using available yarns, knitting machinery, and processing equipment. It follows that a rapid and reliable system for calculating the dimensions of dyed and finished knitted fabrics, starting from the raw yarn, knitting, and processing variables is a necessary requirement for rational fabric engineering. To our knowledge, there is only one such system which is generally available to cotton knitted fabric manufacturers world-wide. This is the STARFISH computer program (1, 2, 3). The current version of the program does not encompass two very popular cotton circular knitted fabrics, namely two-thread and three-thread fleece. Research has been carried out over the past two years in an effort to elucidate the dimensional properties of these fabrics, with a view to developing the simulation equations which will allow them to be included in a future version of the program. This report summarises some of the results obtained from one section of the research on two-thread fleece.

Experimental

Three separate sets of fabrics have been knitted. Each set was based on a different ground yarn, either 18/1 Ne, or 24/1, or 30/1. Each set contained a plain jersey control (no inlay yarn) and four two-thread fleece fabrics with inlay yarns of 12/1 Ne, 14/1, 16/1, or 20/1. All yarns were carded OE rotor spun, purchased in North Carolina. All of the different basic yarn combinations were knitted, at four different levels of average ground stitch length, on an 18 cut, 20 inch diameter machine having 1156 needles. The inlay stitch length was held (more-or-less) constant. Thus each set comprised 20 different qualities, for a total of 60 different fabric rolls in all. The rolls were sewn together in sets and processed in a commercial plant on a continuous peroxide bleach range, using a standard prepare-for-printing recipe, followed by extraction, softening, wet spreading and relax drying with overfeed.

Samples for testing were cut after discarding at least six yards from the ends of the rolls. Four sub-samples from each roll were measured for yarn count, stitch length, course and wale densities and weight per unit area, using standard methods, both before and after being subjected to the STARFISH Reference Relaxation procedure. This procedure comprises one hot wash and tumble dry followed by four cycles of cold rinsing and tumble drying, followed by conditioning. An essential aspect of the relaxation procedure is that tumble drying must continue until all of the samples are bone dry, followed by a short period of cold tumbling. For this report, data from the four sub-samples have been averaged, and only the Reference State data are discussed.

Results and Discussion

The basic equations of knitted fabric dimensions are as follows:

$$Wt = T * L * C * W * F \qquad [1]$$
$$Wid = N / W \qquad [2]$$
$$LenShr = 100 * (C - Cr) / Cr \qquad [3]$$
$$WidShr = 100 * (W - Wr) / Wr \qquad [4]$$

Where:

Wt	=	weight per unit area
T	=	yarn number in tex units
L	=	average stitch length
C	=	course density
W	=	wale density
F	=	a scaling factor
Wid	=	fabric width (circumference for a tubular fabric)
LenShr	=	length shrinkage, per cent
WidShr	=	width shrinkage, percent
Cr	=	course density in the Reference State
Wr	=	wale density in the Reference State

Reprinted from the *Proceedings of the Beltwide Cotton Conference*
Volume 2:1488-1490 (1996)
National Cotton Council, Memphis TN

For a fleece fabric, equation [1] is modified in so far as separate calculations are made for the weight of the ground fabric and the inlay yarn. The two are then added to give the weight of the whole fabric.

In a hypothetical fabric development exercise, a particular yarn (or maybe two) might be chosen and knitted on a given machine at a range of stitch lengths. All of the resulting samples might then be processed through a given wet process route and the final finished samples tested to see which performs closest to the specified performance targets. In such cases, most of the variables contained in equations [1] to [4] are known: either they are selected as knitting inputs (yarn number, stitch length, number of needles) or they are given as primary performance targets (weight and width), or they are a direct consequence of fixing other variables.

For example, if the target weight per unit area has been specified and a yarn number and stitch length have been selected, then the product of courses and wales is known from [1]. Likewise, once the knitting machine (number of needles) has been decided and the required finished width has been specified, then the wale density in the finished fabric is known from [2].

Note, however, that after the knitting inputs have been selected and the primary performance targets have been specified, then the shrinkage values are also determined since, although Cr and Wr may be unknown at this stage, they do have specific values which depend on the knitting inputs and the type of wet process which is used. Thus, the shrinkage of a given fabric can not be specified independently of weight and width (or vice versa) unless the values of Cr and Wr are known.

The problem of rational fabric engineering by simulation then resolves itself into the problem of predicting Cr and Wr, for a given set of knitting inputs and wet processing conditions. From a vast quantity of experimental data, we have concluded that Cr and Wr are determined, with sufficient accuracy for practical purposes, as follows.

$$Cr = Sc / L + Ic \quad [5]$$
$$Wr = Sw / L + Iw \quad [6]$$

Where Sc and Sw are probably constants depending mainly on the fabric construction, whereas Ic and Iw are probably determined mainly by the fibre type, the yarn type, the yarn number, and the type of wet processing which is used. In order to develop simulation equations, Sc and Sw have to be estimated empirically for each different fabric type; Ic and Iw have to be estimated for the different types of yarn and wet processing. This requires an enormous quantity of detailed experimental data, gathered from fabrics which have been manufactured and processed under very closely controlled, but nevertheless fully commercial conditions. In particular, it may be noted that data based upon laboratory-scale wet processing of short lengths of fabric have proved to be of only marginal value in attempts to model full-scale operations.

Figure 1 shows the course and wale densities, as a function of stitch length and yarn number, for the plain jersey control fabrics. Figure 2 shows the corresponding data for the two-thread fleece fabrics of the Ne 24 series. The dotted lines on this graph indicate the plain jersey controls. It is clear that the introduction of an inlay yarn has the effect of reducing the density of both courses and wales, but especially the wales. The heavier the inlay yarn, the greater is the reduction in stitch density. The differences between control and fleece fabrics were even greater in the Ne 30 series, but less in the Ne 18 series - reflecting the greater or lesser differences between the ground and the inlay yarn numbers - but the general pattern was the same

As a first approximation, we can smooth these data by assuming a constant slope for all of these lines. For this report, we have assumed that the grand averages for Sc and Sw for the two-thread fleece fabrics are the same as for the plain jersey controls. When this is done, average values for the intercepts, Ic and Iw can be computed and the effect of yarn number can be derived. Since the effect of the ground yarn number is already known, the independent influence of the inlay yarn can be established. Figure 3 shows the resulting values for Ic and Iw for the three sets of fabrics, as a function of the inlay yarn number. Plain jersey controls are allocated an inlay yarn number of zero.

Having deduced the values for the main parameters of equations [5] and [6], it is possible to construct prediction equations for Cr and Wr, which can then be used to simulate product development trials for two-thread fleece fabrics having any set of knitting inputs and primary performance targets within the range of the data base (and a short distance outside it).

Figures 4 and 5 show the results of such predictions for the three series of fabrics, plotted against the actual measured values. Correlation coefficients for these predictions against measured values are very good for the courses and tolerably good for the wales. In both cases, the slope of the regression line is very close to 1.00 and the standard error of the predictions is consistent with normal variation in measurements of course and wale densities. Correlations may improve after several obvious anomalies (outliers) in the data have been scrutinised carefully.

There is more work to be done, particularly in industrial validation trials which are proceeding among the STARFISH users. Industrial case studies are used to sample and test the products from factories producing similar fabrics, both inside and outside the basic research data base. The resulting data allow the robustness of the predictions to be tested, and also allow the influence of different yarn types and wet process procedures to be deduced. Data are already available from several such case studies but these have not yet been analysed fully.

As a result of this research, and the parallel industrial case studies, we have a working model for simulating the dimensions of cotton two-thread fleece fabrics which will be incorporated into the forthcoming upgrade to the STARFISH computer program. At the same time, the opportunity will be taken to add several important new features to the program.

References

1. E. Friedenberg. Starfish Program Helps Flynt Hit Shrinkage Targets In Cotton Knits. Knitting Times, 1993, 24-25.

2. Heap, S. A., and Stevens, J. C. Starfish Update: Achieving The Required Weight And Shrinkage In Circular Knitted Cotton Fabrics. Textile Horizons, 1994, 38-40.

3. Heap, S. A., and Stevens, J. C. Shrinkage: You Don't Need To Measure It To Be Able To Control It. Proceedings 36th Congress, International Federation of Knitting Technologists, 1994, 107-117.

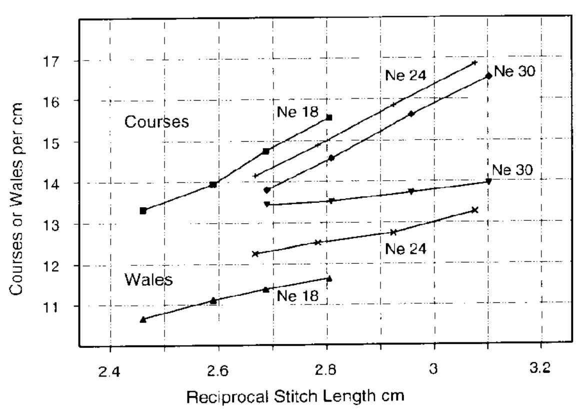

Figure 1: Plain Jersey Controls. Finished, Reference State Courses and Wales.

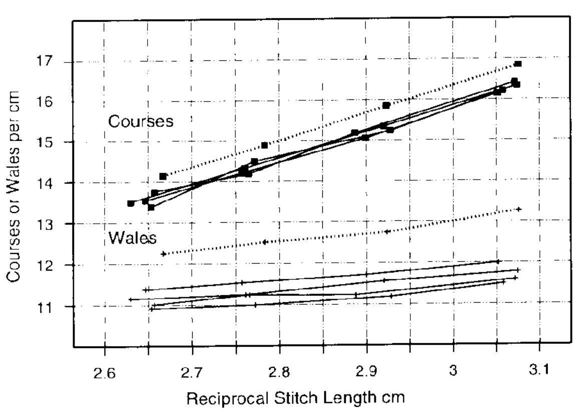

Figure 2: Two-Thread Fleece: Ne 24 Series. Finished, Reference State Courses and Wales.

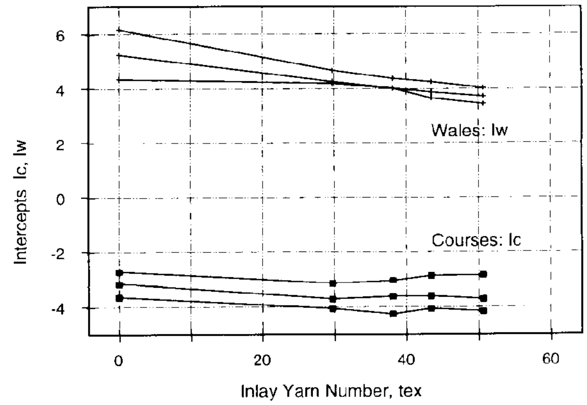

Figure 3: Two-Thread Fleece: Finished. Intercepts Ic, Iw versus Inlay tex

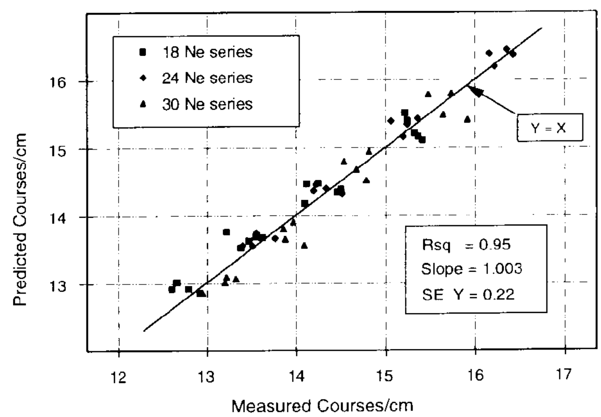

Figure 4: Two-Thread Fleece: Finished. Predicted versus Measured Courses per centimetre.

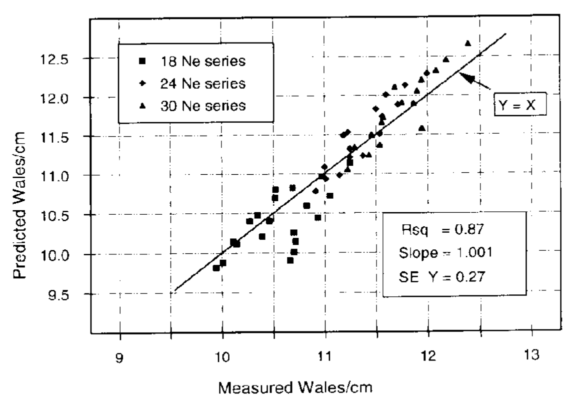

Figure 5: Two-Thread Fleece: Finished. Predicted versus Measured Wales per centimetre