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Influence of Fabric Structure on the Character of Fabric Breakage

Abstract
In this article the influence of fabric structure, expressed by the integrated fabric structure factor φ, on the breaking force and elongation at break of a fabric is analysed. The weaves were divided into two groups, i.e. weaves, the floats of which are distributed at even intervals throughout the entire surface of the fabric, and horizontally striped weaves. We determined that the character of fabric breakage in the weave groups is different. Based on the analysis of the dependence of the breaking force on the factor φ, we can affirm that the dependence between the breaking force and fabric structure is not clearly visible in the woven fabrics tested. Any change in the elongation at break curve of weaves with evenly distributed floats is more intensive in comparison with that of across striped weaves. After evaluation of the dependences of all the weaves, we could see that the dependence determination coefficient is sufficiently high.

Key words: *woven fabric, integrated fabric structure factor, breaking force, elongation at break.*

■ Introduction

All parameters of the fabric structure (warp and weft raw material, warp and weft linear densities, warp and weft settings and fabric weave) influence many mechanical and end-use properties. Various scientists have studied the influence of fabric structure on various end-use properties. Milašius, among others, [1] analysed the influence of a fabric's structure on its air permeability and abrasion resistance. They established that when a fabric's structure stiffens, its air permeability decreases, and abrasion resistance increases.

Nikolic, et al. [2] expressed fabric strength by the thread strength, fabric setting, and thread strength coefficient. It was established that, with an increase in thread strength, the fabric strength also increases. The fabric strength in the warp direction is higher than that in the weft. Frydrych et al. [3], analysed the influence of finishing, raw material and weft setting on a fabric's elongation at break. They established the dependence between the change in friction and the area of warp and weft thread contact. Wang et al. [4], evaluated mechanical warp and weft interaction during shearing, as well as establishing theoretical dependencies between shearing rigidity and fabric structure. Witkowska and Frydrych [5] studied the strength of a fabric tear, and Szablewski and Kobza [6] studied bending rigidity. The different experiments mentioned above were conducted with the aim of studying various fabric properties, but the properties of fabric strength, especially their relation to fabric structure, were not investigated in detail. In the previous work [7] the relationship between fabric structure and tensile strength was determined, but in this article more attention is paid to the different breaking character of various fabrics.

▮ Integrated fabric structure factor

A fabric's structure can be evaluated by seven parameters: warp and weft raw material, warp and weft linear densities, warp and weft settings and the weave of the fabric. All seven parameters of the fabric's structure can be evaluated by integrated fabric structure factors. Various scientists (Newton [8], Seyam [9], Galceran [10], Brierley [11], and

Milašius [12]) proposed different evaluations of all these fabric parameters. According to the methods of evaluation of these parameters, two groups of integrated factors are distinguished: the first is based on the Peirce theory and the second on the Brierley theory [8]. Peirce's group factors express the covering of a fabric surface with thread, and Brierley's group factors express the weavability of a fabric. These factors are more extensively described in reference [13]. It was established in previous investigations [14] that the best way to evaluate fabric structure is using the factor φ, as proposed by Milašius, which can be calculated by the following 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 the woven fabric thread,
P_1 – Milašius' weave factor,
ρ – raw material density,
S_1 – warp setting of the woven fabric,
S_2 – weft setting of the woven fabric.

The value of the integrated fabric structure factor φ can vary from 0 to 1 depending on the density of the fabric structure, i.e. with an increase in the density of the fabric structure, the factor φ approaches the value 1.

■ Materials and methods

To carry out the above-mentioned experiments, fabrics were woven by a STB-2-180 gripper loom from PES 29.4 tex 100 m^{-1} twisted multifilament threads, with a warp setting of 284 dm^{-1}

and weft setting of 229 dm^{-1}. The fabrics were woven in 12 different weaves, which are shown in *Figure 1*. The weaves were chosen in such a way that they could be woven at the same loom setting. The weave factor P_1 of all chosen weaves changed in the widest possible range (from 1 to 1.9). Six of the chosen weaves (1, 2, 4, 5, 6, 7) had floats evenly distributed throughout the whole fabric surface, and six weaves were horizontally striped (3, 8, 9, 10, 11, 12). Therefore the weaves were distributed according to the character of their break. The values of the weave factor P_1 and integrated fabric structure factor φ calculated for the woven fabrics tested are shown in *Table 1*.

Fabric tensile tests were carried out in accordance with international Standard ISO 13934-1 [15], at standard weather conditions, with the use of a Zwick/Z005 standard tensile testing machine.
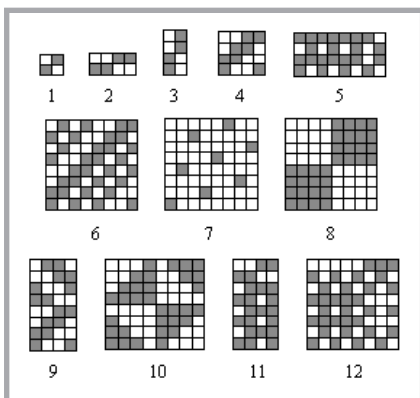

Figure 1. The weaves used for experiments: 1 – plain weave; 2 – weft rib; 3 – warp rib; 4 – twill 2/2; 5 – weft direction Bedford cord; 6 – fancy twill; 7 – sateen; 8 – basket weave; 9 – broken twill; 10 – crape weave; 11 – warp direction Bedford cord; 12 – mock leno.

Table 1. Values of the weave factor P_1 and factor φ of fabrics with different weaves.

Number of weave in Figure 1	P$_1$	φ
1	1	0.7122
2	1	0.7122
3	1.3093	0.5439
4	1.2649	0.5630
5	1.2756	0.5583
6	1.1094	0.6419
7	1.7889	0.3981
8	1.8856	0.3778
9	1.1795	0.6038
10	1.4105	0.5049
11	1.1795	0.6038
12	1.1258	0.6326

The stretching speed was 100 mm/min, and the distance between clamps was 200 mm. In this research only tests of the fabric tensile properties in the warp direction were carried out. This was the reason that the test specimens were cut only in the warp direction. We agreed to test the woven fabrics in the warp direction, which for our research was actually important and satisfying. The test variation coefficient values did not exceed 5%.

Experimental results and discussions

In order to establish the influence of fabric weave on fabric strength, tensile tests were carried out using fabrics of two types. It was observed that the character of fabric breakage, whose floats are distributed evenly throughout the entire fabric surface, and of horizontally striped fabric are different. Fabrics with evenly distributed floats broke at the weakest part of the fabric, i.e. localised, and horizontally striped fabrics broke in all the area of the specimen. It is thought that this happens because the weakest parts of threads in horizontally striped fabrics are placed on the edge of the horizontal stripes, and are distributed throughout the entire fabric surface. This may be the reason why the threads of a fabric break in different places.

On the basis of the test, the dependencies of the breaking force and the elongation at break in the warp direction on the integrated fabric structure factor φ for the different fabric groups and the overall dependencies of all the fabrics were (for both weave groups) determined.

The dependence of the breaking force on the integrated fabric structure factor φ for different fabrics is shown in *Figure 2*. It can be seen from the dependencies obtained that, as the factor φ increases in the initial part of the curves, the fabric's breaking force has a tendency to decrease, and if the factor φ values become 0.45 - 0.50 or higher, the breaking force values increase. We can see that the breaking force values of horizontally striped weaves are higher than those of the evenly distributed floats. It can be implied that even horizontally striped weaves start breaking sooner, but it takes time until all the fabric's threads break completely, and therefore higher breaking force values are achieved. This is the reason that the resulting breaking force

values of horizontally striped fabrics are higher than those of weaves with floats evenly distributed throughout the entire surface of the fabric. The correlation coefficients of the dependencies determined are not high.

Considering all the weaves, (of both types) the resulting dependence was ascertained, which is shown in *Figure 3*. In this dependence the fabric breaking force increases as the factor φ increases, but the correlation coefficient of this dependence is very low. Therefore, in this case we can assert that the dependence between a fabric's breaking force and integrated fabric structure factor φ is not clearly visible. Explicit reasons for these results are difficult to explain at this point.

The dependencies of elongation at break on the structure factor φ for the separate weave groups and the overall dependence for all tests were also determined by these experiments.
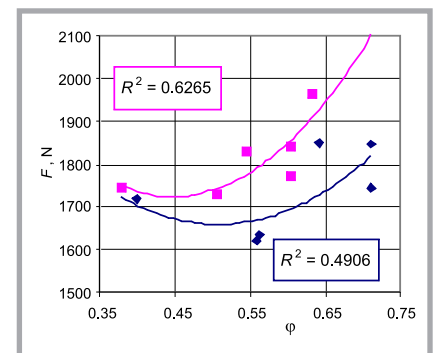

Figure 2. Dependencies of the fabric's breaking force in the warp direction on the integrated fabric structure factor φ: 1 – weaves with evenly distributed floats; 2 – horizontally striped weaves
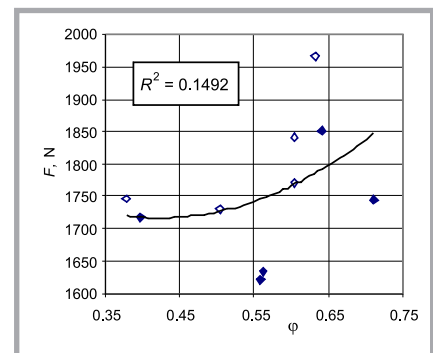

Figure 3. An overall dependence of the fabric's breaking force in warp direction on the integrated fabric structure factor φ for both kinds of weaves: ♦ - points related to weaves with evenly distributed floats, ◊ - points related to horizontally striped weaves.
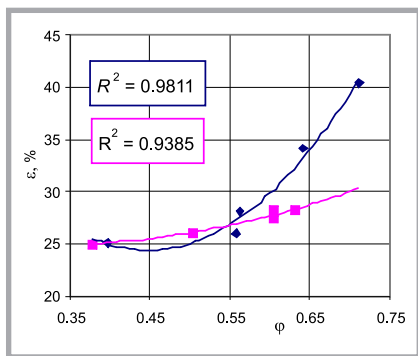
Figure 4. Dependencies of the fabric's elongation at break in the warp direction on the integrated fabric structure factor φ: 1 – weaves with evenly distributed floats; 2 – horizontally striped weaves.
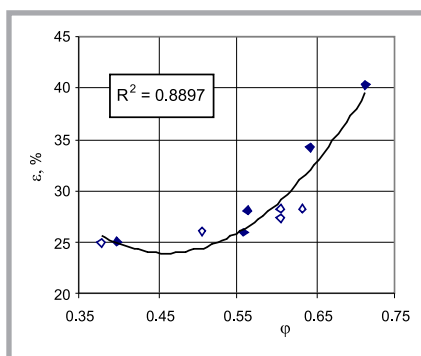

Figure 5. Overall dependence of the fabric's elongation at break in warp direction on the integrated fabric structure factor φ for both kinds of weaves: ♦ - points related to weaves with evenly distributed floats, ◊ - points related to horizontally striped weaves.

The dependence of elongation at break on the factor φ of fabrics woven with evenly distributed floats and horizontally striped weaves is shown in **Figure 4**. We can state that, as the factor φ increases, the elongation at break of horizontally striped weaves also increases. In the initial part of the elongation at break curve for the weaves with evenly distributed floats, the values of elongation do not change or even decreases when the values of factor φ are much lower, than 0.45, but at higher values, the elongation at break increases. We can see that the intensity of change in the curves of horizontally stripped weaves is smaller, in comparison with fabrics of weaves that have floats evenly distributed throughout the entire surface of the fabric, This can be explained by the fact that horizontally striped weaves elongate evenly, with warp threads breaking slowly, and therefore the overall fabric elongation is less dependent on the fabric structure. This may be the cause of the differences in the character of the dependencies deter-

mined. It should be emphasised that the determination coefficients correlated for those dependencies of fabrics of all the weaves analysed have high values.

The resulting dependence of elongation at break on the factor φ is shown in **Figure 5**. As the factor φ increases to 0.45, the elongation at break values decrease slowly, increase or remain constant; but when the values of factor φ become 0.45 or higher, the elongation at break visibly increases. The correlation coefficient for this dependence is quite high.

Similar dependencies were also obtained in the case of other integrated fabric structure factors, but due to the similarity of results, these dependencies are not presented in this article.

■ Summary

On the basis of tensile tests carried out in the warp direction on fabrics produced from PES 29.4 tex twisted multifilament thread on a STB-2-180 gripper loom, we can formulate the following statements:
1. The character of fabric breakage in weaves characterised by evenly distributed floats and those which are horizontally striped is different.
2. The dependencies obtained for the fabric elongation at break in the warp direction on the integrated fabric structure factor φ indicates that, as the factor φ increases, the elongation at break in the initial part of the curve has a tendency to decrease, but after the factor φ reaches 0.45 - 0.50 or higher values, the elongation at break increases explicitly.
3. The breaking force in the warp direction of weaves with evenly distributed floats is lower than that of horizontally striped weaves.
4. The dependence of the breaking force in the warp direction on factor φ initially increases or has a tendency to decrease, but for a given value of factor φ, the fabric's breaking force has a tendency to increase.
5. The intensity of changes in the dependencies of elongation at break in the warp direction of horizontally striped weaves on the factor φ is lower than that of weaves with evenly distributed floats.

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