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# The Influence of Drying Conditions on Dimensional Stability of Cotton Weft Knitted Fabrics

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The dimensional stability of cotton weft knitted fabrics during exploitation has significant effect on their quality. The characteristics of fibre, the characteristics of knitwear structure, pattern of fabric and conditions of technological processes influence geometrical and dimensional stability of knitwear's.

The main goal of this work was to investigate the behaviour of knitted fabric during drying at different conditions, and the influence of these conditions on finished knitwear dimensional stability. The samples were knitted on a circular single face and interlock knitting machines from cotton yarns and their combination with PES yarns. Special method of knitted fabric drying was developed for the experimental testing. Thus industrial drying of knitted fabrics was simulated in experimental conditions. The samples were dried in six different modes: hanged on a line in course and wale directions, spread on a smooth surface, winded by hot air, spread on a heated surface, and in a tumbler-dryer. Shrinkage potential of knitwear samples dried in different conditions was determined. After that samples were washed and dried in domestic conditions. Then it was determined how much drying conditions in finishing process influence knitwear's shrinkage potential and dimensional stability during its exploitation.

*Keywords:* weft knitted fabric, finishing, drying, dimensional stability, shrinkage.

## INTRODUCTION

A variety of different materials and technologies can be used for garment production. One of the commonly used is knitting technology. Knitted fabrics used for clothing production must be of high quality. Structural parameters of knitted fabrics, as well as finishing processes directly influence their mechanical and physical properties and thus are closely connected with wearing properties of knitted garments [1].

Fabric shrinkage is a serious problem for knitwear, originating from dimensional changes in the fabric, particularly stitches. It has become even more prevalent in recent years due to the popularity of casual wear such as tights, pants, blouses, and sportswear.

The structure of knitted fabric is a system of yarns, bent into stitches. Integrity and friction of a yarn bent into the stitch determine the form of a knitted fabric stitch. The friction appears because of stitches interdependent relations. The ties of the second type are flexible and allowing changes of a stitch form and width-height dimensions. The form of stitch becomes as a natural state of a yarn. Anyway, the relaxing resiliency forces do not reach zero level and all the parts of a stitch retain a certain amount of the resiliency forces by the static condition in the sample. On the other hand, it is known, that the value of resiliency forces of a stitched yarn depends on the several factors: the fibre raw material, the yarn structure, the yarn twist, the stitch length, the yarn linear density and an external conditions [2].

Being used knitwear change their dimensions according to the body movements. At that certain time, they undergo either reiterated single or a double directional stretching. The value of the deformation in different parts of knitwear can reach 10 % ÷ 20 % [3]. If a deformation is large enough, a stitch form and a yarn orientation change and contact points between the stitches move.

During the knitting process, the yarns forming the fabric are constantly under stress. As a result, the fabric on the machine is more distorted than in natural relaxed state. When the fabric is removed from the machine, it has time to relax and overcome these stresses, which is easily recognizable by the changes in dimensions [4].

In a time, the relaxation process in knitwear slows down, the internal tensions decreases, and wear gradually moves into a state balancing certain conditions. Two main forces affect the knitwear change from no balanced to balanced condition. The first one, it is the resiliency force of a stitched yarn that try to straighten a yarn, to change its configuration and to switch knitwear into a balanced state. The second one, it is the yarn friction force surmounting the yarn movement in a stitch and fixing the non-balanced state [5].

The non-balanced condition of cotton knitwear is quite easy changing when the knitwear is laundered and dried. Therefore, the geometrical dimensions of knitwear are changing. Being used knitwear undergoes an influence of deformations of different size. Knitted fabrics tend to exhibit residual extension. It is also responsible for creating shrinkage problems in knitted products during laundering, whereby the loads applied to the fabrics during manufacture can induce extensions, which, if the fabric is not allowed to relax before making-up, are only relieved during after-care processes such as laundering, and the fabric shrinks. When the knitwear is made from unbalanced fabric, the dimensions of knitwear after first wear can change so much, that the knitwear will be unfit for use [2].

The heavy shrinkage of knit-goods, especially after the introduction of the tumbler-dryer, which often produced length shrinkage up to 15 % – 20 % and the increased

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quality awareness, summoned the specialists of the textile finishing industry to take appropriate steps. An evolution was triggered off in all areas of textile finishing, which set new standards for obtained fabric shrinkage [6, 7]. On the other hand, it is known, that shrinkage of cotton weft knitted fabrics depends upon its structure and knitting parameters.

Shrinkage is a result of the combined effect of numerous factors such as relaxation, finishing, drying, and effects of machinery [7].

The drying of knitted fabrics is an important part of textile processing. There are two stages of drying: mechanical methods of drying and non-mechanical methods using heat.

After mechanical dewatering, dependent on the nature of the fibre, between 25 % and 80 % of moisture is retained and has to by remove by the application of heat. After mechanical dewatering, the water remaining on the fibre surface and some of the water within the fibre is removed using heat.

In addition to heat energy, radiofrequency, microwave or infrared radiation may be used. These have limited application. Normally non-mechanical drying can by done in two ways:

– by contact with hot surfaces;
– by hot air.

The main goals of this work were to investigate the behaviour of knitted fabric during drying at different conditions, and the influence of that's conditions on finished knitwear dimensional stability.

## EXPERIMENTAL

There sets of samples knitted on a circular 20E gauge single face and interlock knitting machines from cotton yarns and their combination with PES yarns were tested experimenting. The characteristics of tested knitted fabrics are presented in Table 1.

The special method of knitted fabric drying was developed for the experimental testing. On the experimental conditions, it was imitated industrial drying during knitted fabrics finishing. The samples were dried on six different modes: hanged on a line in course and wale directions, spread on a smooth surface, winded by hot air, spread on a heated surface, and in a tumble-dryer. The conditions of the experimental drying are presented in Table 2. The samples were thoroughly wetted-out in warm (40 ºC ±2 ºC) water before the drying.

After drying in different modes the samples were domestic washed and dried three times. Washing procedure for knitted samples: water temperature – 40 ºC, washing time – 90 min, rotation frequency of hydro extraction – 1000 min$^{-1}$, consumption of detergent – 45 ml.

Measurements of each washed and dried sample were taken in the course and wale directions. The shrinkage in longitudinal and transverse directions of laundered samples was calculated after each cycle of washing and drying.

**Table 1.** Characteristics of tested knitted fabrics

| Samples code | Pattern | Yarns | | Course density, cm$^{-1}$ | Wale density, cm$^{-1}$ | Fabric density, g/m$^2$ |
|---|---|---|---|---|---|---|
| | | Linear density | Percentage composition, % | | | |
| *I1* | Interlock | C 11.8 tex × 2 | 100 | 12.0 | 12.0 | 255 |
| *I2* | Interlock | C 11.8 tex ×2<br>PES 10 tex × 2 | 65<br>35 | 11.5 | 12.5 | 265 |
| *PJ* | Plain jersey | C 11.8 tex × 2 | 100 | 9.0 | 13.0 | 175 |

where: C – cotton yarn, PES – polyester yarn.

**Table 2.** Modes and conditions of experimental drying

| Drying mode | Drying conditions |
|---|---|
| 1. Hanged on a line in course direction | The thoroughly wet fabric is carefully depressed and hanged on a line in course direction. Fabric drains in a 22 °C ±2 °C temperature thus full dry out. Then fabric 12 hours is relaxed on a flat, smooth surface. |
| 2. Hanged on a line in wale direction | The thoroughly wet fabric is carefully depressed and hanged on a line in wale direction. Fabric drains in a 22 °C ±2 °C temperature thus full dry out. Then fabric 12 hours is relaxed on a flat, smooth surface. |
| 3. Spread on a smooth surface | The thoroughly wet fabric is carefully depressed, spread on a flat, smooth surface and drains in a 22 °C ±2 °C temperature thus full dry out. Then fabric 12 hours is relaxed. |
| 4. Spread on a heated surface | The thoroughly wet fabric is carefully depressed, spread on a flat, smooth, hot surface (60 °C) and drains thus full dry out. Then fabric 12 hours is relaxed on a flat, smooth surface (without heating). |
| 5. Winded by hot air | The thoroughly wet fabric is carefully depressed and spread on a reticulate surface that is winded by hot air (temperature beside the fabric is 60 °C), and drains thus full dry out. Then fabric 12 hours is relaxed on a flat, smooth surface. |
| 6. In a tumble-dryer | The thoroughly wet fabric is carefully depressed and drains in a tumbler dryer 20 minutes. Then fabric 12 hours is relaxed on a flat, smooth surface. |

The shrinkage value was defined by equation (according to standard ISO 26330:1993 [8]):

$$\lambda = \frac{L - L_0}{L_0}\ 100\ \%\ , \qquad (1)$$

where $L_0$ is the dimension of the sample before washing and drying; $L$ is the dimension of the sample after washing and drying.

Note: the relative error of all counts is less than 5 %.

## RESULTS AND DISCUSSION

The shrinkage of cotton goods during laundering has been one of the main problems for the textile finishers. Knitted fabrics are highly stretchable structures that relax and shrink when subjected to conditions which encourage this relaxation. Wet processing creates the ideal conditions for fabric structures relaxation. Suitable conditions of drying can prolong this relaxation process. Relaxation shrinkage is a particular problem with cotton knitted fabrics.

The dimensional changes in longitudinal (wale) and transverse (course) directions of all the investigated knitted fabrics during drying at different conditions are presented in Figs. 1 – 2. The results demonstrate that in all cases the shrinkage values of fabrics, dried in a tumbler-dryer are the greatest, especially of *PJ* sample knitted in a plain jersey pattern. It means that in a tumbler-dryer knitted fabric has the best conditions to shrink in a free state.

Shrinkage values in longitudinal and transverse directions of fabrics, dried on a reticulate surface, which is winded by hot air, are significant, also. In this drying mode, fabric in part is held on the airflow; therefore fabric is not influenced by friction with a surface.

The shrinkage values of fabrics, dried hanged on a line in course and wale directions were minimal because in that state fabric can not shrink free. Hanged on a line fabric is under the sway of gravity.

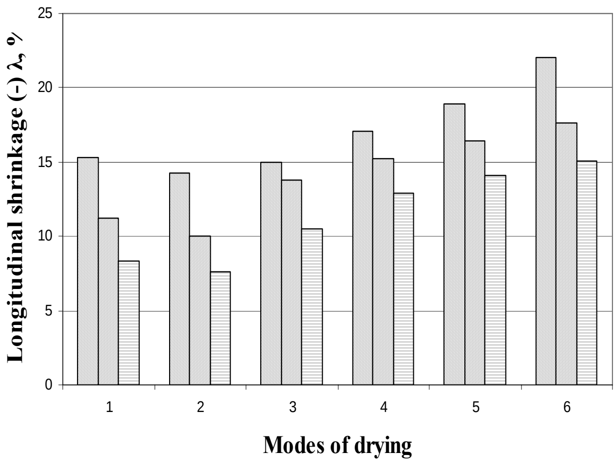


**Fig. 1.** The dependence of shrinkage in longitudinal direction $\lambda$ of *PJ* – ▨, *I1* – ▧, and *I2* – ▤ fabrics upon the mode of drying: 1 – hanged on a line in course direction, 2 – hanged on a line in wale direction, 3 – spread on a smooth surface, 4 – spread on a heated surface, 5 – winded by hot air, 6 – in a tumble-dryer

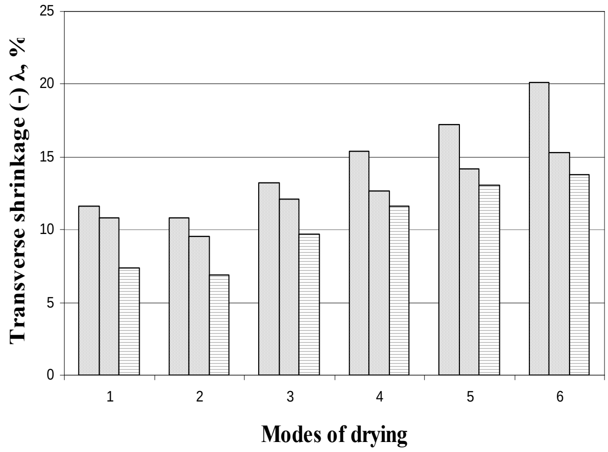


**Fig. 2.** The dependence of shrinkage in transverse direction $\lambda$ of *PJ, I1,* and *I2* fabrics upon the mode of drying (marked as in Fig.1)

As yarn swells within the fabric, the path length of the yarn between interlacing is for the fabric to shrink so that the original path length can be maintained. The shrinkage is energetically favoured compared to the yarn extension and thus there is inherent tendency for fabrics to shrink during wet treatments.

Fabrics that change their dimensions during the drying process significantly more, has more stabile dimensions during wearing and washing. Knitted fabrics with instable dimensions has tendency to shrink during laundering and drying.

Full relaxation and shrinkage is not always attained during the first washing cycle, and often several washing cycles are required before dimensional stability is reached.

The longitudinal shrinkage values of investigated fabrics after first, second, and third washing and drying cycles are presented in Figs. 3 – 5.

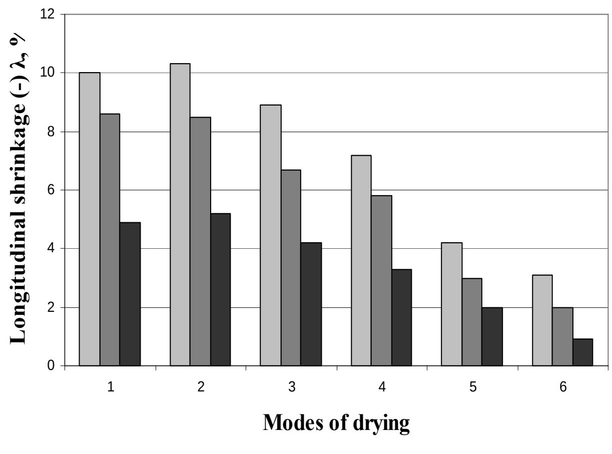


**Fig. 3.** The dependence of shrinkage in longitudinal direction $\lambda$ of *PJ* fabric (dried in different conditions) upon the number of washing and drying cycles: □ – shrinkage value after the first cycle, ▩ – shrinkage value after the second cycle, ■ – shrinkage value after the third cycle; (1 – hanged on a line in course direction, 2 – hanged on a line in wale direction, 3 – spread on a smooth surface, 4 – spread on a heated surface, 5 – winded by hot air, 6 – in a tumble-dryer)

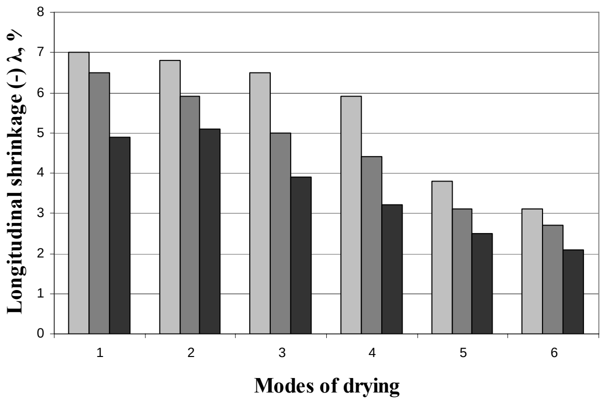


**Fig. 4.** The dependence of shrinkage in longitudinal direction $\lambda$ of *I1* fabric (dried in different conditions) upon the number of washing and drying cycles (marked as in Fig. 3)

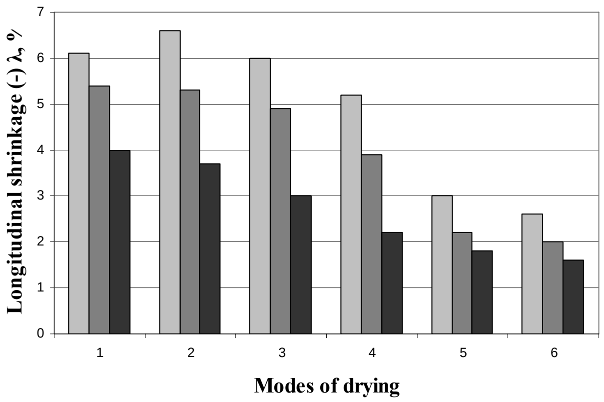


**Fig. 5.** The dependence of shrinkage in longitudinal direction $\lambda$ of *I2* fabric (dried in different conditions) upon the number of washing and drying cycles (marked as in Fig. 3)

The transverse shrinkage values of investigated fabrics after first, second, and third washing and drying cycles are presented in Figs. 6 – 8.

The value of finished cotton knitted fabric shrinkage must not exceed ± 3 % [9] (a sign "–" symbolizes that sample shrunk, and "+" – sample lengthened). It can be seen in Figs. 3 – 8, the shrinkage of all fabrics dried in a tumble-dryer, after the first washing and drying cycle are the minimal, and dos not exceed required limit of 3 %.

The shrinkage of fabrics dried on a reticulate surface winded by hot air after the first washing and drying cycle is also low. The greatest shrinkage value is of the fabric *PJ*, knitted in a plain jersey pattern (– 4.2 % in longitudinal direction and – 4.0 % in transverse direction). The shrinkage values of the interlock fabrics *I1* and *I2* are respectively –3.8 % and –3.0 % in longitudinal direction, and –2.9 % and –2.4 % in transverse direction. The lower shrinkage value has the fabric *I2*, knitted from 65/35 cotton/PES yarns blend because of the influence of PES, which is less prone to shrinkage.

The shrinkage values of all fabrics, dried by spreading on a heated surface, after the first washing and drying cycle were significant, especially in longitudinal direction, because fabrics can not shrink enough during drying process of this mode through the friction with drying device surface.

The shrinkage of all fabrics dried by hanging on a line in course or wale directions are most significant because the worst relaxation conditions.

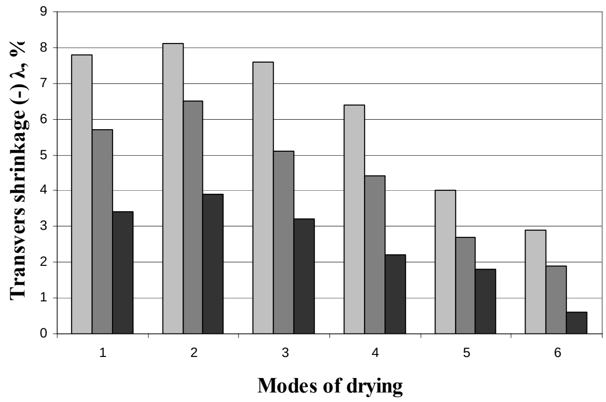


**Fig. 6.** The dependence of shrinkage in transverse direction $\lambda$ of *PJ* fabric (dried in different conditions) upon the number of washing and drying cycles (marked as in Fig. 3)

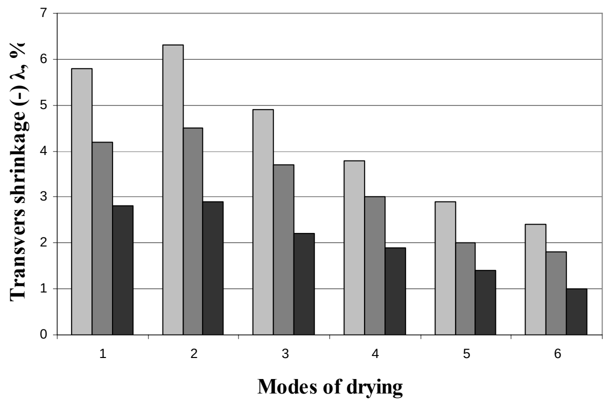


**Fig. 7.** The dependence of shrinkage in transverse direction $\lambda$ of *I1* fabric (dried in different conditions) upon the number of washing and drying cycles (marked as in Fig. 3)

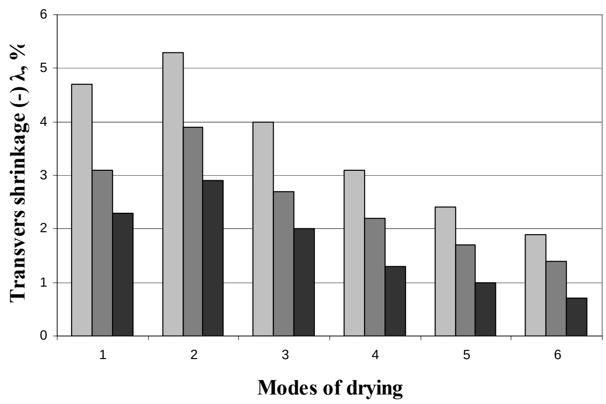


**Fig. 8.** The dependence of shrinkage in transverse direction $\lambda$ of *I2* fabric (dried in different conditions) upon the number of washing and drying cycles (marked as in Fig. 3)

Shrinkage value decreases after repeated washing and drying. After the third washing and drying cycle shrinkage values of all fabrics dried in a tumble-dryer and on a reticulate surface winded by a hot air, were less than –3 %. The values of longitudinal and transverse shrinkage of *PJ* fabric, knitted in a plain jersey pattern, after the third washing and drying cycle were less than –1 %. Thus, after loops reach their fully relaxed shape, the fabric becomes more dimensionally stabile with fewer potential to shrink.

The double structure knitted fabrics, e. g. interlock achieves potential of zero-shrink twice faster than knitted fabrics of single structure, e. g. plain fabrics. Friction between loops in double knitted structures is higher than in single knitted. The potential of zero-shrink during laundering-drying process of knitted fabrics is very complicated finishing process because many factors, such as temperature, time, humidity and others have an influence on the behaviour of knitted goods [6].

The greatest shrinkage value after the first washing and drying cycle had the fabrics, dried on a line hanged in wale and course directions (see Figs. 3 – 8). These knitted fabrics had low potential to relax and shrink during such drying mode. Even after third washing and drying cycle, the shrinkage value of these fabrics in longitudinal direction exceeded – 4 %. The implication is that even after three launderings such sample of knitwear is not dimensional stabile.

The control of fabrics dimensions is critical to ensure that the appearance and performance of finished products made from these fabrics is not impaired during subsequent finishing, laundering or dry-cleaning operations.

## CONCLUSIONS

The shrinking potential of knitted fabrics depends on the conditions of drying during finishing process. In a tumble-dryer the knitted fabrics shrink most of all, and are the most stable in exploitation.

The shrinkage values in longitudinal and transverse directions of fabrics dried in a tumble-dryer meets the requirements already after first washing and drying cycle:

– plain jersey knitted fabric *PJ* shrinks in longitudinal direction 3.1 %, and in transverse direction – 2.9 %;

– interlock knitted fabric *I1* shrinks in longitudinal direction 3.1 %, and in transverse direction – 2.4 %;

– interlock knitted fabric *I1* shrinks in longitudinal direction 2.6 %, and in transverse direction – 1.9 %.

The shrinkage values of plain jersey knitted fabrics after three washing and drying cycles were less than –1 %, because single structure knitted fabrics the zero-shrink-potential achieves faster than double structure knitted fabrics.

The interlock knitted fabrics, especially knitted from cotton/PES yarns blend can be characterized by more stabile dimensions than plain jersey knitted fabrics.

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