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Effect of Raw Material on the Geometrical Properties of Fabrics

Abstract
It was discovered in the process of manufacturing that the parameters of a fabric structure change after taking it away from the weaving loom and its stabilisation. This is probably due to the geometry of the fabric cross-section, i.e. changes in yarn cross-section projections and the fabric structure phase. Thus in this study attempts were made to make an analysis of changes in the parameters of fabrics of different raw material and the dependence on the integrated fabric structure factor φ. Similar research of the above changes had not been performed previously. However, it is very important to study them in order to identify changes in their geometric structure when the fabric structure was stabilised.

Key words: *raw material, cross-section, projection, fabric structure, wave height, integrated fabric structure factor φ.*

Introduction

Each fabric is a complex material and its structure affects its own properties. There are seven major parameters of a fabric structure: the weft and warp raw material, the weft and warp setting, the warp and weft linear density and the fabric weave [1 - 3]. All seven parameters are evaluated by integrated fabric structure factors [4, 5]. The integrated fabric structure factor φ, suggested by Milašius and belonging to the group of Brierley's factors, is employed in this research. The factors of this group reflect fabric weavability [6, 7], which is one of the most important technological properties of fabric, with the possibilities for its processing on a weaving loom dependent on it [8, 9]. Factor φ can be calculated according to the formula:

$$\varphi = \sqrt{\frac{12}{\pi}}\frac{1}{P_1}\sqrt{\frac{T_{av}}{\rho}} S_2^{\frac{1}{1+2/3\sqrt{T_1/T_2}}} S_1^{\frac{2/3\sqrt{T_1/T_2}}{1+2/3\sqrt{T_1/T_2}}}$$

where:
T_1 – warp linear density,
T_2 – weft linear density,
T_{av} – average linear density of woven fabric thread,
P_1 – Milašius' weave factor,
ρ – raw material density,
S_1 – woven fabric warp setting,
S_2 – woven fabric weft setting.

It was discovered in the process of manufacturing that the parameters of a fabric structure change after taking it away from the weaving loom and its stabilisation. As is known, grey fabric shrinkage depends on the fabric structure as well as on the parameters of weaving technology, such as warp tension, the heald-crossing time, the reciprocal position of the backrest and cloth support, and so on. Thus, the warp projection variation also depends on the parameters of weaving technology [11]. The geometry of its cross-section is also likely to change, which is a stage in the cross-section projection and a fabric structure. The shape and measurements of the cross-section are predetermined by peculiarities of yarn material, the fabric setting, the parameters of weaving technology, etc., as well as many other different factors which are very complicated to evaluate theoretically. Therefore, the yarn cross-section very often takes a geometrical form, mostly matching a cross-sectional shape, which can be geometrical forms of a circle (Peirce), an ellipse, a racetrack shape (Kemp) and a convex lens (Milašius) [10, 12].

Milašius and Milašius [11] examined the cross-section of convex lens of warp in polyester fabrics, woven from multi-thread, as this form of cross-section, according to other researches, is typical for such thread. While dealing with the weft, they found no considerable changes in the cross-section and discovered that the cross-section parameters are affected by the specific fabric weave, yarn setting and fabric width [11].

Barburski and Masajtis [12] explored the impact of mechanical strain on the inner structure of fabric and on the geometrical form of its cross-section and yarn properties.

The structure of fabrics changes when they are taken from the weaving loom. The aim of this research was to determine if changes in fabric structure parameters are regular after stabilisation of the fabric structure, because in earlier research [13] it was found that the weft setting varies irregularly. The aim of this article is to explore how parameters of the cross-section of fabrics of different raw material (weft and warp projections, height of yarn wave) change after stabilisation of the fabric structure.

Materials and methods

Five fabrics of different raw material (cotton, wool, polypropylene, polyester,

Table 1. *Primary data.*

Raw material	Weave	Warp and weft linear density, tex	Warp setting S_m, dm^{-1}	Yarn structure
Cotton	Plain	18.5 × 2	260	Plaid yarn
Wool	Crape	92.3	177	Spun yarn
PAN	Plain	347	63	Staple yarn
PP	Plain	166.7	59.1	Staple yarn
PES	Plain	29.4	284	Multi-thread

polyacrylnitrile) were woven under different weaving conditions, i.e. under different weft settings, when φ equals 40, 45, 50, 55, 60, 65 & 70. The fabric structure parameters are introduced in ***Table 1***. Fabrics were woven on a SOMET loom. The parameters of cross- and longitudinal sections in all the fabrics were measured after stabilisation of their structure and in the process of biaxial extension, which was done, imitating the forces affecting the fabrics on the weaving loom. The fabric structure was stiffened and fixated by achromatic silicone. An Askania microscope and Nikon CoolPix 4500 camera were employed for analysis of the fabric geometry. Photos were taken with the help of the Metric 7 programme. In this research 15 measurements of each fabric (stabilised and tensioned) in two different directions (warp and weft) were carried out. The yarn projections measured are introduced in ***Figure 1***. Microscopic pictures of the fabric cross-sections before and after extension are presented in ***Figure 2***. Alteration of the longitudinal and cross projections as well as the wave height were calculated according these formulas:

$$\Delta_a = \frac{a_{tensioned}}{a_{stabilsed\ structure}}$$

where:

Δ_a - alteration of the longitudinal projection,

$a_{tensioned}$ - longitudinal projection after biaxial extension,

$a_{stabilsed\ structure}$ - longitudinal projection of the fabrics after structure stabilisation (before biaxial extension),

$$\Delta_b = \frac{b_{tensioned}}{b_{stabilsed\ structure}}$$

where:

Δ_b - alteration of the cross projection,

$b_{tensioned}$ - cross projection after biaxial extension,

$b_{stabilsed\ structure}$ - cross projection of the fabrics after structure stabilisation (before biaxial extension),

$$\Delta_c = \frac{c_{tensioned}}{c_{stabilsed\ structure}}$$

where:

Δ_c - alteration of the wave height,

$c_{tensioned}$ - wave height after biaxial extension,

$c_{stabilsed\ structure}$ - wave height of the fabrics after structure stabilisation (before biaxial extension).

Experimental results and discussions

In the process of the research attempts were made to find out how parameters of the cross-section in the fabrics of different raw material change after stabilisation of the fabric structure and in the process of biaxial extension, imitating fabric behaviour on a weaving loom. ***Figure 3.a*** (see page 46) introduces the dependence of changes in the longitudinal projections of weft on factor φ among fabrics of different raw material. As is seen in the formula of factor φ, factor φ evaluates lots of structure parameters (linear densities, weave, material density, settings), hence the general evaluation of this factor is fabric tightness because the breast beam and back rest position, as well as the initial warp tension and heald cross advance were stable. In this research only fabric tightness changes, because of which the influence of the fabric structure parameters mentioned were not investigated separately. It is evident that among many fabrics, changes in the longitudinal projections increase when the fabric structure stiffens, i.e. when the integrated fabric structure factor φ increases. Alteration of the longitudinal projections of weft in PAN fabric changed from 0.92 to 1.15 (25%), whereas in PP it was from 0.94 to 1.07 (13.8%). The alteration in PES fabric projections was an increases of 30.8% (from 0.94 to 1.23). As regards cotton and wool fabrics, the situation is different – an increase in factor φ leads to a decrease in changes in the longitudinal

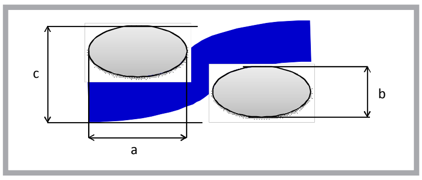

Figure 1. *Yarn projection proportion: a – longitudinal projection; b – cross projection; c – wave height.*

projections of weft. The curve of wool fabric decreases despite the fact that the projection limits vary from 0.84 to 1.31 (55.9%). The line of cotton fabric is significantly different. The stiffening of the fabric structure leads to a significant decrease in the alteration of the longitudinal projections (alteration in the above projections varies from 0.85 to 1.08 i.e. 27.1%). Such behaviour of the above fabric could be explained by the fact that it was woven from secondary plaid yarn, which is prone to insignificant alteration of its own cross-section form when the structure of the fabric stiffens.

Figure 3.b (see page 46) introduces the dependence of the alteration in the cross projections (b) of weft on the integrated fabric structure factor φ when weaving fabrics of different raw material. It is evident that there is a tendency for the lines of PP, PAN and cotton fabrics to decrease, whereas for wool and PES fabrics they increase. Such a contrary tendency among lines is likely due to the fact that the PES fabric was woven from multi-thread, whereas all the rest were made from yarn. Meanwhile, wool differs from the other fabrics as it is woven from crepe weave, whereas the others are made from plain weave. These features distinguish them from other fabrics. The biggest alteration range was for PES fabric (from 0.69 to 1.58, which is 2.2 times), and the smallest was for PAN fabric (from 1.03 to 1.22 (18.2%)).

Figure 3.c (see page 46) introduces the dependence of the alteration in the wave

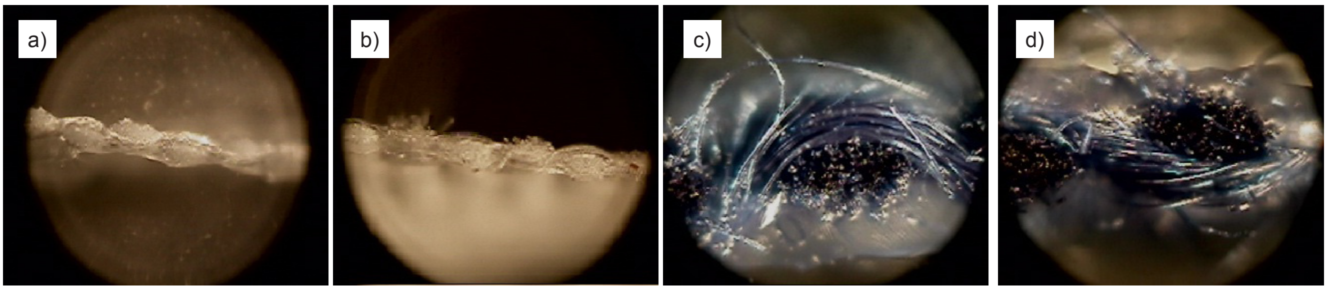

Figure 2. *Microscopic pictures of fabrics cross-sections before and after extension: a – PES fabric before extension; b – PES fabric after extension; c – PP fabric before extension; d – PP fabric after extension.*

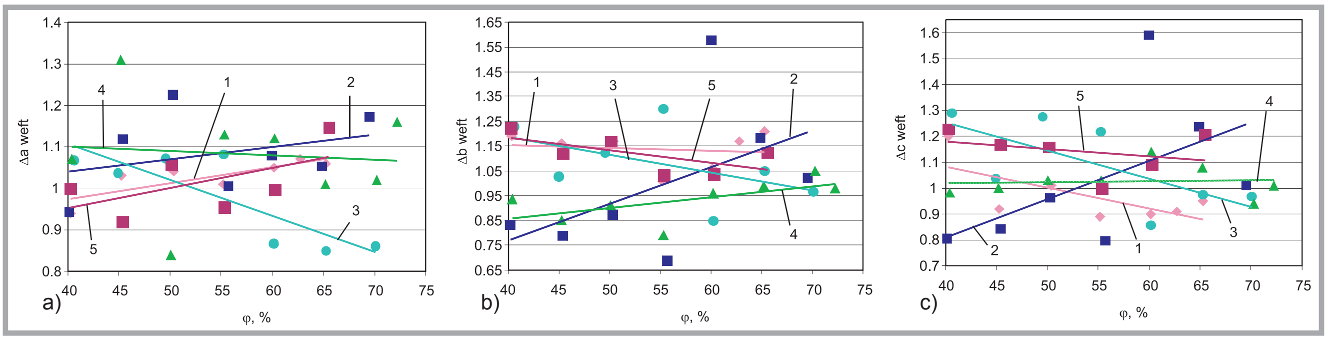

Figure 3. *Dependence of alteration in: the longitudinal projections (a), the cross projections (b), and the wave height (c) of weft on the integrated fabric structure factor φ, when weaving fabrics of different raw material: 1 – PP (♦); 2 – PES (■); 3 – Cotton (●); 4 – Wool (▲); 5 – PAN (■).*

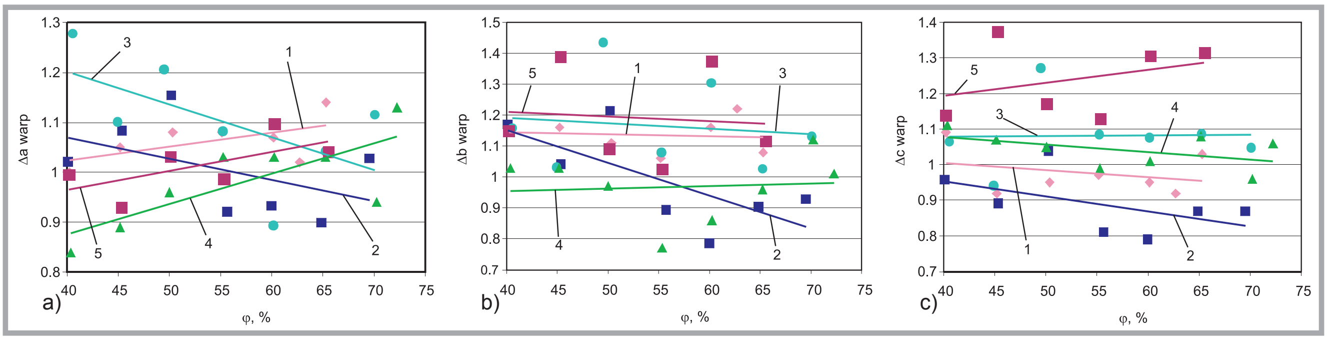

Figure 4. *Dependence of alteration in: the longitudinal projections (a), the cross projections (b), and the wave height (c) of warp on the integrated fabric structure factor φ, when weaving fabrics of different raw material: 1 – PP (♦); 2 – PES (■); 3 – Cotton (●); 4 – Wool (▲); 5 – PAN (■).*

height (c) of weft on the integrated fabric structure factor φ. In this case PES and wool curves can be obviously distinguished. The wool line is parallel to the x axis, and the determination coefficient R^2 is close to 0, which means that the alteration in the wave height of wool weft remains stable when the structure of the fabric changes. It is possible to conclude that the biggest impact on such a result is made by the weave of wool fabric, which, as was mentioned earlier, is crepe. Alteration in the wave height of PES fabric increased together with an increase in factor φ, which is contrary to cotton, PAN and PP - when factor φ increases, the wave height decreases. The range of alteration in PES fabric was the largest (from 0.8 to 1.59), whereas the smallest was for wool (from 0.94 to 1.14).

Figure 4.a introduces the dependence of the alteration in the longitudinal projections of warp on the integrated fabric structure factor φ. The alteration in the longitudinal projections of PAN, PP and wool fabrics was very much the same, i.e. an increase in the integrated fabric structure factor φ is followed by an alteration in the longitudinal projections of warp (a), whereas for PES and cotton the opposite is the case - the alteration decreases, when factor φ increases. Such a particularity is due to the fact that PES fabrics are woven from multi-thread, whereas cotton are made from secondary plaid yarn. The least alteration was for PP fabric – from 1.00 to 1.14 (14%), and for cotton it ranged from 0.89 to 1.28.

Figure 4.b introduces the dependence of the alteration in the cross projections of warp on the integrated fabric structure factor φ. It is obvious that when the fabric structure becomes more rigid (factor φ increases), the alteration in the cross projections of PP, PAN and cotton fabrics slightly decreases i.e. the curves are almost parallel to the x axis. Among wool fabrics this alteration is almost steady and appears to be almost parallel to the x axis. However, the curve of PES fabric shows that the above alteration significantly decreases when the integrated fabric structure factor φ increases. Most probably, such a result is obtained due to the fact that only this fabric was woven from multi-thread. In this case the narrowest range of alteration was found among PP fabrics (from 1.06 to 1.22 (15.1%)), whereas the largest one was discovered among PES fabrics (from 0.79 to 1.21) - 54.5%.

Figure 4.c introduces the dependence of the alteration in the wave height of warp on the integrated fabric structure factor φ. It is obvious that the lines of fabrics from almost all the materials tend to decrease i.e. the alteration in the wave height of PP, PES, wool and cotton fabrics decreases. Contrarily, that of PAN fabrics increases when the integrated fabric structure factor φ starts growing. It is difficult to explain this exceptional phenomenon as the fabric was woven from yarn; however, the weave was like in most of the other fabrics examined. In this case the narrowest range of alteration was found among wool fabrics (from 0.96 to 1.11 (15.6%)), whereas the largest one was discovered among cotton fabrics (from 0.94 to 1.27 i.e. 35.0%).

Figure 5.a introduces the dependence of the alteration in the longitudinal projections (a) of warp on the material density ρ when φ equals 40%, 50% and 65%, which is necessary in order to estimate the influence of the raw material on the alteration in fabric projections. It demonstrates that the curves tend to increase when the integrated fabric structure factor φ equals 40% and 50%, whereas they tend to decrease when φ equals 65%, which can be explained by the fact that

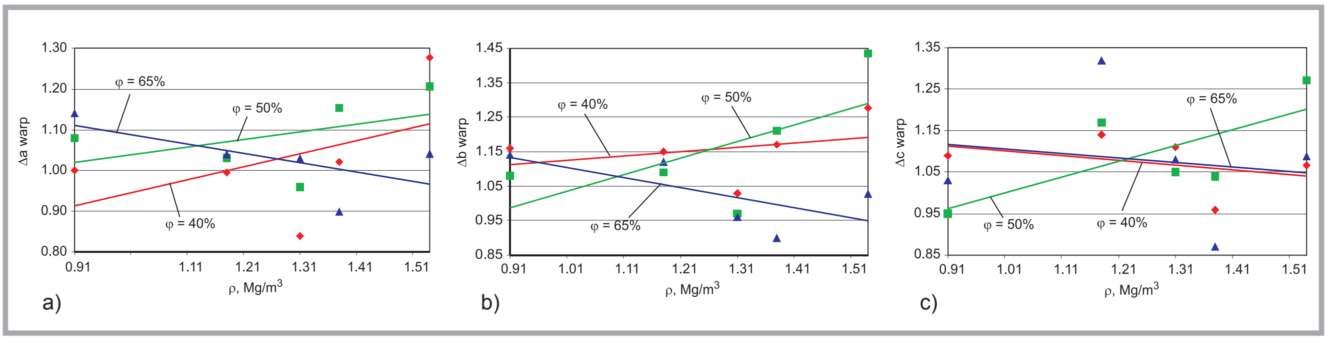

***Figure 5.** Dependence of alteration in: the longitudinal projections (a), the cross projections (b), and the wave height (c) of warp on the material density ρ, when φ equals 40% (♦), 50% (■) and 65% (▲).*

the fabrics are woven under conditions close to marginal. The fabric structure under these conditions can vary significantly. When factor φ equals 40% and 50%, this means that the larger the material density, the larger the alteration in longitudinal projections. When factor φ equals 65%, this means that the larger the material density, the smaller the alteration in longitudinal projections.

A similar tendency is shown in ***Figure 5.b***, which introduces the dependence of the alteration in the cross projections of warp on the material density ρ. When φ equals 40% and 50%, the lines tend to increase, whereas when φ equals 65% they decrease. When factor φ equals 40% and 50%, this means that the larger the material density, the larger the above alteration in the cross projections. When factor φ equals 65%, this means that the larger the material density, the smaller the above alteration in the cross projections.

A different tendency is found in ***Figure 5.c***, which introduces the dependence of the alteration of the wave height on the material density ρ. When φ equals 40% and 65%, the lines tend to decrease, whereas when φ equals 50% they increase. Such a phenomenon is difficult to explain because this value is not woven under marginal conditions. Factor φ equals 50%, which means that the larger the material density, the larger the above alteration in the wave height.

Conclusions

This article describes fabrics of five different raw material and the dependence of the alteration in the cross-section parameters on the integrated fabric structure factor φ when the fabric structure was already stable, imitating the fabric on a loom during biaxial extension.

1. It was discovered that the alteration in the longitudinal projections of weft increased among most fabrics when factor φ also increased. Furthermore the alteration in the longitudinal projections of warp also increases.
2. When the integrated fabric structure factor φ increases with respect to weft and warp, the alteration in the cross projections of most fabrics decreases.
3. In most cases a stiffening of the fabric structure leads to a decrease in the alteration of the wave height of weft and warp.
4. An alteration of the geometrical parameters of fabrics is affected by the yarn structure and weaves, which is proved by exceptional results obtained for PES (woven from multi-thread), cotton (from secondary plaid yarn) and, in some cases, wool (woven in crepe weave) fabrics.
5. An increase in the material density leads to an increase in the longitudinal and cross projections of weft (when factor φ equals 40% and 50%), which leads to a decrease when φ equals 65%. This can be explained by the fact that the fabrics are woven under conditions close to marginal. The fabric structure under these conditions can vary significantly. An increase in the material density leads to a decrease in the wave height of weft (when factor φ equals 40% and 65%), which leads to an increase when φ equals 50%.

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