Investigation of Correlation of Fabric Inequality in Width with Fabric Shrinkage

Abstract
The air permeability and porosity of fabric are not constants in its width; that is, they vary in particular regularity and are higher in the central part of the fabric than in the border parts. This phenomenon hinders accurate prediction of fabric properties. In this article, the suggestion is made that inequality of air permeability in fabric width depends only on inequality of the warp projections because the sets of yarns and projections of weft yarns remain the same. The high coefficients of determination of the linear dependencies of air permeability on the projections of the warp yarns assert this presumption. The correlation of the inequality of fabric properties with fabric shrinkage is also presented in this article. This correlation is different for fabrics manufactured from multifilament yarns and for fabrics manufactured from spun yarns. These different correlations could occur because of the different cross-section deformation character of the yarns in the fabric. The investigations allow us to predict the fabric inequality and to define the fabric width in which air permeability and porosity are steady.

Key words: fabric inequality, air permeability, cross-section.

Introduction
Technical fabrics constitute a great part of all fabrics; they are widely used in industry, medicine, agriculture, transport and aviation. The polyester fabrics are used to cover airplane wings and other constructions. Fabrics of this kind should have certain special properties, air permeability among them [1,2]. Barrier textiles are used for manufacturing protective clothing to be used in clean areas, as in the electronic, pharmaceutical industries, in order to protect the manufactured goods against physical and microbiological human-borne impurities. Fabric porosity and air permeability are also important characteristics [3], which are very important not only for hygienic purposes, but also to estimate some technological indices, i.e. the opportunity to blow air through fabrics during finishing operations. The filtration technology is also a very important area of technical textile applications, and the fabric structure is highly significant. In filtration technology the particles are of different sizes. In such cases, the precisely determined size of pores in fabrics is of major importance, as it decides the fabric’s usability [1,3].

Fabric porosity and air permeability depend on many factors, such as fabric weave, the raw material of yarns, the set of yarns and other parameters [4]. As stated earlier, fabric porosity is not a constant in its width; it varies in particular regularity [1,5]. As mentioned in earlier investigations, fabric porosity and air permeability are higher in the central part of the fabric than in the border parts. This phenomenon makes it harder to predict the fabric’s properties. Additionally, another question arises – is it possible to use the fabric in the whole width because of unequal properties? On the other hand, if it is impossible to use the fabric in its whole width, what distance from the fabric edge is preferable, that is, at what width are these properties constant? In this article, the investigations of correlation of fabric inequality and fabric shrinkage are presented.

Materials and Methods
Sixteen different fabrics were chosen for experimental investigations. The choice was carried out according to different raw material, weave, sets, looms and width in reed. All fabrics are loom-state fabrics and are manufactured in various Lithuanian textile companies for various technical purposes – in other words, these are real fabrics, and no intervention by the authors into their manufacturing process was made. The settings of all fabrics are presented in Table 1.

As seen in Table 1, very diverse fabrics were chosen: from 9.4 tex to 187 tex of linear densities of multifilament yarns, and from 18.5 tex x 2 to 210 tex of linear densities of spun yarns, from 72 dm⁻¹ to 400 dm⁻¹ of sets, from 90 cm to 180 cm of width in reed with 5 different weaves, and the fabrics were manufactured on 4 different looms (projectile STB, rapier weaving Dornier and two types of air-jet loom, PN 130 and PN 170). The raw materials used for these fabrics were also different: polyester and polyamide multifilament, polyester-textured multifilament, metaaramid spun, cotton spun, and blended polyester- and cotton-spun yarns.

The air permeability of fabrics was determined according to the EN ISO 9237 standard, with the pressure difference of 50 Pa (by use of the VPTM-2M instrument). The investigations of yarn projections were carried out on a personal computer with the Mustec 12000 SP Plus scanner, whose resolution is 1200 dpi. The projections of yarns can be measured using the Rulers of Corel Photo paint program. The resolution of the equipment used allows the parameters of fabric structure to be measured with an accuracy of ±0.01 mm.

Experimental Results and Discussions
During the first stage of the investigations, the air permeability at various
As seen in Figure 1, the dependencies of air permeability on fabric width are different, but the character of the curves is the same for all fabrics; in other words, the air permeability increases closer to the central part of the fabric. The values of the fabric constant structure point \( L_C \) for various fabrics are different (the air permeability from this point to the central part is steady within the error limits). Figure 1 also shows that in fabric C, air permeability starting from the edge of the fabric increases, and when the \( L_C \) value is 40 cm it becomes constant and varies only very slightly. In both A and D fabrics, the values of air permeability vary similarly; the value of point \( L_C \) is 25 cm. Closer to the central part of the fabric, the steady nature of the properties may also be noted, although these values are not the same. The steady nature of air permeability in this part of the fabric is proved by the criterion of \( F \) distribution (the experiment in this part is non-informative). In fabric B, air permeability increases to the value of \( L_C=65 \) cm, and only at this point, i.e. almost in the centre of the fabric, do the values become constant. It should be noted, that coefficients of the variation \( F \) of air permeability in all experimental points of all 16 fabrics do not exceed 5%, and the width of variation \( \delta \) does not exceed \( \pm 10\% \) except at two points of fabric D (the points when \( L=40 \) cm and \( L=50 \) cm). In the last cases \( V<12\% \) and \( \delta\leq15\% \), but even for this fabric the constant structure point of \( L_C \) can be obtained, however not exactly.

In the next stage of the investigation, some characteristics of fabrics were investigated, namely sets of yarns and projections of yarns on the plane of the fabric. Both the earlier investigations [1] and the investigations of the 16 fabrics discussed proved that sets of yarns and projections of weft yarns remain the same, and only variations in the projections of warp yarns are observed. The dependence determined of the projections of the warp in the fabric width is presented in Figure 2.

As seen in this figure, the projections of the warps decrease towards the central part of the fabric, i.e. the dependence character is similar to the dependence of air permeability on the distance from the fabric edge, as presented in Figure 1. The dependence of air permeability on warp projections is presented in Figure 3.

As is seen in Figure 3, all fabrics have the same character of dependence - if the projections of the warp yarns increase, the values of air permeability decrease. The linear regression equation describes the dependence of air permeability on the projections of the warp yarns very well (the coefficients of the determination are high; \( R^2 = 0.7882 \) to 0.9577). Thus, it is possible to assert that the inequality of air permeability depends only on the inequality of the warp projections.

On the last stage of the investigations, it was hypothesised that inequality of fabric properties can be correlated on fabric shrinkage. During the present investigation, the values of the fabric constant structure point \( L_C \) were calculated, and the correlation of fabric inequality with fabric shrinkage was determined as follows:

\[
S = \frac{L_R - L}{L_R} \times 100 \quad (1)
\]

where:
- \( S \) - fabric shrinkage,
- \( L_R \) - fabric width in the reed,
- \( L \) - loose fabric width.

Table 1. Settings of fabrics.

<table>
<thead>
<tr>
<th>Fabric</th>
<th>Weave</th>
<th>Wide in reed</th>
<th>Loom</th>
<th>Warp T, tex</th>
<th>S1, dm⁻¹</th>
<th>Weft T, tex</th>
<th>S2, dm⁻¹</th>
<th>Raw material (warp and weft)</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>Plain</td>
<td>122</td>
<td>PN 130</td>
<td>9.4</td>
<td>360</td>
<td>9.4</td>
<td>300</td>
<td>Polyester multifilament yarns</td>
</tr>
<tr>
<td>B</td>
<td>Weft rib 2/2</td>
<td>162</td>
<td>PN 170</td>
<td>15.6</td>
<td>400</td>
<td>27.7</td>
<td>200</td>
<td>Polyester multifilament yarns</td>
</tr>
<tr>
<td>C</td>
<td>Plain</td>
<td>160</td>
<td>PN 170</td>
<td>18.5x2</td>
<td>300</td>
<td>18.5x2</td>
<td>345</td>
<td>Metaaramid spun yarns</td>
</tr>
<tr>
<td>D</td>
<td>Plain</td>
<td>180</td>
<td>STB</td>
<td>210</td>
<td>100</td>
<td>210</td>
<td>80</td>
<td>Blended polyester and cotton spun yarns</td>
</tr>
<tr>
<td>E</td>
<td>Plain</td>
<td>162</td>
<td>PN 170</td>
<td>29.4</td>
<td>240</td>
<td>27.7</td>
<td>180</td>
<td>Polyester multifilament yarns</td>
</tr>
<tr>
<td>F</td>
<td>Plain</td>
<td>162</td>
<td>PN 170</td>
<td>15.6</td>
<td>400</td>
<td>27.7</td>
<td>200</td>
<td>Polyester multifilament yarns</td>
</tr>
<tr>
<td>G</td>
<td>Twill 2/2</td>
<td>160</td>
<td>PN 170</td>
<td>24.5</td>
<td>360</td>
<td>24.5x2</td>
<td>200</td>
<td>Polyester textured multifilament yarns</td>
</tr>
<tr>
<td>H</td>
<td>Twill 2/2</td>
<td>163.6</td>
<td>STB</td>
<td>18.5x2</td>
<td>400</td>
<td>18.5x4</td>
<td>138</td>
<td>Blended polyester and cotton spun yarns</td>
</tr>
<tr>
<td>I</td>
<td>Plain</td>
<td>158.5</td>
<td>PN 170</td>
<td>9.4</td>
<td>360</td>
<td>9.4</td>
<td>300</td>
<td>Polyester multifilament yarns</td>
</tr>
<tr>
<td>J</td>
<td>Plain</td>
<td>123</td>
<td>PN 130</td>
<td>29.4</td>
<td>160</td>
<td>29.4</td>
<td>160</td>
<td>Polyester multifilament yarns</td>
</tr>
<tr>
<td>K</td>
<td>Plain</td>
<td>162</td>
<td>PN 170</td>
<td>29.4</td>
<td>240</td>
<td>29.4</td>
<td>180</td>
<td>Polyester multifilament yarns</td>
</tr>
<tr>
<td>L</td>
<td>Twill 3/1</td>
<td>160</td>
<td>PN 170</td>
<td>24.5</td>
<td>360</td>
<td>24.5x2</td>
<td>126</td>
<td>Polyester textured multifilament yarns</td>
</tr>
<tr>
<td>M</td>
<td>Twill 2/1</td>
<td>160</td>
<td>PN 170</td>
<td>18.5x2</td>
<td>300</td>
<td>18.5x2</td>
<td>228</td>
<td>Metaaramid spun yarns</td>
</tr>
<tr>
<td>N</td>
<td>Plain</td>
<td>90</td>
<td>PN 130</td>
<td>187</td>
<td>160</td>
<td>187</td>
<td>72</td>
<td>Polyamide multifilament yarns</td>
</tr>
<tr>
<td>O</td>
<td>Twill 3/1</td>
<td>90</td>
<td>PN 130</td>
<td>187</td>
<td>160</td>
<td>187</td>
<td>92</td>
<td>Polyamide multifilament yarns</td>
</tr>
<tr>
<td>P</td>
<td>Twill 2/2</td>
<td>158</td>
<td>Dornier</td>
<td>50x3</td>
<td>204</td>
<td>50x3</td>
<td>120</td>
<td>Cotton spun yarns</td>
</tr>
</tbody>
</table>
where:

\[
\Delta = \left(1 - \frac{L - 2L_C}{L}\right) \times 100
\]

\(\Delta\) - fabric inequality, \\
\(2L_C\) - fabric width in which air permeability varies (coefficient 2, because properties vary from both edges of the fabric), \\
\(L\) - loose fabric width.

The correlation of fabric inequality with shrinkage is presented in Figure 4. As seen in Figure 4, the coefficients of determination of both correlations are very high (\(R^2 = 0.8856\) and \(R^2 = 0.964\)). Hence, it is possible to assert that the fabric properties’ inequality is correlated with the shrinkage, but the correlations are different in fabrics manufactured from multifilament yarns and those manufactured from spun yarns. The different correlations could have occurred because of the different cross-section deformation character of the yarns in the fabric. It is evident that the yarns in the fabric are squeezed and the geometry of their cross-section structure has thus become more sophisticated. The raw material peculiarities, the fabric set and the weaving technology parameters are the deciding factors on the fabric cross-section’s shape. The cross-section of the yarns is approximated by the geometrical configuration, which corresponds to the cross-section [6-9]. While analysing the investigations of different cross-sections, the different characters of the cross-sections of multifilament yarns and spun yarns in the fabric were noted. Multifilament yarns, as presented in Figure 5, are ready to assume a flatter shape than spun yarns; that is, the alteration of the geometry of their cross-section is greater (the cross-section of loose yarns is round).

For a certain shrinkage, the fabric inequality is also higher for fabrics manufactured from multifilament yarns than from spun yarns (see Figure 4). This phenomenon can be explained by unequal multifilament yarn, and spun yarn’s tendency to change the geometry of its cross-section in the fabric. Therefore, it can be suggested that the correlations as determined can be used to predict the inequality of air permeability on the fabric width, both for fabrics manufactured from multifilament yarns and for fabrics manufactured from spun yarns.
Conclusions

The investigations showed that air permeability is not constant in the fabric width, and depends on distance from the fabric edge. The inequality of warp projections in the fabric width is the reason for the dependencies. The values of the projections of the weft yarns are steady in the whole fabric width, but the values of the projections of the warp yarns are lower in the central part of the fabric than in the border part. Likewise, the inequality of air permeability does not depend on the yarn sets; the variation of this parameter in the fabric width is within the error limits. The inequality of fabric air permeability is correlated with the shrinkage, but the correlations are different for fabrics manufactured from multifilament yarns and those manufactured from spun yarns. The different correlations could have occurred because of the different cross-section deformation character of the yarns in the fabric.

The investigations allow the fabric inequality to be predicted without investigating its properties by measuring only the fabric shrinkage, and to define the fabric width, in which air permeability and porosity remain steady.

References