# The Influence of Constructional Parameters on Deformability of Elastic Cotton Fabrics

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**ABSTRACT**
This research is focused on the influence of constructional parameters such as the type of weave and density on deformability of pure cotton and cotton/elastane fabrics. In the research, two basic weaves were used: the plain and twill weave without (pure cotton) and with 6.2 percent of elastane in the weft direction. The density of the warp yarns was before bleaching 22yarns/cm and after end treatment (bleaching) from 24 to 31 yarns/cm. The chosen densities in the weft direction were 17 and 20 yarns/cm.

The fabrics were cyclically loaded with maximum load 17.66 N. The non-recoverable deformation was measured after 30 seconds of relaxation after the fourth cycle of loading, according to ASTM D 3107-75.

The research results show that elastane incorporation significantly decreased the non-recoverable deformation after loading. In the case of the twill weave, the decrease of non-recoverable deformation was from around 20% – twill without elastane to around 5% – twill with elastane – fabrics 7B and 8B. The non-recoverable deformation level decrease with fabrics in plain weave was also significant (from around 24% – plain without elastane to around 12% – plain with elastane). From the results of non-recoverable deformation, it is clearly seen that the chosen type of weave, plain and twill, significantly influenced the non-recoverable deformation level.

The increase of density in the weft direction from 17 yarns/cm to 20 yarns/cm for pure cotton and cotton/elastane fabrics insignificantly influenced the non-recoverable deformation level. This means that the density increase of 3 yarns/cm is too low to significantly influence the deformability of pure cotton and cotton/elastane fabrics.

**Keywords:** type of weave, density, cotton and cotton/elastane fabrics

## INTRODUCTION
Knowledge about constructional parameters and their influence on deformability, especially for elastic fabrics with elastane yarn, is very important for apparel production. The market is saturated with fabrics that have various constructional properties and compositions. Knowing the behavior of various constructed fabrics during production and end-use is very important when choosing an appropriate fabric for cloth-making with a reasonable price.

Knowledge about constructional parameters of woven fabric is the basis for analyzing the deforming behavior of fabric by longitudinal loading. Due to that fact, several research studies have been written on the behavior of woven fabrics upon application of an external load. The first analyzes were carried out in 1969 by Hearle, J. W. S., Grosberg, P. and Backer, S. who wrote about the structural mechanics of yarns and fabrics [1]. In the last twenty years, many studies have been done on the field of deformation properties of woven fabrics and their anisotropy [2–5]. Some authors dealt with anisotropy of fabric deformation after stretching [6], while others studied fabric deformation under various loading conditions [7]. Many researchers concentrated on the mechanical properties of fabric yarns and fabric [8-10]. In the last few years, a number of authors investigated the influence of structural parameters on the elasticity of woven fabrics [11–13].

The focus with this research was directed to the influence of constructional parameters on the deformability of elastic (cotton/elastane) and conventional pure cotton fabrics.

In addition to ordinary fabrics, the production and usefulness of textile material from blended yarns, especially the blends of natural fibres with elastane yarns, has increased. The blends with elastane filaments show a high level of elasticity. For this reason care in regard to the deformations that appear on material during cutting, sewing and after-treatment should be given [14-16]

The price of blended cotton yarns with elastane is about 30 percent higher than pure cotton yarns. So by increasing the density of cotton/elastane yarn in the weft direction, the price of the fabric will be higher. That is the reason to pay special attention to the density of elastic fabrics in the warp or weft direction depending upon the direction of incorporation of elastane in the yarn (warp or weft or in both directions). [16-18]

With this research, there are two questions needed answers: "Does the selection of the weave influence the level of fabric deformation?" and "Does the density increase of cotton/elastane yarns in the weft direction improve elastic behavior and decrease the deformation of fabric?" The research also focused on increasing density (for three yarns) in the weft direction and its effect on non-recoverable deformation.

In order to find the answers to the questions above, the research focused on the two basic weaves – plain and twill – with two different densities (17 and 20 yarns/cm) in the weft direction. In the first case, the cotton weft yarns consist of pure cotton (100-percent), while in the second case the weft yarns incorporate 6.2 percent of elastane multifilament (core-spun yarn). The mentioned weaves are intended for summer season shirt cloth production.

## DEFORMABILITY OF ELASTIC FABRIC

With tensile loading, the fabric deforms in the acting load direction. The deformation means increasing the length in the acting load direction in comparison to the length of fabric before loading. At the beginning, the fabric behaves linearly until the range of load reaches the linearity limit, which could be quite low. The fabric acts like the rigid body. This means the relation between the deformation and load is linear. The linearity between the load and deformation is presented with Hook`s law. So the behavior of fabrics falls between the two extremes of Hookean elastic response and Newtonian viscous behavior [19, 20]. Hook`s law presents the linear union between a load F and deformation ε. The proportionate factor between the load and deformation is elasticity modulus E. In Newton`s law, the load is related to the velocity gradient of deformation (dε/dt). The proportionate factor between the relation of the load and velocity gradient of deformation is the viscosity η. Above the limit load, the level of deformation is wider than the level of load and the non-linearity between the load and deformation appears. This means the growing of deformation is faster than the load. At that point, fabric behaves like the liquid that is presented through Newton's law. The behavior of fabric above the limit load is called viscoelastic behavior. Until the level of load reaches the load limit, the deformation is completely recoverable (elastic deformation), meanwhile above the load limit, the deformation is time-dependent, i.e. recoverable with time dependence. The region of so-called time-dependent deformation has a limit load, i.e. limit of viscoelastic region. Above the viscoelastic limit, plastic, non-recoverable deformation appears [19-21].

The complete recovery of deformation is presented as total relaxation of fabric; meanwhile partly recovered deformation is time-dependent. The total relaxation depends upon the load level, the time of loading of material with the definite load and the time intended for relaxation. Elastic recovery represents the union between elastic extension and total extension and is expressed in percent, Eq. (1).

$$E_e = \frac{\varepsilon_e}{\varepsilon} \cdot 100 \qquad (1)$$

Where: $E_e$ – elastic recovery, in%; $\varepsilon_e$ – elastic extension, in% and ε – total extension, in%.

The total extension ε consists of the elastic extension $\varepsilon_e$ and so-called time-depended extension $\varepsilon_t$. Depending upon the magnitude of tensile load, the time-depended extension is separated on the recoverable extension with the time $\varepsilon_{tr}$ and non-recoverable extension $\varepsilon_{tnr}$.

With loading the material under the limit load (yield point), the deformation is recoverable; above the load limit (yield point), part of the deformation is recoverable with time or non-recoverable. [19 - 22].
The research deals with the non-recoverable extension $\varepsilon_{tnr}$, which is calculated from the difference between total extension ε and elastic extension $\varepsilon_e$ ($\varepsilon - \varepsilon_e$) and is presented as the relation between the mentioned difference ($\varepsilon - \varepsilon_e$) and total extension in percent, also called the non-recoverable deformation $E_{nr}$ ($E_{nr} = \frac{(\varepsilon - \varepsilon_e)}{\varepsilon} \cdot 100$.).

## CONSTRUCTIONAL PARAMETERS OF ELASTIC FABRIC

The properties of woven fabrics are dependent upon construction, fineness of yarn, warp and weft density and the type of weave.

Fabrics with elastane that are used for summer cloths are usually woven in plain and twill weaves.

The plain weave is the basic weave where one warp yarn is lifted over one weft yarn. The interlacing is opposite in all neighboring cells. Plain weave allows the highest possible number of interlacings. The plain weave offers the highest defence to loading and has consequently higher breaking force and lower breaking extension.

The twill weave has a pattern of diagonal lines. Each warp yarn lifts over more than one weft. The diagonal lines in fabric reach high densities, so the fabric has very good mechanical properties.

Fabrics in the twill weave have a lower breaking force and higher breaking extension than fabrics in the plain weave [23] . If fabric in the twill weave has the elastane in the weft direction, then the breaking extension is about 15-percent higher in the weft direction. With the twill weave with elastane in the weft direction, the breaking extension is even 50-percent higher than ordinary fabrics in twill weave [14, 24, 25].

With the plain weave with elastane in the weft direction, the breaking extension is also about 50-percent higher, but the breaking extension of fabrics in plain weave is lower than the breaking extension of fabrics in the twill weave [14, 24, 25].

## MATERIALS AND METHODS

During the research, pure cotton (conventional) fabrics and cotton fabrics with elastane in the weft direction (6.2 percent) were analyzed. The analyzed fabrics were in the plain and twill (T3/1) weaves. The cotton yarn of fineness 20 tex was made on a rotor spinning machine, while the elastane with fineness 44 dtex was cored with cotton fibres – elastane core-spun yarn.

The density of warp yarns of fabric were before bleaching 22 yarns/cm and after end treatments (bleaching) increased to amounts from 24 yarns/cm to 31 yarns/cm (*cf. Table I*). The chosen densities in the weft direction were 17 and 20 yarns/cm. The fabrics 1B, 2B, 5B and 6B are made by pure cotton rotor yarn of fineness 20 tex in the warp and weft direction while fabrics 3B, 4B, 7B and 8B are made by cotton rotor yarn, 20 tex in the warp direction and cotton/elastane core-spun yarn, 20 tex in the weft direction.

The fabrics were exposed to cyclic loading with force 17.66 N, according to the standard ASTM D 3107-75 [26], where four cycles were done *(Figure 1)*. The maximum load (17.66 N) that was chosen for the experiment belongs to the viscoelastic part (above the yield point – the limit of elasticity) of the stress/extension curve of analyzed fabrics (1–8 B). With the method of ASTM D 3107-75 [19], the specimen is clamped at the bottom and top on a tensile testing machine INSTRON 6022. The distance between the clamps was 300 mm and was marked on the specimen. The specimen was loaded from 0 N to 17.66 N and returned back to 0 N again four times, taking approximately 5 seconds per cycle. After the fourth cycle, the specimen was relaxed for 10 seconds at the zero position; after that the control cycle was done. With the control cycle, the non-recoverable deformation was measured at the point where the first load appears.

Furthermore, after the three cycles and control cycle, the non-recoverable extension was measured and elastic recovery was calculated (Eq. 1). The level of non-recoverable deformation represents one part of the total extension, which represents 100-percent. The other part of the total extension is represented by the recoverable deformation.

The influence of the construction parameters means the type of weave (plain and twill), the elastane incorporation in the weft direction and the density increase (from 17 to 20 yarns/cm) on the non-recoverable deformation level were proved through statistical analysis.

The analysis of variance (ANOVA) was done to find the significance of the above mentioned parameters on non-recoverable deformation level.

The basis of one factor ANOVA is the partitioning of sums of squares into between-class ($SS_b$) and within-class ($SS_w$). It enables all classes to be compared with each other simultaneously rather than individually; it assumes that the samples are normally distributed. The one factor analysis is calculated in three steps: first the sum of squares for all samples, then the within-class and between-class cases. For each stage, the degrees of freedom df are also determined, where df is the number of independent 'pieces of information' that go into the estimate of a parameter. These calculations are used via the Fisher statistic to analyze the null hypothesis. The null hypothesis states that there are no differences between means of different classes, suggesting that the variance of the within-class samples should be identical to that of the between-class samples.

If $F \geq 1$, then it is likely that differences between classes means exist. These results are then tested for statistical significance or p-value, where the p-value is the probability that a variant would assume a value greater than or equal to the value observed strictly by chance. If the p-value is low (e.g. $p \leq 0.05$ or $p \leq 5\%$), then the null hypothesis is rejected, meaning that the differences between classes exist and are statistically significant. If the p-value is high (e.g. $p \geq 0.05$ or $p \geq 5\%$), then the null hypothesis is proved, meaning that the differences between classes are accidental [27].

The ANOVA was done using SPSS Statistics software.

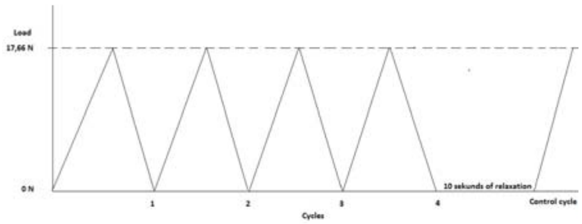


FIGURE 1. The review of cyclic loading according to the method of ASTM D 3107-75.

Basic and mechanical (viscoelastic) properties of analyzed fabrics are listed in *Table I* and *Table II*.

TABLE I. Basic properties of analyzed fabrics.

| Fabric | Composition | Yarn density, g / yarn $cm^{-1}$ | | Mass, $M/gm^{-2}$ | Thickness, h / mm | Weave | Elastane in the yarn direction | Percentage of elastane in the yarn (%) |
|---|---|---|---|---|---|---|---|---|
| | | Warp | Weft | | | | | |
| 1 B | Cotton | 24 | 17 | 86.8 | 0.174 | plain | | 0 |
| 2 B | Cotton | 24 | 20 | 94.0 | 0.169 | plain | | 0 |
| 3 B | Cotton/elastane | 28 | 17 | 101.8 | 0.209 | plain | weft | 6.2 |
| 4 B | Cotton/elastane | 28 | 20 | 107.2 | 0.197 | plain | weft | 6.2 |
| 5 B | Cotton | 24 | 17 | 86.0 | 0.224 | twill | | 0 |
| 6 B | Cotton | 24 | 20 | 93.0 | 0.253 | twill | | 0 |
| 7 B | Cotton/elastane | 31 | 17 | 106.6 | 0.331 | twill | weft | 6.2 |
| 8 B | Cotton/elastane | 29 | 20 | 111.0 | 0.347 | twill | weft | 6.2 |

TABLE II. Mechanical properties of analyzed fabrics.

| Fabric | Direction | Breaking stress, $\sigma_{pr}$ / $Nmm^{-2}$ | Breaking extension, $\varepsilon_{pr}$ /% | Elasticity modulus, $E_0 Nmm^{-2}$ | Extension with $E_0$, $\varepsilon_0$% | Stress at the yield point, $\sigma_y Nmm^{-2}$ | Extension at the yield point, $\varepsilon_y$% |
|---|---|---|---|---|---|---|---|
| 1 B | warp | 36.78 | 5.52 | 2.81 | 0 | 0.63 | 0.25 |
| | weft | 21.59 | 24.34 | 1.12 | 0 | 0.08 | 1.0 |
| 2 B | warp | 22.15 | 6.59 | 1.99 | 0 | 0.49 | 0.25 |
| | weft | 26.50 | 23.09 | 0.122 | 0 | 0.13 | 1.0 |
| 3 B | warp | 35.19 | 8.53 | 0.51 | 0.6 | 0.68 | 0.7 |
| | weft | 25.84 | 49.97 | 0.08 | 0 | 0.04 | 1.25 |
| 4 B | warp | 21.28 | 7.93 | 0.99 | 0 | 0.19 | 0.2 |
| | weft | 35.56 | 49.2 | 0.08 | 0 | 0.03 | 1.25 |
| 5 B | warp | 25.44 | 5.52 | 1.21 | 0 | 0.72 | 0.5 |
| | weft | 14.76 | 21.84 | 0.107 | 0 | 0.06 | 1.25 |
| 6 B | warp | 22.33 | 5.52 | 1.49 | 0.4 | 0.59 | 0.5 |
| | weft | 17.02 | 22.34 | 0.08 | 0 | 0.06 | 1.25 |
| 7 B | warp | 21.67 | 7.53 | 0.31 | 0 | 0.06 | 0.2 |
| | weft | 3.26 | 52.72 | 0.01 | 0.25 | 0.01 | 1.5 |
| 8 B | warp | 19.52 | 7.52 | 0.27 | 0 | 0.08 | 0.3 |
| | weft | 11.15 | 57.72 | 0.02 | 0 | 0.01 | 1.5 |

## RESULTS AND DISCUSSION

### Results of the Breaking Extension

The highest breaking extension was measured with fabrics 7 B and 8 B in the weft direction with elastane yarn (above 50%). Elastane in the yarn of fabrics 7 B and 8 B increases the level of breaking extension from about 20% to 50% compared to fabrics 5 B and 6 B that were without elastane (cf. *Table II*). The increase of the breaking extension of fabrics 7 B and 8 B compared with 5 B and 6 B (without elastane) is statistically significant (p-value = 0.001).
Furthermore, with fabrics 3B and 4B with elastane in plain weave, compared with fabrics 1 B and 2 B without elastane, the breaking extension level significantly increased from around 23% to around 49%. Fabrics 7 B and 8 B were in the twill weave that has a pattern of diagonal lines and enables a higher breaking extension (above around 57%) level increase in comparison with fabrics 3 B and 4 B in plain weave (under 50%). It could be stated that differences in the breaking extension level comparing plain and twill weaves exist and are statistically significant (p-value = 0.00473).

The density increase in the weft direction (from 17 to 20 yarns/cm, cf. *Table I)* of fabrics from pure cotton 2 B in plain weave and 5 B in twill weave did not influence a significant breaking extension increase (p-value = 0.593). That is valid also with fabrics 4 B and 8 B with elastane in the weft direction. This means that an increasing number of elastane yarns (from 17 to 20 yarns/cm) with fabrics 3 B, 4 B, 7 B and 8 B insignificantly affects the breaking extension increase, which is very low. So with fabrics in the plain weave (1–4 B) and in the twill weave (5–8 B), the increasing of density in the weft direction does not cause significant changes of breaking extension level.

The results of breaking extension are shown in *Figure 2*.

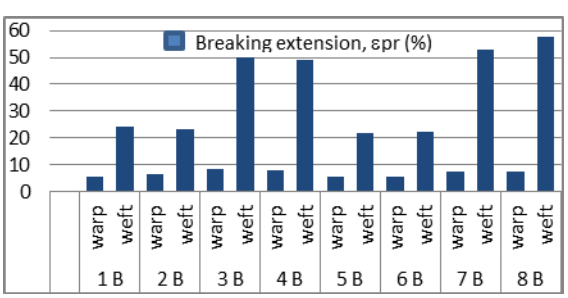


FIGURE 2. Breaking extension of the fabrics in the plain weave (1–4 B) and in the twill weave (5–8 B) in the warp and weft direction

### Results of the Limit of Extension (The Yield Point)

The results of limit of extension, i.e. the extension in the yield point, are listed in *Table II*.

The yield point presents the wideness of the region of elastic and completely recoverable deformations after loading. As described previously, the chosen load for the experiment (17.66 N) belongs in the viscoelastic region (above the yield point) and a non-recoverable deformation is expected. The wideness of the viscoelastic region depends upon the yield point value. If the yield point is high, then the viscoelastic region (above the yield point) is narrow; the opposite is true if the yield point is low, then the viscoelastic region is wider.

From the results of the extension in the yield point (*cf. Table II*), it is clearly seen that the highest extension in the yield point was calculated with fabrics 3 B, 4 B, 7 B and 8 B (from 1.25% to 1.5%), which have elastane in the weft direction, and also the highest breaking extension compared to fabrics without elastane in the yarn. The incorporation of elastane in the weft direction causes a significant increase in the yield point, the region of elastic deformations, (p-value = 0.034).

Furthermore, the influence of the chosen weave (plain and twill) on the yield point level was analyzed. The statistical analysis ANOVA showed significant changes in the yield point (the extension in the yield point) from the point of view of the chosen twill or plain weave (p-value = 0.04). The mentioned results are expected. With all fabrics in the twill weave (fabrics 5–8 B), the higher extension in the yield point and also the breaking extension were measured. The reason lies in the diagonal construction of the twill weave, which is more deformable than the plain weave.

The analysis also shows that the yarn density increase from 17 yarns/cm in fabrics 1 B, 3 B, 5 B and 7 B to 20 yarns/cm in fabrics 2 B, 4 B, 6 B and 8 B has an insignificant influence (p-value = 0.705) on the yield point level (*cf. Table II*). That fact is maintained with fabrics with and without elastane in the weft direction. The same results were obtained with the breaking extension. The analysis of breaking extension also concludes that the yarn density increase insignificantly influences the breaking extension level.

It is assumed that the yarn density (*cf. Table I*) that moves from 24 to 31 yarns/cm in the warp direction and two chosen densities 17 and 20 yarns/cm in the weft direction of the analyzed fabrics are too low to be used for summer season cloths. That is the reason the values of extensions at the yield point are very close (from 1.0–1.5% in the weft direction).

**Results of the Elasticity Modulus**

The results of the elasticity modulus that expresses the deformability level of fabric and presents the resistance of fabric on the acting load are listed in *Table II*. If the resistance of fabric on the acting load is high, it means the elasticity modulus is high and consequently the fabric has a low level of deformability especially at the beginning of loading (in the elastic region of the stress-extension curve).

The highest elasticity modulus was calculated with fabrics 1 B and 2 B (0.12 and 0.122 N/mm$^2$), while the lowest elasticity modulus was calculated with fabrics 7 B and 8 B (around 0.02 N/mm$^2$). The obtained results are very interesting, especially because with fabrics 3 B and 4 B with elastane, the value of elasticity modulus is 0.08 N/mm$^2$, while that value for fabrics 7 B and 8 B is about four times lower (0.02 N/mm$^2$). Even fabrics 3 B and 4 B have incorporated elastane in the weft direction; they are also in the plain weave, which is more compact and non-deformable than the twill weave is. The decrease of elasticity modulus when comparing fabrics with and without elastane in the plain weave is lower (from 0.12 N/mm$^2$ to 0.08 N/mm$^2$) than with fabrics in the twill weave (from 0.08 N/mm$^2$ – pure cotton to 0.02 N/mm$^2$ – cotton/elastane).

The decrease of elasticity modulus with fabrics 7 B and 8 B that have incorporated elastane and are also in twill weave is statistically significant (p-value = 0.042). That is also valid with fabrics 3 B and 4 B, which have also elastane and are in the plain weave. This means that elastane incorporation in the weft direction has an important influence on the elasticity modulus

The analysis of elasticity modulus has also shown that the type of weave (plain and twill) has a significant influence on the elasticity modulus level (p-value = 0.034). Fabrics in the twill weave, especially 7 B and 8 B, have a much lower value of elasticity modulus than fabrics 3 B and 4 B. While with analyzing fabrics 1 B and 2 B in plain weave and 5 B and 6 B in twill weave that are without elastane in the weft direction, the values of elasticity modulus fluctuate between 0.122 N/mm$^2$ and 0.08 N/mm$^2$ and are about 1.5 times lower for fabrics in the twill weave in comparison with fabrics with elastane 3 B and 4 B in plain and 7 B and 8 B in the twill weave where the decrease in the elasticity modulus is the highest (about four times – from 0.08 N/mm$^2$ to 0.02 N/mm$^2$).

The analysis also shows that the yarn density increase from 17 yarns/cm in fabrics 1 B, 3 B, 5 B, 7 B to 20 yarns/cm in fabrics 2 B, 4 B, 6 B and 8 B has an insignificant influence (p-value = 0.705) on the elasticity modulus level. That applies (*cf. Table II*) for fabrics with and without elastane in the weft direction. The reason lies in the low density of analyzed fabrics in the warp (from 24 to 31 yarns/cm) and also in the weft direction where the two densities 17 and 20 yarns/cm were chosen. It could be said that increasing the density by 3 yarns/cm has an insignificant influence on the elasticity modulus, i.e. the deformability of fabrics.

On the other hand, the elastane incorporation in the weft direction significantly increases the deformability level and consequently the recovering of fabric to the start position at the moment the load is removed.

**Results of the Non-Recoverable Deformation**

The results of non-recoverable deformation are graphically presented in *Figure 3*.

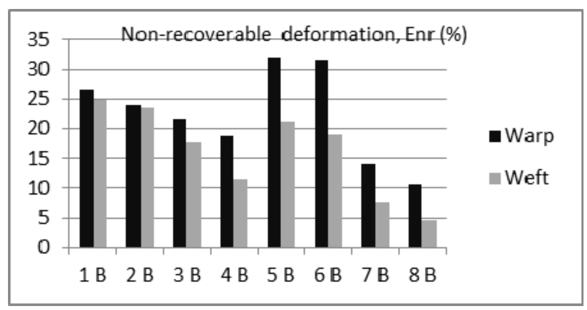


FIGURE 3. The results of non-recoverable deformation $E_{nr}$ in the warp and weft direction.

The non-recoverable deformation $E_{nr}$ represents the non-recoverable part under the stress-extension curve to the maximum load 17.66 N according to the standard ASTM D 3107-75 [19], while elastic recovery $E_e$ represents the recoverable deformation. The sum of the elastic recovery and non-recoverable deformation represents 100%, i.e. the total extension to the maximum load 17.66 N [19].

With fabrics 1 B and 2 B in the plain weave in the weft direction, without elastane in the yarn, the highest non-recoverable deformation was calculated (around 24%, *cf. Figure 3*), while the lowest non-recoverable deformation was calculated with fabrics in the twill weave with elastane in the weft direction (around 5%, *cf. Figure 3*). With fabrics 3 B and 4 B that have elastane in the yarn, the level of non-recoverable deformation decreases by about 20% compared to fabrics 1 B and 2 B. The fact is that incorporated elastane in the weft direction significantly decreases (p-value = 0.0057) the level of non-recoverable deformation from around 24% to around 12% when comparing fabrics 1 B and 2 B (pure cotton) with 3 B and 4 B (with elastane) in plain weave. In the comparison of fabrics 5 B and 6 B (pure cotton) with 7 B and 8 B (with elastane) in twill weave, the non-recoverable deformation decrease is higher than with fabrics in plain weave and decreases from around 20% to the lowest value of 5%.

The decrease of the non-recoverable deformation, in both cases with the plain and with the twill weave, is statistically significant (p-value = 0.013). In the case of twill weave, the decrease of non-recoverable deformation is much higher, especially in the case of fabrics 7B and 8B with elastane in the weft direction. This means that elastane incorporation in the weft direction with fabrics in the twill weave improves the deformability of fabric comparing with fabrics in the plain weave, where elastane incorporation also influences a significant decrease in non-recoverable deformation, but the level of decrease of non-recoverable deformation is lower (*cf. Figure 3*).

It was already stated that the twill weave has the typical diagonal construction and the return of fabric to the start position after unloading is easier than with the plain weave, which is more compact. Elastane in the weft yarn improves the ability to recover the fabric to the start position, and the result is the lowest level of the non-recoverable deformation (around 5 – 7%, *cf. Figure 3*).

The increase of density in the weft direction, from 17 to 20 yarns/cm, insignificantly influences (p-value = 0.064) the decrease of the non-recoverable deformation value with all analyzed fabrics.

The changes (reduction) to the non-recoverable deformation due to yarn density increase are a bit higher with fabrics 3 B, 4 B, 7 B and 8 B, which have elastane in the weft direction, but the decreasing of non-recoverable deformation is not statistically significant.

It could be stated that the increase of the number of elastic yarns in the weft direction does not improve the elasticity of woven fabric significantly.

The lower level of non-recoverable deformation is expected with stretchable fabrics such as 3 B, 4 B, 7 B, 8 B with elastane, and the decrease (from around 20% to only about 5%) of non-recoverable deformation in those cases is statistically significant.
On the other side, the increase of the elastane density in the weft direction with cotton/elastane fabrics (fabrics 3 B, 7 B – with density 17 yarns/cm compared with 4 B and 8 B – with density 20 yarns/cm) does not significantly affect the non-recoverable deformation decrease level. That fact is also maintained in the comparison of pure cotton (non-elastic) fabric 1 B and 5 B with density 17 yarns/cm and 2 B and 6 B with density 20 yarns/cm.

**CONCLUSION**

From this research on the influence of constructional parameters on deformability of elastic cotton fabrics, the following conclusions were drawn:

- Elastane incorporation significantly increased the breaking extension level (from around 20% to around 50%) and the limit of extension (the extension at the yield point from 1% to 1.5%) and significantly decreased the elasticity modulus (from 0.12 N/mm$^2$ to 0.08 N/mm$^2$ – plain weave and from 0.08 N/mm$^2$ to 0.02 N/mm$^2$ – twill weave) and the non-recoverable deformation (from around 24% to 12% – plain weave and around 20% to only 5% – twill weave).
- The twill weave that was more deformable than the plain weave. The chosen type of weave significantly influenced the breaking extension level (especially with fabrics with elastane the breaking extension of which increases from 49% – plain to 57% – twill), the limit of extension (the extension at the yield point increased from 1.0% – plain to 1.5% – twill), the elasticity modulus (decreased from 0.12 N/mm$^2$ to around 0.08 N/mm$^2$ – plain weave and from 0.08 N/mm$^2$ to 0.02 N/mm$^2$ – twill weave). In the case of twill weave, the non-recoverable deformation was the lowest (decreased from 20% – plain to around 5% – twill).
- The density increase (from 17 to 20 yarns/cm) insignificantly influenced the breaking extension level, the limit of extension, elasticity modulus and the non-recoverable deformation level.

From the conclusions drawn above, it is clear that elastane incorporation in the weft direction significantly increases the deformability and the field of elastic deformations of cotton fabrics. That is more obvious with fabrics in the twill weave, which is more deformable than the plain weave is. On the other hand, elastane incorporation decreased the deformation level at the moment the load was removed and ensured easier recovery of the fabric to the start position after loading. The above mentioned decrease was much higher – about 75% in the case of twill weave with elastane compared to twill weave without elastane (in the case of plain weave that decreased about 25% when comparing fabrics with and without elastane). The density increase of three yarns was too small to affect the deformability level of cotton and cotton/elastane fabrics.

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