SOME NEW TECHNIQUES TO PREDICT THE DIMENSIONAL STABILITY OF PRE-SHRUNK COTTON FABRICS

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Abstract

This work describes some new procedures that can be used to identify the nature and extent of instability present in pre-shrunk cotton fabrics so as to control the dimensions of the relaxed garments by providing appropriate margins in the cutting and sewing operations. The effectiveness of each method/procedure was evaluated using pre-shrunk denim fabrics that represented different degrees of longitudinal stability. Results showed that the procedures based on load cycling and energy recovery measurement are less reliable compared to those that related stability to the change in dimensions of the wet relaxed fabrics. Thus procedures based on the measurement of the relaxed dimensions of the fabric subsequent to quick relaxation in the presence of heat and moisture were found to be the most useful and practical procedures to predict the stability of pre-shrunk fabrics.

Statement Of The Problem

Medium and heavy weight cotton fabrics such as denims, and ducks usually exhibit high levels of shrinkage in washing and so it is common to pre-shrink these fabrics before they are cut and sewn into garments. The amount of pre-shrinking required in sanforization, is, however, different for different fabrics and it usually relates to fabric construction parameters such as weave pattern, basis weight, yarn count, twist level, thread density, yarn bulk and many other yarn structural parameters, including the type of spinning system used to produce the yarn. Unfortunately, no clear guide-lines currently exist to define the amount of pre-shrinking required for fabrics exhibiting differences in the construction parameters. As a result, most fabrics are either over-shrunk or under-shrunk, which leaves a net residual shrinkage in some fabrics and residual expansion in others. The garment manufacturer, who receives these fabrics from the textile manufacturer, fails to correctly identify the nature and extent of instability in individual fabrics and experiences difficulty in maintaining the size and dimensions of the finished garment. Also, since the rate at which a pre-shrunk fabric undergoes change in dimensions is very much a function of the temperature and humidity conditions prevailing in the atmosphere, the same cotton fabric produced and shipped by a particular textile manufacturer during the summer and winter months may exhibit widely different levels of instability, making it even more difficult to control fabric and garment dimensions.

Reprinted from the *Proceedings of the Beltwide Cotton Conference*
Volume 1:742-745 (1997)
National Cotton Council, Memphis TN

Facts On The Shrinkage Of Woven Cotton Fabrics

Shrinkage due to Stress relaxation: Part of the shrinkage observed in woven and knitted fabrics is due to the relaxation of : a) the longitudinal and torsional stresses imposed on the fibers in the spinning process and b) the longitudinal stresses imposed on the yarn in the weaving/knitting process. However, some of the woven cotton fabrics are known to shrink as much as 16% and knitted fabrics shrink even more. Obviously the observed shrinkage quite often exceeds what can be logically expected from stress relaxation alone and the excess shrinkage is known to result from the diametrical swelling and de-swelling of cotton fibers.

Shrinkage due to Swelling of Fibers and Yarns: Fiber diameter increases by as much as 20 % and fiber length by about 1 % when cotton fibers are fully immersed in water. Water molecules are believed to position themselves between the molecular chains and cause lateral fiber swelling. The increased separation of molecular chains due to sorption of water allows the elongated and axially aligned molecules to retract to their more probable (original) configuration. Thus wetting of cotton induces stress relaxation in fibers and yarns, while at the same time increasing the diameter of fibers and yarns. In a densely woven 100% cotton fabric such as a denim, the increased diameter of the filling yarn due to absorption tends to stretch the warp yarn longitudinally. However, on the basis of the energies required, it will be easier for the filling yarns to move closer rather than for the warp yarns to be stretched. The moving together of the filling yarns results in longitudinal fabric shrinkage.

Other Facts: The shrinkage obtained due to the relaxation of inbuilt fiber and yarn stresses can be considered permanent in nature. In other words, the reduction of length or width achieved due to relaxation of stresses alone is a permanent reduction. The longitudinal shrinkage of fabric obtained due to diametrical swelling of fibers and yarns should be reversible after the fabric is dried to its natural regain. In reality, however, the shrinkage reversal happens to be only partial because of the fact that warp and filling yarns tend to acquire more and more crimp with repeated wetting and drying. Also, tighter the fabric construction, more gradual should be the shrinkage. Thus other things being equal, fabrics containing more threads per inch can be expected to shrink more gradually. Also, plain weave fabrics can be expected to shrink less rapidly compared to satin, sateen or twill weaves which carry long yarn floats.

Facts On The Expansion Of Pre-Shrunk Cotton Fabrics

Stressing of thermoplastic materials such as a polyester yarn or fabric under heat results in the breaking and reforming of intermolecular bonds. As a result, the thermoplastic material becomes stable in the deformed condition This, however, is not true in the case of natural fibers such as cotton. Thus a coarse cotton fabric subjected to compressive shrinkage in sanforization with the intention of reducing its wet shrinkage can either shrink or expand in the first wash treatment, depending on the level of forced shrinkage imposed on the fabric. A cotton fabric subjected to mechanical compression in sanforization can also be expected to expand in storage and transportation. The amount of expansion will depend not only on the level of fabric compression but also on factors such as the temperature and humidity of the atmosphere in which the compressed fabric is stored, conditions of sanforization, storage time, storage conditions, etc. Microwave heating of a moist cotton fabric compressed in sanforization can be expected to instantly relieve compressive stresses because the presence of heat and moisture makes it much easy for the cotton fibers and yarns to get relieved of the compressive stresses. In fact, this behavior has been clearly demonstrated by several researchers in the past[1-5].

Methods For The Prediction Of Residual Growth Or Shrinkage

Kawabata Tensile Test : The KES tensile test characterizes both deformation and recovery behavior of fabrics by subjecting them to gradual stressing and de-stressing. Test specimens measuring 6" in the warp direction and 4" in the filling direction were mounted between two sets of clamps of the tester that were initially separated by 2". The front set of clamps was then moved at a rate of 1 cm. per minute to stress the test specimen in the warp direction to a peak load of 10 kg. After peak load, the motion of the moving clamps was reversed to measure the recovery behavior. The test specimens were loaded repeatedly fifteen times and the energy levels corresponding to stressing and recovery were recorded for each load cycle. A total of 10 specimens were tested for each of the experimental fabrics. The parameters considered for the evaluation of fabric stability are the unrecovered instantaneous extension and the tensile resilience values corresponding to the first and 15th load cycles.

Steaming of Dry Fabrics: Test specimens measuring 18" x 18" were prepared for each of the nine fabrics. Each specimen was marked with five 16" lines in the warp direction. One set of marked specimens representing the nine different fabrics were then placed in the dry steaming vat such that the marked side of each specimen is exposed to the steam discharged at the bottom of the vat. The drain pipe of the steel vat was kept open so as to continuously drain the condensed water. The specimens were steamed for 25 minutes at a temperature of 210^0 F and a pressure of 30 PSI. The steamed specimens were allowed to attain room temperature before they were removed from the vat and tumble dried for 15 mins. After drying, the specimens were conditioned for 24 hours under standard conditions and then measurements were made along the marked lines.

Heating of Moist Fabrics in Microwave Oven: Five specimens measuring 8" by 8" were prepared for each of the nine fabrics. Straight line marks, each measuring 7" along the warp direction and spaced at 1" from each other were made on all the test specimens. The marked specimens were sprayed with 2cc of water in the form of a fine mist and the spraying was done on both the face and back sides with the help of a domestic spray nozzle. Care was taken to ensure that the spray is as uniform as possible on both sides of the fabric. Also the spray was controlled such that the specimens do not get wet after they are sprayed on both sides. The moist samples were then stacked up one on top of the other and the stack was loaded with a 5 kg flat weight that extended over the entire surface of the top specimen in the stack.

The loaded stack was left undisturbed for 30 minutes to allow the diffusion of moisture from wet to dry spots in the stack. After this, the stacked specimens were lifted one at a time, two folded, creased and positioned in a rectangular microwave utensil in such a way that the marked sides of the specimens are exposed to the microwave energy. The utensil was then heated for a period of 5 minutes (one minute per specimen with a one minute relaxation break after 2.5 minutes of heating) at a microwave energy level of 800 watts. The heated specimens were then allowed to condition in standard atmosphere for a period of one hour before measurements were made along the warp direction. The remaining test specimens were also heated and conditioned five at a time before measurements were made along the 7" straight lines.

Repeated Loading on the Instron Tensile Tester: Specimens measuring 15" by 3" (15" along warp direction and 3" along the filling direction) were prepared for each fabric. Two parallel lines spaced at l2" in the longitudinal direction, and a single vertical line at the center of the 3" dimension were drawn on each specimen. The marked specimens with a 12" test length were then centrally mounted on an Instron tensile tester which used 3" wide holding clamps. The mounted specimens were stretched ten times to a total span of 14". After ten cycles, the specimens were removed from the clamps and allowed to condition under standard atmospheric conditions. The parameters considered to characterize fabric stability are the immediate residual extension, residual extension after 60 hours of conditioning of the stretched samples, residual extension of the stretched, conditioned and steam relaxed samples. The last row of Table 2 shows the permanent extension values left in the stretched specimens after the specimens were conditioned for 60 hours and then steam relaxed.

Tumble drying of Moist Specimens: Test specimens measuring 18" by 18" were prepared from the nine fabrics. Marks extending to 16" in the warp direction were made on each specimen. The specimens were sprayed with 10 cc of water in the form of a fine mist. The sprayed specimens were left in a stack for 30 minutes and then tumble dried for 30 minutes. A group of nine specimens were rolled in the dryer at one time. The dried specimens were conditioned for two hours before measurements were made along the marked lines.

WIRA Steam Cylinder: The template supplied with the WIRA steam cylinder is useful not only as a standard tool for the marking and cutting of test specimens for steaming but also to measure the percentage growth or shrinkage of the steamed specimens. As recommended by the manufacturers of the steam cylinder, four specimens representing four different fabrics to be evaluated were loaded into the cylinder at one time. The specimens were steamed for a total period of three minutes with a 30 second break after the first and second minutes of steaming. After the third minute, the specimens were removed from the steam cylinder, and the percentage change in length of the specimens was recorded using the template.

Results And Discussion

To evaluate the potential test methods, we used a group of nine denim fabrics which exhibited differences in growth potential. From Table 1 which gives the measured growth values for four different test procedures, it can be seen that all the test methods gave a negative growth value (net shrinkage) for the fabric that carried no growth potential. Thus a negative growth value obtained in any of the four designated growth tests is an indication that the fabric is not likely to grow. Negative value may also suggest that the fabric has a very high shrinkage potential. Three of the four test methods(WIRA, Tumble Dry, and Microwave methods)were able to generate growth values that correctly reflect the predetermined growth potential of the fabrics. The microwave method carries a potential fire risk and is also difficult to standardize. The WIRA method and the Tumble Drying Procedure appear to be the most promising test methods for growth prediction.

Tables 2 & 3 give the results of Kawabata and Instron loading tests. It is clear that the tensile resilience(RT%) values given by the KES tensile tester are not of any value in predicting dimensional stability. This is true for the resilience measured in the first and fifteenth load cycles. The residual elongation values appear to reflect the growth potential somewhat but the values fail to clearly differentiate between high and medium growth fabrics. The residual extension values measured on the Instron tester also exhibit a trend similar to that of KES residual extension values. However, the residual extension measured on the steam relaxed samples shows good agreement with the growth potential of the fabrics. Repeated loading of the fabrics either on the Instron or KES tensile tester, followed by steam relaxation of the stretched samples can be a possible test procedure for the prediction of the nature and extent of instability of woven cotton fabrics. This procedure, however, is more complicated and more time consuming than the WIRA or Tumble Dry procedures. Results thus point to the WIRA and Tumble Dry methods as the most suitable methods for the prediction of the stability of woven cotton fabrics.

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Table 1. Longitudinal Expansion Values in Relation to Growth potential.

Fabric	Growth Potential	WIRA Expansion (%)	Microwave Oven Expansion (%)	Dry Steaming Expansion (%)	Tumble Dry Expansion (%)
A	Zero	-0.8	-0.5	-2.2	-1.5
B	Low	0.65	0.0	0.6	1.3
C	Med	1.1	0.9	1.5	1.6
D	Med	1.5	2.4	2.5	1.8
E	Med	1.5	2.8	1.1	2.5
F	High	2.6	2.7	3.3	2.9
G	High	2.6	3.1	1.9	2.9
H	High	3.9	4.5	2.8	3.4
I	High	3.0	2.7	1.5	2.9

Table 2. Tensile Resilience and Residual Extension Properties in Relation to Growth Potential (KES).

Fab-ric	Growth Potential	KES TENSILE TEST			
		First Cycle		15th Cycle	
		RT%	Res.E%	RT%	Res.E%
A	Zero	23.1	0.60	42.9	1.0
B	Low	22.1	0.73	39.4	1.3
C	Med	23.3	1.50	50.7	2.2
D	Med	16.1	1.20	40.2	2.0
E	Med	20.1	1.50	44.9	1.9
F	High	20.0	1.50	42.4	2.1
G	High	20.1	1.30	43.1	2.2
H	High	16.9	1.50	41.5	2.2
I	High	21.3	1.60	45.6	2.2

Table 3. Tensile Resilience and Residual Extension Properties in Relation to Growth Potential (Instron).

Fab-ric	Growth Potential	INSTRON CYCLE TEST % Res. Extn. after 10 Cycles		
		Immed.	60 Hrs	Steamed
A	Zero	10.8	7.0	0.0
B	Low	10.9	6.6	1.6
C	Med	11.1	7.0	1.7
D	Med	12.0	8.2	2.3
E	Med	12.0	8.3	2.0
F	High	11.8	8.6	2.8
G	High	12.2	8.5	2.9
H	High	12.4	8.7	2.8
I	High	12.3	8.7	2.8