Vytautas Milašius,
Rimvydas Milašius,
Egle Kumpikaite,
Asta Olšauskiene

Kaunas University of Technology,
Faculty of Design and Technologies,
Department of Textile Technology
Studentu 56, LT-3031 Kaunas, Lithuania
Phone: 370-7-451645,
E-mail: vytautas.milasius@dtf.ktu.lt

Influence of Fabric Structure on Some Technological and End-use Properties

Abstract
In this article, some experience of the possibilities of employing the integrating fabric structure factor φ proposed by V. Milašius is presented. The proposed fabric firmness factor has been devised to compare the structure of various different weaves in a much better way than other integrating factors. Analysis of experimental data shows that the fabric firmness factor φ is workable for fabric structure evaluation in the weaving process as well as for some fabric properties. The investigations presented shows that the fabric firmness factor φ can be used as a basis for comparing woven fabrics with various structure parameters.

Key words: *woven fabrics, fabric firmness factor φ, fabric's properties, beat-up parameters.*

Introduction

Designing woven fabrics always poses the problem of how to predict their technological and end-use properties. The first stage in solving this problem is the generalisation of the fabric structure features by one integrated factor. Peirce [1] particularly precisely disclosed the meaning of an integrating fabric structure factor: "It ... gives a very suitable basis of comparison for any experimental investigation, not only of cover but also of hardness, crimp, permeability and transparency, limits of picking, etc., in which fabrics of similar cover factors show similarity." The second stage is estimating the statistical dependence of the technological and end-use properties on this integrated fabric structure factor. The integrating fabric structure factors can be distributed into two groups: those based on Peirce's [1] theory and those based on Brierley's [2] theory of maximum setting. Various factors are proposed, such as Galceran [3], Seyam and El-Shiekh [4], Newton [5], and Milašius [6]. The main aim of this article is to determine the influence of the integrated fabric structure factor proposed by Milašius (Brierley's group) on some technological and end-use properties.

Integrated Structure Factors

Any fabric structure factor is always calculated by comparing a certain mathematical expression of the parameters of the given fabric structure with the maximum value of a so-called standard fabric. In Brierley's case, the fabric structure factor is the ratio of setting of the given fabric 'square' (balanced) structure analogue with the setting of the standard 'wire' plain weave fabric [2]. The original Brierley factor, which he called *Maximum Setting/ Maximum Density*, can be calculated by equation (1), where:

F^m - the empirical weave factor,
S_1, S_2 - warp and weft setting, respectively,
T_1, T_2 - the warp and weft linear density, respectively,
g=2/3, if $F_1 \geq F_2$, and
g=3/2, if $F_1 < F_2$ (excepting weft faced ribs, in this case g=2).

Galuszynski [7], analysing weaving resistance, found that Brierley's formula "requires some modification of certain values of the coefficients m and g for some weft- and warp-faced ribs", and proposed the coefficient of fabric tightness $T_{Galuszynski}$. For the weft-faced ribs, the value F is taken as an average for the weave with g=2/3 (whereas Brierley suggested that the value of F has to be taken as an average for the warp threads and g should be equal to 2). For warp-faced ribs, Galuszynski proposed the value of m=0.35 instead of 0.42 given by Brierley.

Milašius *et al*. [8,9] proposed a new integrating fabric firmness factor that can be calculated by equation (2), where: P_1 - weave factor [8].

The two main differences from Brierley's proposals are as follows: firstly, in equation (2) only a factor's g value equal to 2/3 is used (and, above all, it is independent of the type of weave). Secondly, the new weave factor P calculated directly from the weave matrix [8] is used, and it has no relation to the cloth setting or the linear density of the threads.

Earlier, the factor φ was examined and compared to other integrating fabric structure factors [9]. For comparison, the weaves were chosen in such a way that they would have different ratios of the weave factors F_1 and F_2 - for the part of the weaves $F_1 = F_2$, for the second part $F_1 > F_2$, and for the third part $F_1 < F_2$. Some of them cannot be evaluated using the Brierley and Galuszynski methods. Experiments with samples of different weaves were carried out by weaving the fabrics on various looms (shuttle, projectile, and air-jet) other things being equal. So, the fabrics woven should have the same integrating factor of cloth structure, and the variance of the results served as an indicator of the quality of the fabric integrating structure factor. The least variance [9] was obtained in the case of the integrated fabric structure fac-

Equations 1 and 2.

$$[MS/MD] = \sqrt{\frac{12}{\pi}}\,\frac{1}{F^m}\sqrt{\frac{T_{average}}{\rho}}\,S_2^{\frac{1}{1+g\sqrt{T_1/T_2}}}\,S_1^{\frac{g\sqrt{T_1/T_2}}{1+g\sqrt{T_1/T_2}}} \quad (1)$$

$$\varphi = \sqrt{\frac{12}{\pi}}\,\frac{1}{P_1}\sqrt{\frac{T_{average}}{\rho}}\,S_2^{\frac{1}{1+2/3\sqrt{T_1/T_2}}}\,S_1^{\frac{2/3\sqrt{T_1/T_2}}{1+2/3\sqrt{T_1/T_2}}} \quad (2)$$

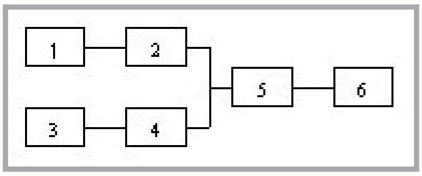

Figure 1. The connection scheme of measurement devices: 1 - the warp force measurement feeler, 2 - the tensiometric amplifier, 3 - the voltage feeding source, 4 - the fixation feeler of a beat-up moment, 5 - the PC-20 processed information panel, 6 - the personal computer.

tor proposed by Milašius. The firmness factor φ of woven fabric can be used in the design of new fabrics, to evaluate their properties and consider the weaving process parameters.

In this article, some experiments of the employment of the integrated fabric structure factor φ proposed by Milašius for analysing some technological and end-use properties are presented.

Experimental Results and Discussions

Influence of fabric structure on the parameters of weaving process

It is important to evaluate the weavability of newly designed fabrics before their production. Weavability may be defined by researching one of the most important parts of the weaving process - the beat-up. This part of the weaving process may be evaluated by warp force during the beat-up, the beat-up time, and the impulse of beat-up force. A measurement device was connected according to the scheme presented in Figure 1. A tensiometric feeler 1, the starting signal of which was amplified by the amplifier 2, measured the warp force. The force was measured between the dropper and backrest. The beat-up moment was fixed by the feeler 3 acting on a magnetic principle and receiving voltage from the supply source 4. Both signals reach the processed information panel 5, thanks to which it was possible to watch the measured signals on the monitor of a personal computer 6. The signals were fixed at an accuracy of 0.5 degree of the rotation angle of the loom's main shaft.

The estimation of beat-up parameters is presented in Figure 2. The plot indicates the warp stress diagram (the upper curve) and the beat-up moment fixation (the lower one) during one loom cycle. In this case only part of the warp stress is of importance during beat-up; in other words, the part of warp stress which arises due to e.g. shedding, cloth-take up etc., may be eliminated (force F in Figure 2). From the warp stress curve it is possible to fix the beginning and end beat-up moments, i.e. beat-up moments, and calculate beat-up duration *t* (in Figure 2 beat-up duration *t* was fixed by the rotation angle degree of the crankshaft).

The beat-up impulse *I* can be calculated by the formula:

$$I = \int_0^T F dt$$

beat-up duration being expressed in seconds using the numerical method.

The influence of weft setting and weave on the parameters of the above-mentioned weaving process was investigated. Figure 3 shows the beat-up force, beat-up duration and beat-up impulse dependence on weft setting when weaves [9] are different.

These curves are expressed well enough by power functions, and their determination coefficients are 0.60-0.95. One can see that the curves do not ascend so steeply when the weave coefficient P_1, decreases. The angle of this slope is a little higher for warp ribs because of the high setting of such a fabric, and so the wefts may lay on each other, and in this case two weft layers are formed.

Figure 4 shows the dependencies of beat-up parameters on fabric weave coefficient P_1 when the weft settings are different. The curves may be expressed by power equations, and their determination coefficients are 0.60-0.90. From the equations one can see that the change of the curve becomes more intensive when the setting increases.

From the data presented, we can take an approximated view of the influence of the individual parameters of fabric structure on beat-up process parameters. However, if all fabric structure parameters must be estimated, the integrated fabric structure factor must be used. The dependencies of beat-up process parameters on the fabric structure factor φ are shown in Figure 5.

In this case, the curve determination coefficients are 0.79-0.83. They are higher than Brierley's other group factors, the calculated determination coefficients of which are 0.70-0.78, and much higher than Peirce's group factors, the determination coefficients of which are 0.43-0.62. It is worth noting that the dependence $I=f(\varphi)$ is distinguished by the highest determination coefficient, equal to 0.83. Nosek [10] suggested assuming the beat-up force impulse as a basic one in beat-up parameters because it describes this process best. Thus it may be considered as an integrated beat-up parameter. Hence, this research work has shown that the integrated beat-up parameter *I* dependence on the integrated fabric structure parameter φ is the most exact because of its highest determination coefficient. So, we may conclude, while designing a new fabric, that its weavability should be predicted by referring to its integrated fabric structure parameter φ.

Influence of fabric firmness factor φ on air permeability

The firmness factor φ can also be used for the prognostication of fabric properties; for example, air permeability of fabric depends on thread settings as well as on weave. Figures 6 and 7 present these dependencies of fabric from multifilament 29.4 tex yarns both in warp and weft.

The experimental investigations of determining air permeability dependence on weave were done with 8 different weaves: plain, twill 2/2, twill 4/4, warp rib 2/2, weft rib 2/2, basket weave 4/4, rib-basket weave 2/4 and 8 healds sateen. The fabrics were manufactured in three series with the

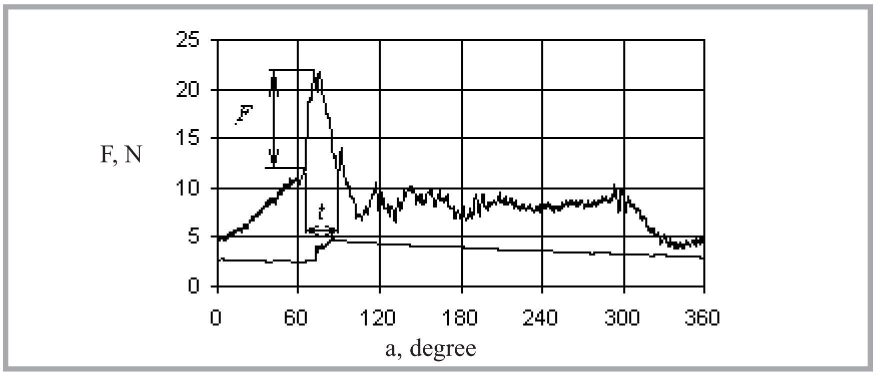

Figure 2. The warp stress curve during one loom cycle.

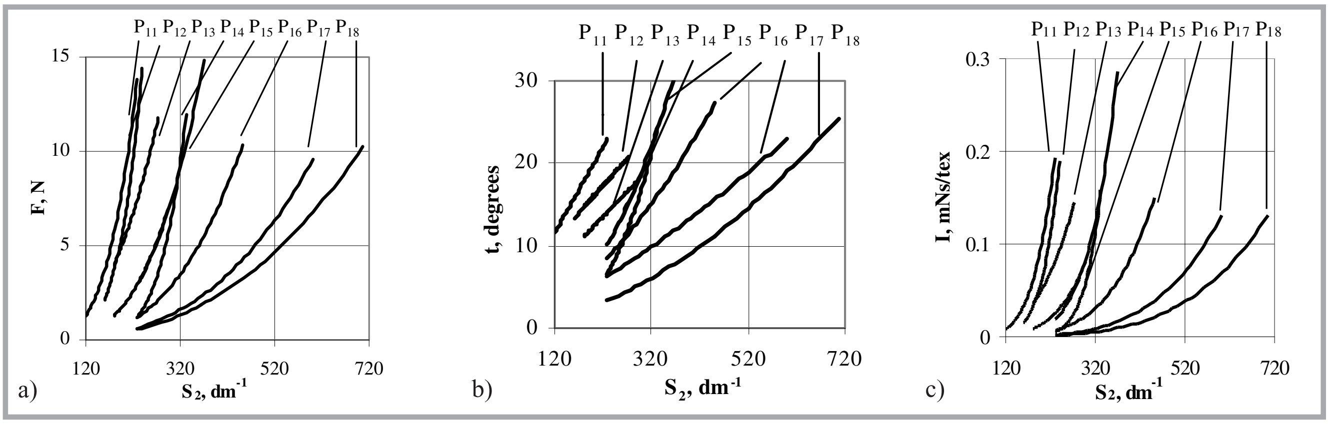

***Figure 3.** Dependencies of beat-up process parameters on warp setting S_2, when weaves are different - P_1=P_{11}<P_{12}<P_{13}<P_{14}<P_{15}<P_{16}<P_{17}<P_{18}: a) beat-up force F; b) beat-up duration t; c) beat-up force impulse I.*

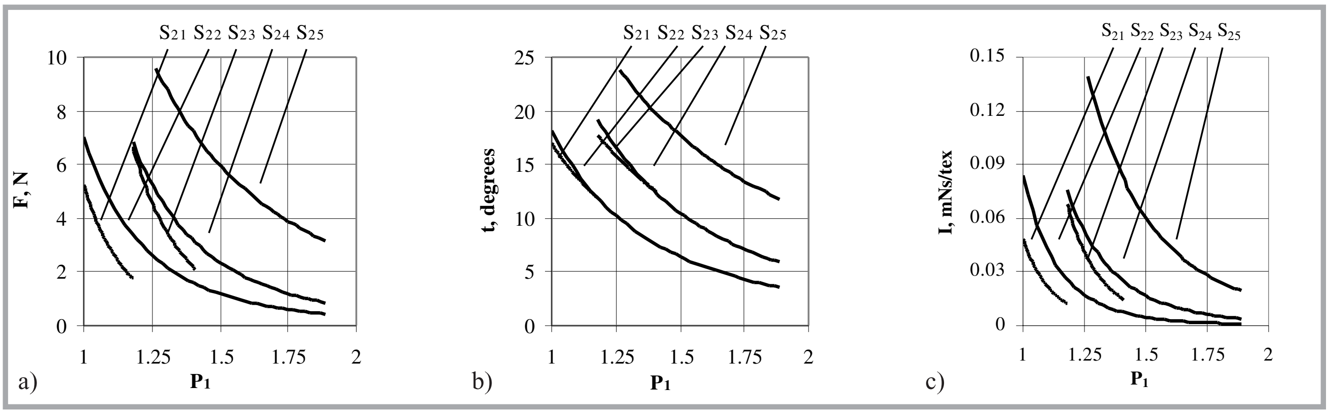

***Figure 4**. Dependencies of beat-up parameters on weave coefficients P_1 when weft settings are different - S_2=S_{21}>S_{22}>S_{23}>S_{24}>S_{25}: a) beat-up force F; b) beat-up duration t; c) beat-up force impulse I.*

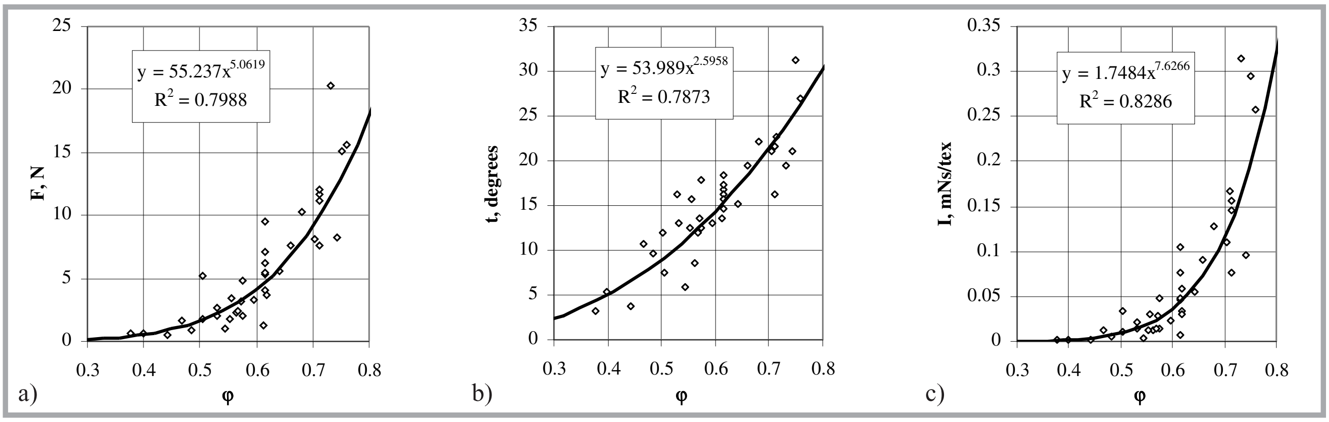

***Figure 5.** Dependencies of beat-up process parameters on the integrated fabric structure factor φ: a) beat-up force F; b) beat-up duration t; c) beat-up force impulse I.*

same setting of warp (S_1=284 dm^{-1}): series 1 with the same setting of weft S_2=230 dm^{-1}, series 2 and series 3 with the same firmness factor φ (φ=71.5% and φ=61.5%), the setting of weft for each weave being calculated according to equation 2. Figures 6 and 7 show that although the air permeability depends on settings as well as on weave factor P (coefficient of determination R^2 of series 1 in Figure 7 is high - 0.8276) in the case when firmness factor φ is constant (Figure 7 series 2 and 3), the influence of weave factor P on air permeability is very low (R^2 is negligible, only 0.0002 for series 2 and 0.0242 for series 3). So, it can be stated that the air permeability does not depend on weave factor P, i.e. Q is constant for all weaves, if the firmness factor φ is constant, too.

The same can be noted for air permeability dependence on set. In Figure 8 the dependence of air permeability on weft setting is presented. The 8 different weaves mentioned above with the same firmness factor φ (φ=71.5%, series 2), and five plain weave fabrics (series 1) with different setting in weft of both series were used for investigation.

One can see from Figure 8 that the weft setting has a very great influence (R^2 is high, 0.9999) on fabric air permeability (series 2), but in the case of the same firmness factor φ (series 1) this influence is negligible (R^2 is only 0.0557), and Q is constant for all weaves. So, it is possible to reach constant air permeability for fabrics with different settings by choosing a necessary weave for each setting: the weave factor *P* in this case is calculated by equation 2.

Conclusions

Earlier the integrated structure factor *φ* was proposed and declared to be a suitable basis of comparison for many experimental investigations, in which fabrics of similar factors show similarities. An analysis of the experimental data presented shows that the fabric firmness factor *φ* is workable for fabric structure evaluation for the weaving process, as well as for some of the fabric properties. One of the most important parts of the weaving process, the beat-up, may be evaluated by the main parameter, the impulse of the beat-up force. The results obtained have shown that the dependence of this integrated beat-up parameter on the integrated fabric structure parameter *φ* is the most exact because of its high determination coefficient. So while designing a new fabric, its weavability should be predicted by referring to its integrated fabric structure parameter *φ*. The dependencies of all parameters of beat-up process on fabric firmness factor are very close (R^2=~0.82). In the case when firmness factor *φ* is constant, the influence of weave factor and weft settings on air permeability are very low. However, the fabric air permeability dependence on fabric firmness factor is very close (R^2=~0.83). So, this fabric structure factor allows us to look for the goal which was earlier formulated by Pierce - to give "... a very suitable basis of comparison for any experimental investigation, not only of cover but also of hardness, crimp, permeability and transparency, limits of picking, etc., in which fabrics of similar cover factors show similarity."

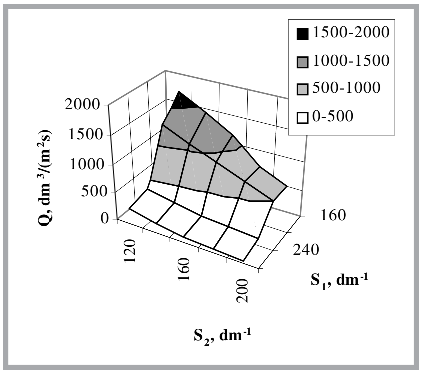

Figure 6. *Dependence of plain weave fabric air permeability Q on warp and weft settings S_1 , S_2, respectively.*

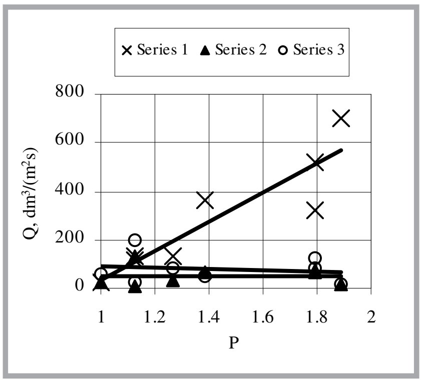

Figure 7. *Dependence of fabric air permeability Q on weave factor P: 1 - S_2=const (230 dm^{-1}), 2 and 3 φ=const (2 - 71.5% and 3 - 61.5%).*

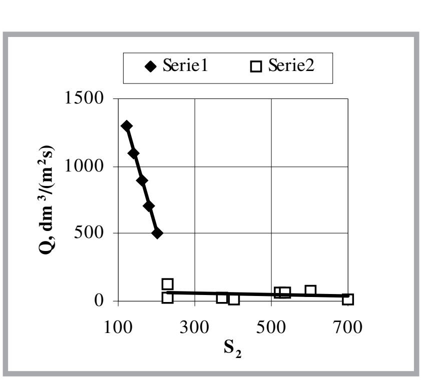

Figure 8. *Dependence of fabric air permeability Q on weft setting S_2.*

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