**Edita Malčiauskienė,**
**Žaneta Rukuižienė,**
**Rimvydas Milašius**

**Kaunas University of Technology**
**Department of Textile Technology**
Studentu Str. 56, LT-51424 Kaunas, Lithuania
Tel: 370-7-300221
e-mail: zaneta.rukuiziene@ktu.lt

# Investigation of Linen Honeycomb Weave Fabric Shrinkage After Laundering in Pure Water

**Abstract**
*The stability of dimensions is a very important factor that depends on fabric structure and final treatment. Fabric shrinkage capacity during laundering also depends on laundering conditions such as water solidity, washing powder, temperature, and mechanical action. The most popular and simple way to decrease the shrinking capacity of single-layer fabric is to increase the density of loomstate fabric. Preliminary investigations showed that the increase in yarn density increases the honeycomb weave fabric shrinkage after laundering, however. The later investigations showed that such contradictory results depend on the specific structure of honeycomb weave fabrics. Therefore, with increases in honeycomb weave fabric density (density or linear density of yarns), the structure of the fabric became more sophisticated than that of usual single layer fabrics – the yarns of the same system go one under another, that is, in some parts of the fabric it obtains the structure of multilayer fabric. The only way to decrease the shrinkage after laundering of fabric of such structure is by stabilisation.*

**Key words:** *linen fabric, honeycomb weave, shrinkage.*

## Introduction

Laundering is the most usual process for care of textiles. The complex combination of thermal, mechanical, and physical factors influences fabrics during the laundering process. It is known that textile garments change their dimensions during laundering by expanding or shrinking. The stability of dimensions is a very important factor which depends on fabric structure and final treatment. Fabric shrinking capacity during laundering also depends on laundering conditions such as water solidity, washing powder, temperature, and mechanical action [1-3].

Shrinking capacity is a very important factor for the clothing industry and very strict claims are made for this property. No more than 2% shrinkage in the cross and lengthways directions of the fabric is allowable. A matter of primary interest for fabric shrinking capacity is fabric structure, which is characterised by seven main parameters: fabric warp and weft raw material, linear density of warp and weft yarns, densities of warp and weft, and fabric weave. All these factors together determine the fabric‘s formation, parameters, and characteristics [4-6]. To evaluate them, the firmness factors of fabric structure are used. It is known that the fabric integrating firmness factor characterises not only the fabric formation process, but also properties such as air permeability, strength, and so on, rather well. [7-9]. The raw material of fabric also has a strong influence on the stability of its dimensions after laundering. This is because the properties of yarns influence fabric properties: the more hygroscopic the fibre, the more it swells after being affected with moisture [10].

The shrinking capacity of fabric after laundering can also be decreased with fabric stabilisation. The negative aspect is that an additional technological process is needed, making the fabric more expensive. For some fabrics, such as sauna clothes, finishing is not necessary.

The most popular and simple way to reduce the shrinking capacity of single-layer fabric is to increase the density of loomstate fabric. Increasing the fabric density causes the spacing fields in the fabric to decrease; the coeficient of filling beomes higher, the yarns do not have enough space to displace, and so the dimensions of the fabric vary less after laundering . But this method is not suitable for all fabric weaves. There are weaves which have a specific structure and salience surface, one of which is fabrics with honeycomb weave. This weave is very popular for sauna clothes: towels, bathrobes, caps, and so on. In Lithuania, as in other northern European countries, linen sauna clothes are very popular. Previous investigations showed that for honeycomb weave fabrics the usual shrinkage decreasing methods (increasing the linear density or density of yarns) used for single-layer fabrics do not have a positive effect.

The aim of this paper is to investigate the shrinkage phenomenon of linen honeycomb weave fabric for bathing after laundering and to identify ways of decreasing the shrinkage.

## Materials and Methods

Nine different linen fabrics were weaved for the investigations, all with the same honeycomb weave (***Figure 1***). Structural parameters of the fabrics are presented in ***Table 1***.

All the fabric variants which are presented in ***Table 1*** have the same linear density and density in warp: $T_{warp}$ = 56 tex, $S_{warp}$ = 300 dm$^{-1}$. The fabrics were laundered for 30 minutes at a temperature of

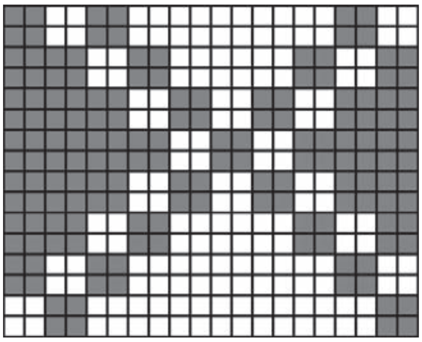


***Figure 1.*** *Honeycomb weave.*

***Table 1.*** *Structural parameters of fabrics used in experiment.*

| Fabric | $T_{weft}$, tex | $S_{weft}$, dm$^{-1}$ |
|---|---|---|
| 1 | 50 | 210 |
| 2 | 56 | 210 |
| 3 | 68 | 210 |
| 4 | 50 | 240 |
| 5 | 56 | 240 |
| 6 | 68 | 240 |
| 7 | 50 | 270 |
| 8 | 56 | 270 |
| 9 | 68 | 270 |

30 °C. No washing powder was used during this process. After each laundering cycle, the fabrics were dried at a room temperature of 20 °C in a loose state, and then the shrinkage of the dried fabric was measured. The parameters of laundering and drying were chosen according to real usage conditions of such fabric. Usually sauna clothing is dried at room temperature and it is often affected with warm water. The preliminary investigations showed that fabric hardly shrinks after the fourth laundering cycle. After the fifth cycle of laundering, no more shrinkage was observed. Therefore five laundering cycles were chosen.

Fabric shrinkage y (in warp $y_1$ and weft $y_2$) after each laundering is calculated according to the formula:

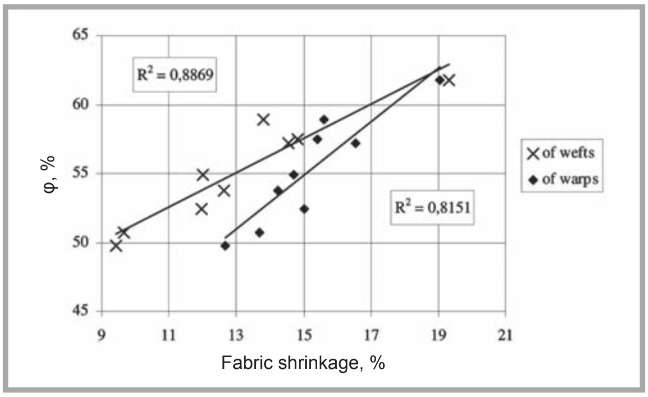
$$y = \frac{l_0 - l}{l_0} 100\%$$

where:
$l_0$ – the initial fabric width before laundering;
$l$ – the fabric width after laundering, when the fabric has shrunk.

Fabric thickness was measured with an Automatic Micrometer (with a measurement accuracy of 0.01 mm). For the fabric cross-sectional investigations an Askania microscope was used (with a measurement accuracy 0.0005 mm).

The stabilisation of fabrics was carried out according to the following parameters: the stabilisation solution consisted of acic acid 0.5 g ($CH_3COOH$), 5 l reacnit (FF), and 1 kg magnesium chloride ($MgCl_2$) in 100 l $H_2O$, and the fabric went through the drying machine at a speed of 6 m/min and a temperature of 140 °C. Then the fabric was passed through the drying machine once more at a speed of 9 m/min and temperature of 180 °C. The technological parameters presented are usually used in Lithuanian companies for finishing linen fabrics.

*Figure 2. The dependencies of loom-state fabric weft and warp yarn shrinkages on the fabric firmness factor φ after five laundering cycles.*



## Experimental Results and Discussion

The investigations initially determined the influence of the fabric firmness factor φ on fabric shrinkage after laundering. ***Figure 2*** presents the dependencies of fabric weft and warp yarn shrinkage after five laundering cycles on fabric firmness factor φ [5, 6].

As seen in ***Figure 2***, the values of coefficients of determination are high ($R^2 = 0.8869$ or $R^2 = 0.8151$). So, we can assert that fabric shrinkage depends on fabric firmness factor φ. The higher this factor φ, the greater the shrinkage of fabric in both warp and weft directions after laundering, however. The situation became contraverse the more the fabric is filled with yarns (i.e. factor φ is higher), the higher are the shrinkage values. This process is not specific to single-layer fabrics overall. So, during later investigations the influences of yarn density and yarn linear density were investigated. The dependencies of weft density and weft yarn linear density on shrinkage after five cycles of laundering are presented in ***Figures 3*** and ***4***.

As seen in ***Figures 3*** and ***4***, both parameters have a significant influence on fabric structure after laundering. Even from the results of three experimental points it can be stated that when these parameters increase, the shrinkage after laundering increases, too. More experiments are required to determine the precise dependencies, of course. But the principal tendencies of the dependencies obtained are seen: shrinkage increases when density increases. As mentioned earlier, this phenomenon is not typical of single-layer fabrics at all.

Because of these unexpected results, the alteration of the internal fabric structure after laundering was investigated. It is well known that the shape of the fabric cross-section has a great influence on fabric properties [11, 12]. Microscopic analyss of the fabric cross-section along longer warp yarn floats in weave was performed. As seen in ***Figures 5 (a)*** and ***(c)***, comparison of loomstate fabrics with weft densities of 210 $dm^{-1}$ and 270 $dm^{-1}$ shows how fabric structure changes when weft density increases. If warp yarns are placed close together in the same plane in the case of fabric with weft yarn density of 210 $dm^{-1}$, then in fabric with 270 $dm^{-1}$ weft density the warp yarns of long floats go one under

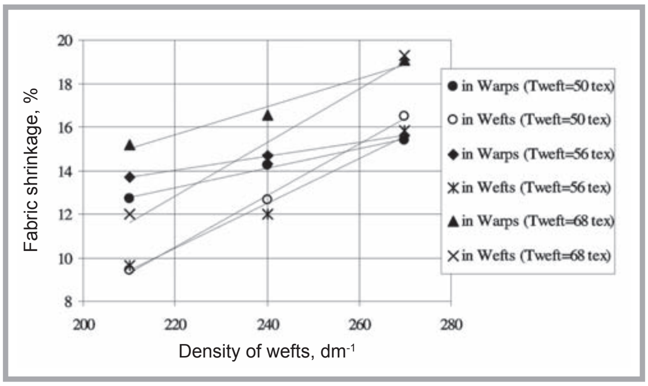


*Figure 3. The dependence of fabric shrinkage after five laundering cycles on weft yarns density.*

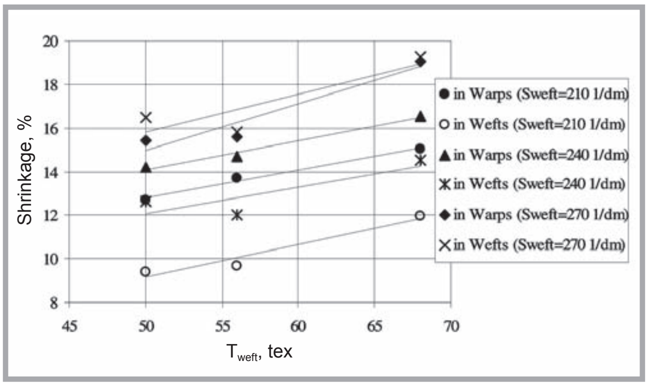


*Figure 4. The dependence of fabric shrinkage after five laundering cycles on linear density of weft yarns.*

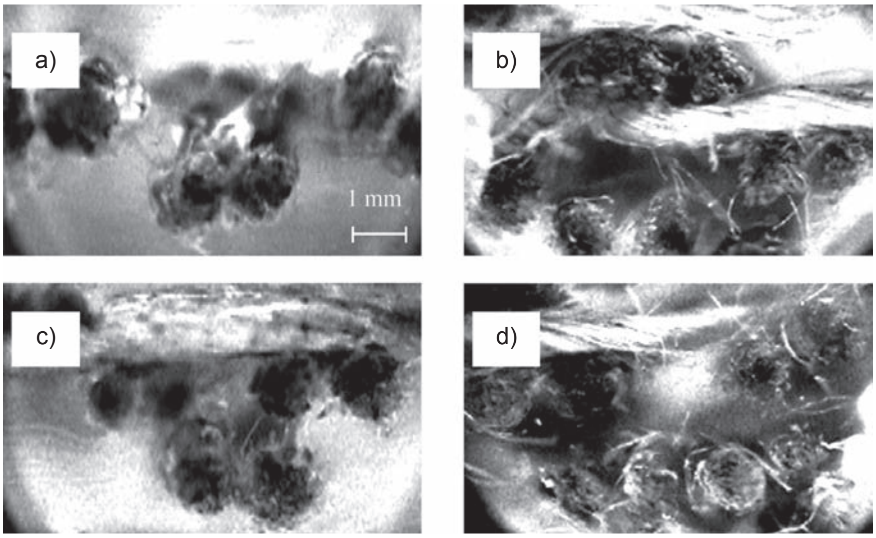


*Figure 5. Cross-sections of fabrics from 56 tex linen spun yarns: (a) loomstate fabric, with $S_2$ = 210 dm$^{-1}$, (b) fabric after laundering, with $S_2$ = 210 dm$^{-1}$, (c) loomstate fabric, with $S_2$ = 270 dm$^{-1}$, (d) fabric after laundering, with $S_2$ = 270 dm$^{-1}$.*

another and the wefts of the fabric ‚laminate‘.

The following phenomena occur more intensively in fabric after laundering. As seen in ***Figure 5 (b)***, the warp yarns of long floats also go one under another in fabric after laundering with lower weft yarn density. For fabric with higher yarn density, the ‚laminating‘ process after laundering became very intense (see ***Figure 5 (d)***).

So, with the increase in the honeycomb weave fabric density (density of yarns or linear density), the structure of the fabric became more sophisticated than that of the usual single-layer fabrics: the yarns of the same system go one under the other, in other words in some places the fabric obtains the structure of a multilayer fabric. It is natural that the parameters of single-layered fabric structure estimation, for example parameter φ, do not fit multilayered fabric, which is why the contradictory results arise.

The investigations of fabric thickness confirmed that the thickness of honeycomb weave fabric increases intensively when the density or linear density of weft yarns increases (***Figures 6*** and ***7***), and this increase in thickness is very significant for fabric after laundering.

Therefore the usual methods for decreasing the shrinkage of single-layer fabric after laundering are not suitable for honeycomb weave fabric. These fabrics must undergo additional technological processes, that is, stabilisation. The shrinkage of stabilised fabric after laundering is presented in ***Table 2***.

As seen from ***Table 2***, stabilisation significantly decreases the shrinkage after laundering by a factor of between 6 and 19 (see ***Figures 3*** and ***4*** and ***Table 2***). Therefore this is the only way to decrease the shrinkage of honeycomb weave fabric after laundering.

***Table 2.*** *The shrinkage of stabilised linen honeycomb weave fabric after laundering.*

| $T_{weft}$, tex | $S_{weft}$, dm$^{-1}$ | Shrinkage, % | |
|---|---|---|---|
| | | In warp | In weft |
| 50 | 210 | 1.50 | 0.50 |
| | 240 | 1.00 | 0.50 |
| | 270 | 1.35 | 2.05 |
| 56 | 210 | 2.00 | 1.00 |
| | 240 | 1.00 | 0.85 |
| | 270 | 2.38 | 2.50 |
| 68 | 210 | 1.00 | 1.00 |
| | 240 | 0.85 | 1.35 |
| | 270 | 2.36 | 2.15 |

## Conclusions

- Linen honeycomb weave fabrics including sauna clothes must be stabilised. The usual methods of decreasing shrinkage (by increasing fabric yarn density and linear density) of single layer fabric do not ensure positive results.
- The opposite effect is obtained when the density or linear density of yarns of honeycomb weave fabric increases: shrinkage increases more in both warp and weft directions.
- This negative effect happens because the honeycomb weave fabric after laundering is not a typical single-layer fabric. The long floats of warps and wefts go one under another, so the cross-section of the fabric assumes a shape which is not specific to single layer fabrics. Such phenomena are due to the specific honeycomb weave fabric structure and original salience surface.
- It can be stated that the third dimension of woven fabric (the shape and structure of the fabric cross-section) also has a strong influence on its properties.

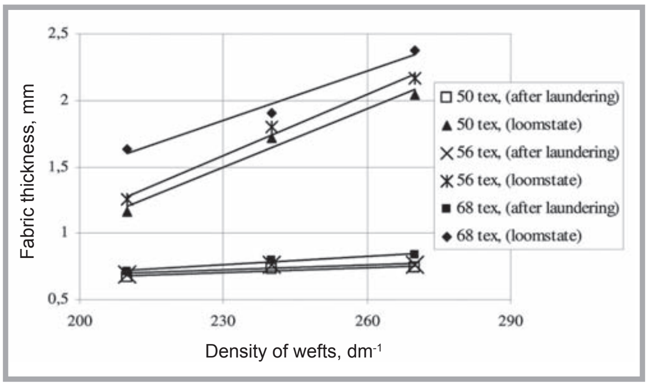


***Figure 6.*** *Thickness variation of fabric and increasing density of wefts when linear density of wefts is constant.*

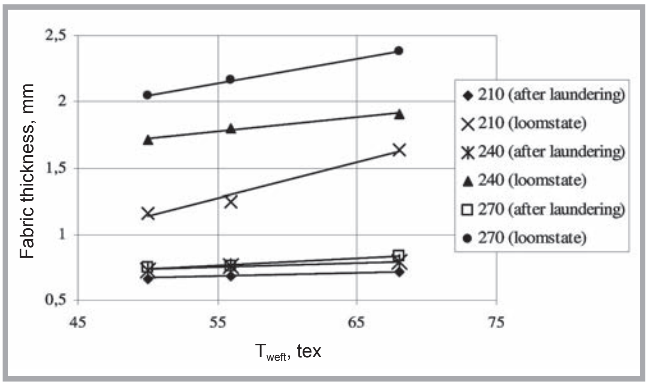


***Figure 7.*** *Thickness variation of fabric and increasing linear density of wefts, when density of wefts is constant.*

## References

1. Higgins L., Anand S.C., Holmes D.A., Hall M.E., Underly K.: *Effects of various home laundering practices on the dimensional stability wrinkling, and other properties of plain woven cotton fabrics: Part I: Experimental overview, reproducibility of results, and effect of detergent. Textile Research Journal, , vol. 73, no. 4, pp. 357-366, 2003.*
2. Higgins L., Anand S.C., Holmes D.A., Hall M.E., Underly K.: *Effects of various home laundering practices on the dimensional stability, wrinkling, and other properties of plain woven cotton fabrics: Part II: Effect of rinse cycle softener and drying method and of tumble sheet softener and tumble drying time. Textile Research Journal, vol. 73, no. 5, pp. 407-420, 2003.*
3. Shurkian O., Amirbayat J., Gong R.H.: *Effects of repeated laundering and crease-resistant treatment on fabric properties Journal of Textile Engineering, vol. 48, no 1, pp. 1-4, 2002.*
4. Milašius V., Milašius A., Milašius R.: *Comparison of integrating structure factors of woven fabric. Materials Science (Medžiagotyra), vol. 7, no. 1, pp. 48-53, 2001, Kaunas, Technologija.*
5. Milašius V.: *An integrated structure factor for woven fabrics. Part I: Estimation of the weave. Journal of the Textile Institute., vol. 91, part 1, no. 2, pp. 268-276, 2000.*
6. Milašius V.: *An integrated structure factor for woven fabrics. Part II: The fabric-firmness factor. Journal of the Textile Institute., vol. 91, part 1, no. 2, pp. 277-284, 2000.*
7. Milašius R., Milašius V.: *Investigation of unevenness of some fabric cross-section parameters. Fibres & Textiles in Eastern Europe, vol. 10, no. 3 (38), pp. 47-49, 2002.*
8. Milašius R., Milašius V., Kumpikaitė E., Olšauskienė A.: *Influence of fabric structure on some technological and end-use properties. Fibres and Textiles in Eastern Europe, vol. 11, no. 2 (41), pp. 49-52, 2003.*
9. Milašius A., Milašius V.: *New employment of integrating structure factor for investigation of fabric forming. Fibres and Textiles in Eastern Europe, vol. 13, no. 1 (49), pp. 44-46, 2005.*
10. Lund G.V., Waters W.T.: *The stability to laundering of fabrics made from cellulosic fibers. Textile Research Journal, vol. 29, no. 12, pp. 950-960, 1959.*
11. Milašius R., Rukuižienė Ž.: *Inequality of woven fabric elongation in width and change of warp inequality under axial and bi-axial tensions. Fibres and Textiles in Eastern Europe, vol. 14, no. 1 (55), pp. 36-38, 2006.*
12. Milašius R., Rukuižienė Ž.: *Influence of reed on fabric inequality in width. Fibres and Textiles in Eastern Europe., vol. 11, no. 4 (58), pp. 44-47, 2006.*

☐ ***Received 22.05.2008 Reviewed 2.10.2008***