Eglė Kumpikaitė

Kaunas University of Technology,
Faculty of Design and Technologies,
Department of Textile Technology
Studentu Str. 56, LT-3031 Kaunas, Lithuania
E-mail: Egle.Kumpikaite@ktu.lt

Analysis of Dependencies of Woven Fabric's Breaking Force and Elongation at Break on its Structure Parameters

Abstract

In this article, the woven fabric weave factor P_1 and the integrated fabric structure factor φ, suggested by Milašius, are described. Their qualities are emphasised in comparison with other woven fabric factors. The research results of the woven fabric structure's influences on its breaking force and elongation at break are also presented in this article; in other words, the dependence of the above-mentioned woven fabric factors on these parameters are presented. The research performed shows that there is no correlation between the weave factor and woven fabric breaking force, although the range of resulting points is wide. As the woven fabric rigidity of weave increases, the weave factor P_1 decreases, and the woven fabric elongation at break increases. The integrated fabric structure factor φ which evaluates all parameters of the fabric structure, such as warp and weft materials, warp and weft linear densities, warp and weft settings and the fabric weave, also has similar tendencies of dependence.

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

Introduction

It is well-known that the woven fabric's qualities are closely dependent on the structure of the fabric. The tensile qualities of woven fabric have been researched by Nikolic and others [1]. He proposed investigating woven fabric's strength as a function of thread strength, fabric density and thread strength coefficient. It was established that as thread strength increases, the woven fabric's strength also increases. While investigating woven fabrics of different weaves, it was established that plain weave is the strongest. Frydrych et al. [2] investigated the influence of woven fabric finishing, weft setting and raw materials on the elongation at break. Wang et al. [3] analysed the interrelation between warp and weft thread during the deformation of shearing. During the experiment, theoretical equations were established which describe the dependence between shearing rigidity and woven fabric structure. For short float weave fabrics, the dependence on friction change ratio and the contact warp & weft area is approximately rectilinear. Milašius et al. [4 - 6] investigated the influence of woven fabric structure on fabric air permeability, abrasion resistance and some of the technological properties of woven fabrics. It was established that as woven fabric structure density increases, air permeability decreases and abrasion resistance increases. To summarise, many studies have been performed on the woven fabric structure's influence on different fabric properties, but woven fabric strength has scarcely been investigated. Therefore, in this article we investigate those very fabric properties and their relationship with the woven fabric's structure.

Fabric factors

Woven fabric stucture is complex, because in its evaluation we need to take into consideration many woven fabric structure parameters, such as warp and weft materials, warp and weft linear density, warp and weft settings and fabric weave. All these woven fabric structure parameters can be evaluated together as well as separetely, but woven fabric weave evaluation is the most complex, because it is important to consider the nature of the float, its arrangement, interlacing of adjacent threads, etc. Many authors (Ashenhurst [7], Galceran [8], Brierley [9]) have proposed woven fabric weave factors. Milašius [10] proposed his weave factor P_1. Its point of distinction is that he evaluates the interlacing of adjacent threads, whereas many other weave factors only evaluate the interlacing of a single thread, and can easily be calculated using the weave matrix.

When evaluating all the woven fabric structure parameters, integrated fabric structure factors are used. Various authors (Newton [11], Seyam [12], Galceran [8], Brierley [9], Galuszynski [13]) evaluate all the woven fabric parameters in different ways and present different factors. Perhaps the most recent one is Milašius' [14] proposed integrated structure factor φ. This can be described as a ratio of the analysed woven fabric setting and the standard woven fabric setting, and is calculated according to 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 – the warp linear density,
T_2 – the weft linear density,
T_{av} – the average woven fabric thread linear density,
P_1 – Milašius' weave factor,
ρ – the raw material density,
S_1 – the woven fabric warp setting,
S_2 – the woven fabric weft setting.

The standard woven fabric is made with the maximum density of threads, using plain weave, and maximum thread setting (all for both: warp and weft). Milasius integrated factor belongs to the group of Brierley factors, and differs from many other factors proposed by other authors, which are based on Peirce's theory, and are estimated as a ratio of the thread-covered area and the whole woven fabric area. Milašius' factor is also easier to calculate than other factors in this group.

Materials and methods

The objects of our investigation were woven fabrics from PES 29.4 tex (twist 100 m^{-1}) multifilament yarn in warp and weft, woven in different weft settings and 12 different weaves, which are shown in

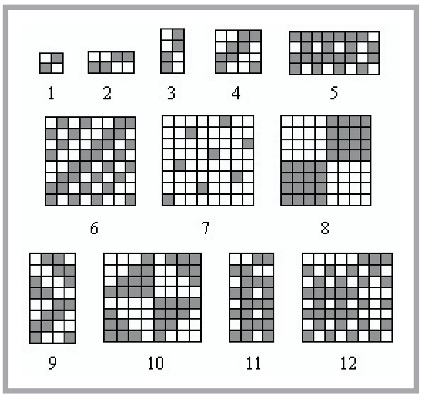

Figure 1. The weaves used for the experiment: 1 – plain weave; 2 – weft rib; 3 – warp rib; 4 – twill 2/2; 5 – weft direction Bedford cord; 6 – fancy twill; 7 – sateen; 8 – basket weave; 9 – broken twill; 10 – crape weave; 11 – warp direction Bedford cord; 12 – mock leno.

Figure 1. The weaves used in the experiment were woven without resetting the weaving loom. The weaves were chosen in such way that their weave factor P_1 would be distributed in a wide range. Part of the weaves was with the more or less expressed transversal stripiness, and other weaves had floats evenly distributed along the whole width of the woven fabric. The fabrics were woven using a gripper STB-180 weaving loom. The warp setting used was 28.4 cm^{-1}.

Breaking force and elongation at break experiments were carried out according to standard ISO 13934-1 [15] for woven fabrics. The experiments were performed with a tensile-testing machine Zwick/ Z005 in standard weather conditions. The coefficient of variation of the tests' results was 5%. Tests were performed only in the warp direction, because woven fabric is formed along the warp, and it was shown in earlier tests [16] that

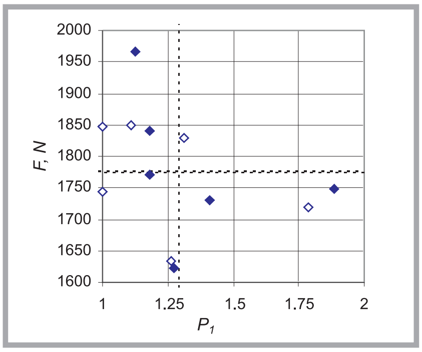

Figure 2. The dependence of the breaking force F on the weave factor P_1: ◊ - weaves, whose floats are evenly distributed within the whole area of the woven fabric; ♦ - transversal weaves; the dotted line shows the average of values of the breaking force and weave factor P_1.

the properties of woven fabric along the warp direction are more important.

Experimental results and discussions

Principally, dependencies of woven fabric strength and extensibility on fabric factor P_1 were researched. The fabric breaking force's dependence on this weave factor is shown in Figure 2. It is seen that as weave factor P_1 or weave rigidity changes, the breaking force changes accidentally; that is, no correlation between these parameters exists. It can be noted that points of weaves with transversal stripiness and weaves with floats evenly distributed within the total fabric area are distributed evenly on both sides of the mean line. This shows that the points are distributed accidentally. However, it cannot be said that these parameters are not dependent on each other, as the breaking force differs within a wide range.

During the tensile tests, it was noted that transversal striped weaves and weaves with floats evenly distributed within the total fabric area break in different ways. In weaves transversal striped, the threads break throughout the total length of the sample, but in samples where the weaves have floats evenly distributed within the total fabric area, breaks occur in a localised manner, i.e. in the weakest area. The breaking points of the test samples in both cases are shown in Figure 3. This most probably happens because in transversalstriped weaves, the weakest points are at the edge of the stripe and they are distributed evenly throughout the total length of the fabric. Their breaking curves, as shown in Figure 4, are different as well. We can see that in case of plain weave, where the floats are distributed evenly, the intensity of the curve is smaller than in the case of warp ribs, i.e. the transversal striped weave.

Figure 5 shows the fabric elongation at break's dependence on the fabric weave factor P_1. We can see that as the fabric weave factor P_1 decreases or the fabric rigidity increases, the fabric elongation at break increases. In the case of a more rigid weave, the threads are more closely connected but also more crimped; therefore, in the event of elongation they become straightened, and in the case of a more rigid weave, the elongation at break is greater than in a less rigid weave. It can be seen that the coefficient of determina-

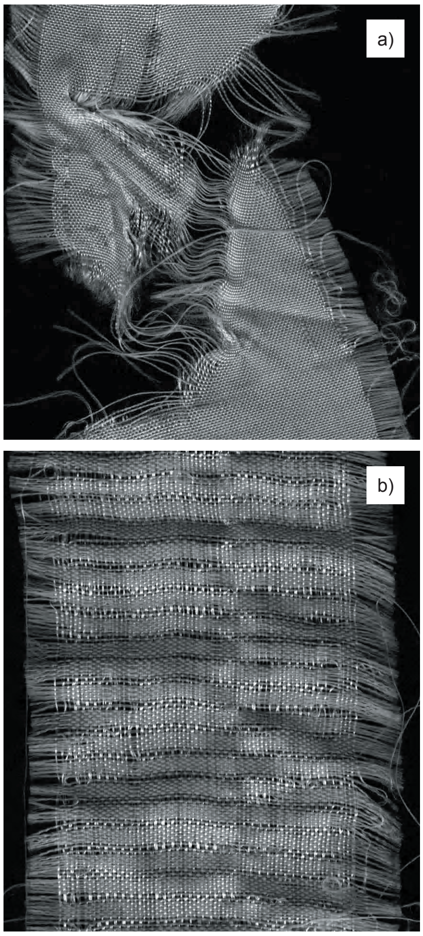

Figure 3. The viewes of break: a) weaves, whose floats are evenly distributed within the whole area of the woven fabric;b) transversal weaves.

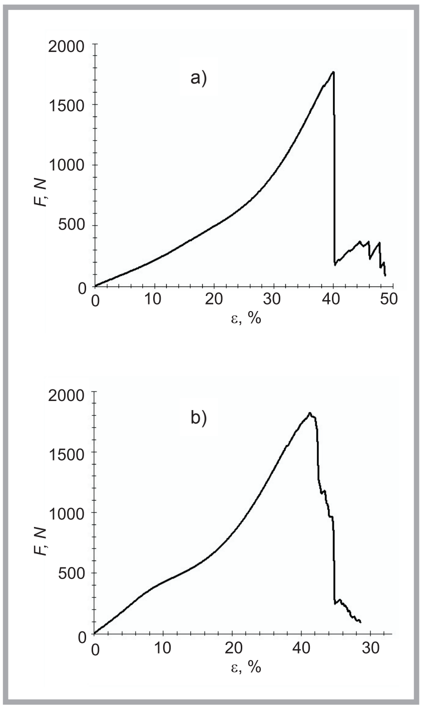

Figure 4. The stress-strain curves: a) weaves, whose floats are evenly distributed within the whole area of the woven fabric;b) transversal weaves.

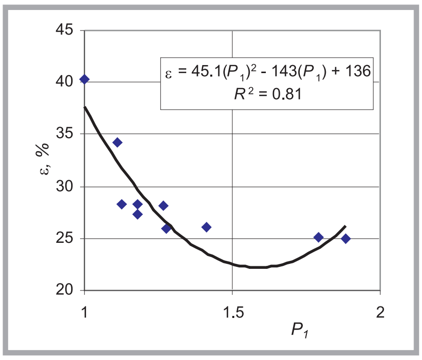

***Figure 5.** The dependence of ε elongation at break on the weave factor Kl_1 having deducted the warp and weft rib weaves.*

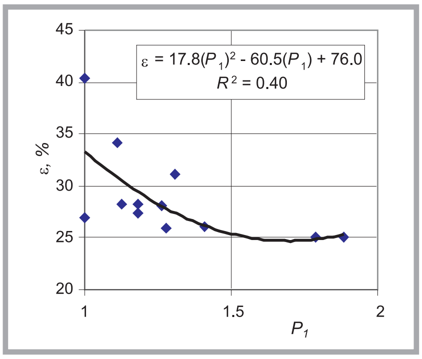

***Figure 6.** The dependence of ε elongation at break on the weave factor P_1 with the warp and weft rib weaves.*

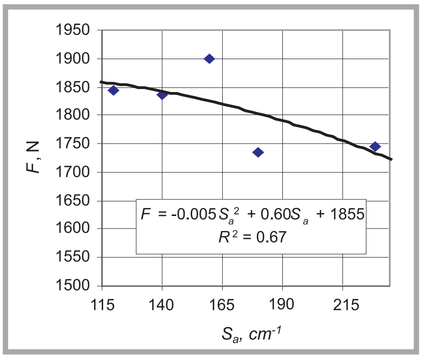

***Figure 7.** The dependence of breaking force F of plain weave fabric on the weft setting of woven fabric S_a.*

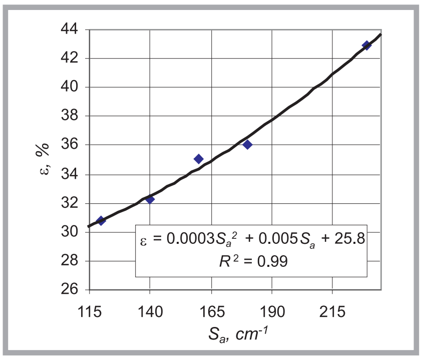

***Figure 8.** The dependence of elongation at break ε of plain weave fabric on the weft setting of woven S_a.*

tion is large. However, in this case we ignored the points of the warp and weft ribs' weaves, because these weaves are non-standard and their results significantly distort the resulting dependencies. Brierley [17] and Galuszynski [13] considered rib weaves as specific instances, to which the formulas and regularities valid for other weaves do not apply. The same elongation at break dependence on the weave factor, evaluating all the tested weaves, is shown in Figure 6. We can see that after evaluating the warp and weft ribs' weaves, the coefficient of determination is much smaller. Therefore, this experiment also confirmed the exclusivity of rib weaves.

Another structural parameter of woven fabric which was changed during the experiment is weft setting. Figure 7 shows the dependence of plain weave fabric breaking force on the weft setting. We can see that as the weft setting increases, the fabric's breaking force decreases. This can be explained by the fact that with a larger weft setting, the threads squirm more, and during the stretching they are apt to straighten. The resulting coefficient of determination is average. However, in the case of other weaves, the coefficient of determination ranges from 0.6 to 0.9.

The elongation at break's dependence on weft setting in the case of plain weave fabric is shown in Figure 8. We can see that as the setting of weft increases, the breaking force of the fabric increases. In the case of high weft setting, the threads are more twisted and, as the fabric is stretched, the possibility increases that they will become straightened. Therefore, the elongation at break in a denser fabric is greater than that of a less dense fabric. The coefficient of determination is large, as it is in the case of other weaves. However, as mentioned earlier, the fabric's qualities depend not only on weave and weft setting, but also on other parameters of fabric structure, which can be evaluated by integrated fabric structure factors. In this article, we have investigated the dependence of the woven fabric's breaking force and elongation at break on the integrated fabric structure factor φ. The dependence of breaking force *F* on the factor φ is shown in Figure 9. We can see that all the weave points, as in the case of weave factor P_1, are distributed accidentally. In this case, sorting the weaves on the basis of the type of float distribution would be inexpedient, as we have to evaluate other

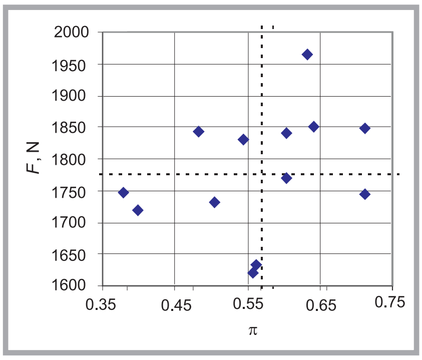

***Figure 9.** The dependence of breaking force F on the integrated factor φ of woven fabric structure.*

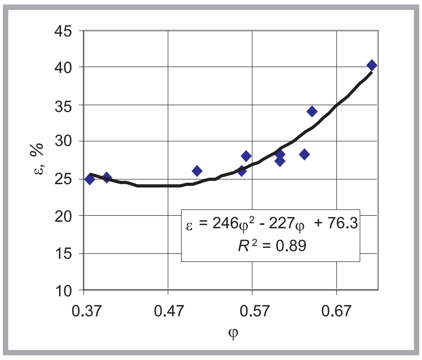

***Figure 10.** The dependence of elongation at break ε on the integrated fabric structure factor φ.*

fabric structure parameters which could influence the breaking force. However, the points shown in Figure 9 are distributed almost evenly on both sides of the mean line, i.e. accidentally. Therefore, there is no correlation between the test results.

The dependence of fabric elongation at break on the integrated structure factor φ is shown in Figure 10. We can see that as φ increases, and at the same time the rigidity of the fabric increases, the fabric's elongation at break increases as well. The coefficient of determination is large. For this reason, we can affirm that the integrated fabric structure factor φ evaluates the fabric structure's elongation at break sufficiently well.

Conclusions

After weaving 12 fabrics in different weaves and different weft settings, and investigating their breaking force and elongation at break, we can make the following conclusions:

1. From the resulting dependencies of fabric breaking force and elongation at break on fabric weave factor P_1, it was established that there is no

correlation between the fabric weave factor and breaking force, and as the coefficient of weave increases, i.e. the rigidity of weave decreases, so the elongation at break decreases.
2. Based on the fabric's breaking force and elongation at break dependencies, it was established that as the weft setting increases, the fabric's breaking force slightly decreases, and the elongation at break increases.
3. Based on the fabric breaking force and elongation at break dependencies from the integrated fabric structure factor φ, it was established that there is no correlation between φ and the breaking force, and as the fabric structure becomes denser, the elongation at break increases.
4. The elongation at break of a woven fabric can be stated from the established dependencies before the weaving process.

References

1. *Nikolic M., Michailovic T., Simovic Lj.: "Real Value of Weave Binding Coefficient as a Factor of Woven Fabrics Strength", Fibres and Textile in Eastern Europe, 2000, 11, pp. 74-78.*
2. *Frydrych I., Dziworska G., Matusiak M.: "Influence of Yarn Properties on the Strength Properties of Plain Fabric", Fibres and Textile in Eastern Europe, 2000, 4, pp. 42-45.*
3. *Wang F., Xu G., Xu B.: "Predicting the Shearing Rigidity of Woven Fabrics", Textile Research Journal, 2005, 75(1), pp. 30-34.*
4. *Milašius V., Milašius R., Kumpikaitė E., Olšauskienė A.: "Influence of Fabric Structure on Some Technological and End-use Properties", Fibres & Textiles in Eastern Europe, Vol. 11, No. 2 (41), 2003, pp. 48-51.*
5. *Milašius R., Milašius V., Kumpikaitė E., Olšauskienė A.: "Development of Employment of Fabric Firmness Factor φ", Conference „Archtex'2003", 2003, pp. 149-154.*
6. *Milašius A., Milašius V.: „New Employment of Integrating Structure Factor for Investigation of Fabric Forming", Fibres & Textiles in Eastern Europe, Vol. 11, No. 1 (49), 2005, pp. 39-43.*
7. *Ashenhurst Thos. R.:. "A Treatise on Textile Calculations and the Structure of Fabrics", 1884, Huddersfield, England.*
8. *Galceran V.:. "Technologia del Tejido", 1961, Terrasa, Spain (Spanish).*
9. *Brierley S.: "Cloth Settings Reconsidered", The Textile Manufacturer, 1952, 79, pp. 349-351.*
10. *Milašius V.: "An Integrated Structure Factor for Woven Fabrics, Part I: Estimation of the Weave", The Journal of the Textile Institute, 2000, 91, Part 1, No. 2, pp. 268-276.*
11. *Newton A.: "The Comparison of Woven Fabrics by Reference to Their Tightness", The Journal of the Textile Institute, 1995, 86, pp. 232-240.*
12. *Seyam A., El-Shiekh Aly: "Mechanics of Woven Fabrics. Part IV: Critical Review of Fabric Degree of Fabric Tightness and Its Applications", The Textile Research Journal, 1994, 64, pp. 653-662.*
13. *Galuszynski S.. "Fabric Tightness: A Coefficient to Indicate Fabric Structure", The Journal of the Textile Institute 1 1981: pp. 44-49.*
14. *Milašius V.: "An Integrated Structure Factor for Woven Fabrics, Part II: Fabrics-firmness Factor", The Journal of the Textile Institute, 2000, 91, Part 1, No. 2, pp. 277-284.*
15. *ISO 13934-1, "Textiles – Tensile properties of fabrics – Part 1: Determination of maximum force and elongation at maximum force using the strip method", 1999, pp. 16.*
16. *Kumpikaitė E., Milašius V.: "Influence of Fabric Structure on Its Weavability", Materials Science (Medžiagotyra), 2003, Part 9, No. 4, pp. 395-400.*
17. *Brierley S.: "Cloth Settings Reconsidered", The Textile Manufacturer, 1953, 58, pp. 534.*

Received 17.03.2006 Reviewed 19.06.2006

39th Interuniversity Conference of Metrologists

organised in the 60th anniversary year
of the Faculty of Textile Engineering and Marketing (formerly the Textile Faculty)
under the patronage of Professor Izabella Krucińska Ph.D., D.Sc.
24–26 September 2007 Łódź, Poland

Organised by:
- the Department for Automation of Textile Processes in co-operation with:
- the Department of Fibre Physics and Textile Metrology and
- the Department of Clothing Technology

Guests of honour:
- Professor Witold Żurek Ph.D., D.Sc., Eng., doctor honoris causa of the Technical University of Łódz
- Professor Wojciech Szmelter Ph.D., D.Sc., Eng.

Chairman of the Scientific Committee:
Professor Wiesław Kiciński, Ph.D., D.Sc., Eng.

Chairman of the Organising Committee:
Professor Krzysztof Gniotek, Ph.D., D.Sc., Eng.

The scope of the Conference includes six general fields, each divided into seven to nine thematic groups:
1. Basic problems of metrology.
2. Metrology of electric and non-electric quantities.
3. Measurement and control devices and systems.
4. Digital processing and analysis of measurement signals.
5. Applications of metrology.
6. Didactics of metrology.

Among the almost sixty lectures which will be offered, selected lecture titles connected with textiles are given:
- Pressure measurements in a woven fabric under transient air flow.
- Methods of recording, processing, and analysing images to describe a manikin's surface.
- System for measuring a bullet's velocity when testing bullet-proof textile armours.
- Automation and visualisation of sorption and desorption measurements in textile products.
- Metrological investigation of an optical wave-guide sensor of breathing rhythms.
- Measurements of selected electro-mechanical properties of electro-conductive threads.
- Thermal property measurements of flat textile products by a non-contact method.
- Influence of the position of electronic elements in a clothing packet on changes of thermal insulation properties.

For more information please contact:

Secretary of the Organising Committee, Magdalena Tokarska; tel. (48-42) 631-33-99
e-mail: emagda@p.lodz.pl http://www.bravo.iem.pw.edu.pl/mkm2007/