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# Dependence of Air Permeability on Various Integrated Fabric Firmness Factors

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The present article deals with the dependence of air permeability of technical assignment fabrics on various parameters of fabric structure. It has been established that although fabric air permeability depends on weft density and weave factor $P_1$, however, it is possible to achieve the same air permeability of different weaving fabrics if to calculate weft densities $S_2$ for each weaving when $\varphi$ = const. It means that it is possible to design a corresponding air permeability fabric according to the fabric firmness factor $\varphi$.

The article presents a number of factors of various fabric structure (Milašius, Brierley, Galuszyski, Galceran) and in this respect fabric air permeability to be compared. It has been established that the structure factor $\varphi$ proposed by Milašius evaluates all the weaves except weft rips 2/2 best and should be used for designing a fabric according to necessary air permeability.

*Keywords*: air permeability, fabric structure parameters.

## 1. INTRODUCTION

The air permeability of fabric is one of very important properties of technical fabrics. The air permeability depends on shape and value of the pores and the inter-thread channels, which are dependent on the structural parameters of the fabric [1, 2]. The main structural parameters, which have influence on fabric air permeability, are set and linear densities of yarns and weave.

Early it was established air permeability dependences on weave and set of yarns particularly [3]. Designing fabrics and their technological parameters and analysing their properties we are constantly in contact with a problem how to generalize fabric structure properties by one integrating factor. Peirce [4] particularly precisely disclosed the meaning of 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 integrating fabric structure factors can be distributed into two groups: referring to Peirce's [4] theory and referring to Brierley's [5] theory of maximum setting. Whatever fabric structure factor is it is always calculated comparing a certain mathematical expression of parameters of the given fabric structure with maximum value of so called standard fabric. In the first case it is the ratio of the area covered by one or two yarn systems with the whole area of fabric (it is a meaning of all fabric firmness factors). There are several integrating structure factors corresponding to Peirce theory, namely: Galceran [6], Seyam and El-Shiekh [7], Newton [8]. However, here we are going to analyse more widely only Galceran factor because it evaluates the fabric structure from this group of factors best [9].

According to Galceran [6] the fabric tightness $O$ can be calculated by following equation:

$$O = \frac{\frac{S_1\sqrt{T_1}}{\sqrt{1000}} + \frac{S_2\sqrt{T_2}}{\sqrt{1000}}}{\frac{5\sqrt{\pi\rho_1}}{1+0.73Kl_1} + \frac{5\sqrt{\pi\rho_2}}{1+0.73Kl_2}}100\,; \qquad (1)$$

here: $S_{1/2}$ is the set of the warp and weft, respectively, $T_{1/2}$ is the linear density of the warp and weft, $\rho_{1/2}$ is the warp and weft fiber density, $Kl_{1/2}$ is the weave factors.

The precision explaining of this and other equations it is possible to found in presented references.

In the Brierley's case fabric structure factor is the ratio of set of the given fabric "square" (balanced) structure analogue with the set of the standard "wire" plain weave fabric [5]. The original Breirley's factor called him as *Maximum Setting/Maximum Density* can be calculated by following equation:

$$[MS/MD] = \sqrt{\frac{12}{\pi}}\,\frac{1}{F^m}\sqrt{\frac{T_{average}}{\rho}}\,S_2^{\frac{1}{1+g\sqrt{T_1/T_2}}}\,S_1^{\frac{g\sqrt{T_1/T_2}}{1+g\sqrt{T_1/T_2}}}\,; \qquad (2)$$

here: $F^m$ is the empirical weave factor, $g = 2/3$, if $F_1 \geq F_2$, and $g = 3/2$, if $F_1 < F_2$ (excepting weft faced ribs, in this case $g = 2$), $S_{1/2}$, $T_{1/2}$ and $\rho$ – as in eq. (1)

Galuszinski [10] 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 $T_{Galuszinski}$. For the weft-faced ribs value $F$ is taken as an average for the weave with $g = 2/3$ (whereas Brierley suggested that 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 Galuszinski proposed the value of $m = 0.35$ instead of 0.42 given by Brierley.

Milašius [11 – 13] proposed new integrating fabric firmness factor that can be calculated by equation:

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

here: $P_1$ is the weave factor, $S_{1/2}$, $T_{1/2}$ and $\rho$ – as in eq. (1)

The two main differences from Brierley's proposals are – firstly, in equation (3) only factor's $g$ value equal to 2/3 is used (and above all it is independent from the type of the weave). Secondly – the new weave factor $P$ calculated directly from the weave matrix [11] is used. It has no relation with cloth setting and the linear density of threads.

The firmness factor $\varphi$ also can be used for fabric properties prediction, for example, air permeability of fabric depends on threads set as well as on weave [14].

The goal of presented investigations is to show a possibility of air permeability designing by integrated firmness factor $\varphi$ and to compare a various integrated firmness factors in respect of air permeability.

## 2. EXPERIMENTAL RESULTS AND DISCUSSIONS

Experimental investigations establishing the dependence of fabric air permeability on their weft density were carried out with 8 fabrics of different weavings, namely: plain, twill 2/2, warp rib 2/2, weft rib 2/2, 8 healds sateen, basket weave 4/4, twill 4/4 and rib-basket weave 2/4. All these fabrics were woven on the STB projectile weaving loom from polyester yarns 29.4 tex when the warp set $S_1 = 284$ dm$^{-1}$. Fabric air permeability was established according to LST EN ISO 9237:1997 standard [15]. According to this standard air permeability is the air yield passed through a definite area of a fabric during a specified period of time with the pressure difference of 50 Pa (the instrument VPTM – 2M).

The air permeability of fabrics depends on a number of factors, one of them being thread set of fabrics. Fig. 1 presents fabric air permeability $Q$ of various weavings of polyester fabrics on the set of weft $S_2$ (the coefficients of variation of all experimental points do not exceed 10 %).

Fig. 1 presents 8 different weavings having the same integrated firmness factor $\varphi$ ($\varphi = 71.5$ %), and air permeability dependence on weft set (series 1). The stable $\varphi$ is hold by changing weft set $S_2$ when warp set $S_1 = 284$ dm$^{-1}$. So, we see that fabric air permeability of different weavings changes slightly.

The other curves (series 2 – 9) present air permeability dependences of individual weaves on weft set $S_2$ (in this case, too, $S_1 = 284$ dm$^{-1}$, however, $\varphi$ = const). From these curves we can see that when weft set increases provided warp set is stable, fabric air permeability decreases.

If we choose $S_2$ for each weaving securing $\varphi$ stability, air permeability changes slightly (series 1), the coefficient of determination of the straight line of series 1 being negligible $R_1^2 = 0.0571$. So we can state that according to the formula (4) having calculated $S_2$ (provided $\varphi$ = const) for each weaving it is possible to achieve the same air permeability for different weaving fabrics.

Fig. 2 presents air permeability dependences on the weave factor for fabrics made of multifilament 29.4 tex polyester yarns both in warp and in weft. The fabrics were manufactured in four series with the same set of warp ($S_1 = 284$ dm$^{-1}$ and, series 1 – with the same set of weft $S_2 = 230$ dm$^{-1}$, series 2, series 3 and series 4 – with the same firmness factor $\varphi$ ($\varphi = 53.1$ %, $\varphi = 61.5$ % and $\varphi = 71.5$ %).

As can be seen in Fig. 2 air permeability dependence on the weave factor when the sets of weft and warp are constant can be described by the second order equation with a rather high coefficient of determination, which show a regressive equation correspondence to experimental

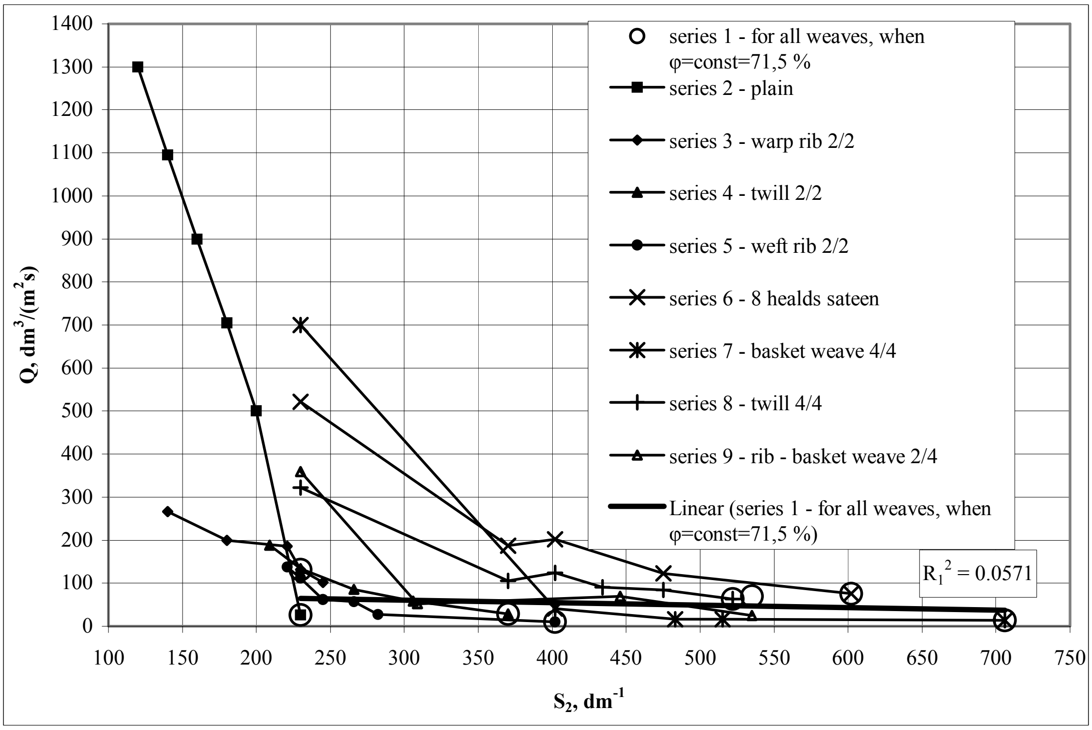



**Fig. 1.** Dependence of fabric air permeability $Q$ on weft set $S_2$

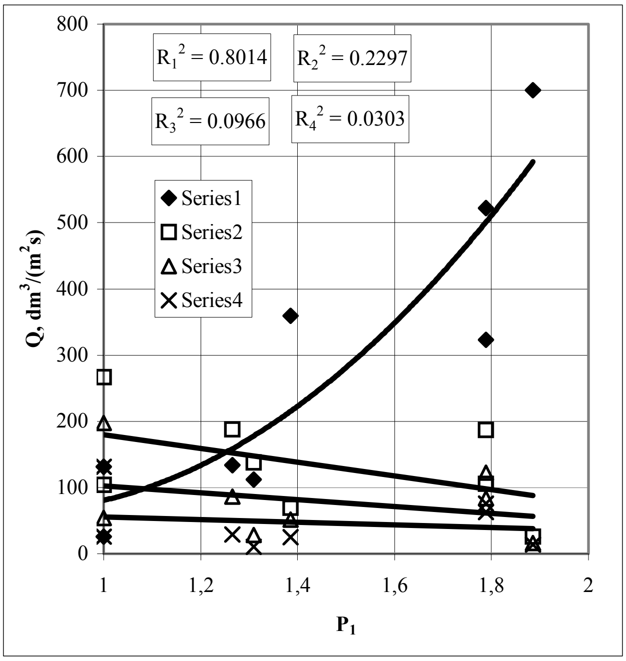



**Fig. 2.** Dependence of fabric air permeability $Q$ on weave factor $P_1$: 1 – $S_1$ = const (284 dm$^{-1}$), $S_2$ = const (230 dm$^{-1}$), 2, 3 and 4 – $\varphi$ = const (2 – 53.1 %, 3 – 61.5 % and 4 – 71.5 %).

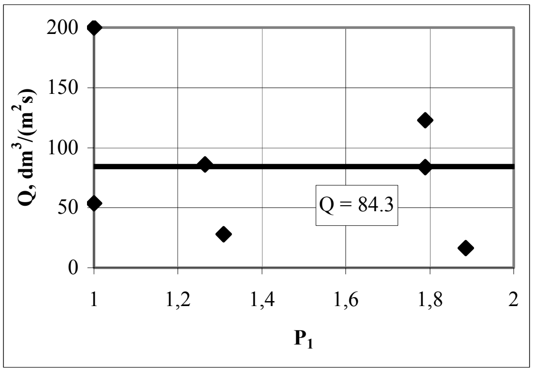
values ($R_1^2 = 0.8014$). Meanwhile when the factor $\varphi$ is constant the dependence of fabric air permeability on the weave factor $P_1$ is very low ($R^2 = 0.0303 \div 0.2297$). So we may state that air permeability $Q$ does not depend on the fabric weave factor $P_1$, if the integral filling factor $\varphi$ is constant.

Although air permeability strongly depends on both thread density and weaving, however, air permeability dependences on $S_2$ and $P_1$ (on fabrics woven by these different parameters but having the same $\varphi$) are negligible. It means that it is possible to design a fabric of suitable air permeability according to the fabric firmness factor $\varphi$.

When experimenting we used structure factors offered by Milašius, Brierley, Galuszynski and Galceran because as it has been established earlier they evaluate the structure of a fabric best [9]. The drawback of the fabric structure factor *MS/MD* offered by Brierley is that the weave factor $F^m$ is empirical and $m$ depends on a weave type and can be obtained only experimentally. So we declined the rib – weave 2/4 weaving fabric because this empirical factor for this weaving is unknown (Brierley has not established it). Since as it can be seen in Fig. 2 in this case when $\varphi$ = const, the dependence of air permeability on the weave factor $P_1$ changes slightly, so later we did not draw a straight line equation, but a mean value line.

A plain fabric was chosen as an indication point calculating various fabric structure factors (Milašius, Brierley, Galuszynski and Galceran) provided $S_1$ = 284dm$^{-1}$ and. $S_2$ = 180 dm$^{-1}$. According to the calculated structure factor the sets of other weaves wefts were determined keeping up the constant warp set ($S_1$ = 284 dm$^{-1}$).

The fabric structure factor value proposed by Galceran differs from the other proposed factors because this factor was calculated according to the formula (1), which differs virtually from the calculation formulas of the other structure factors (Milašius, Brierley, Galuszynski).

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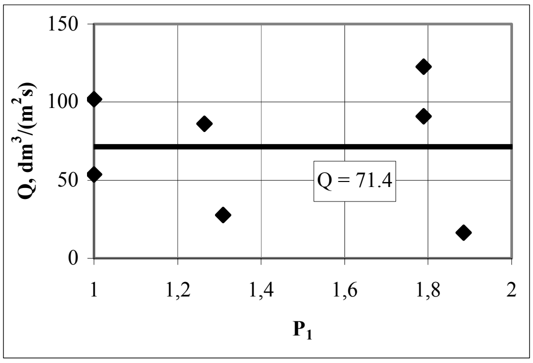


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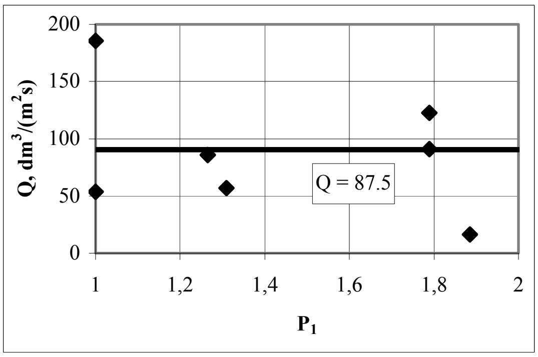


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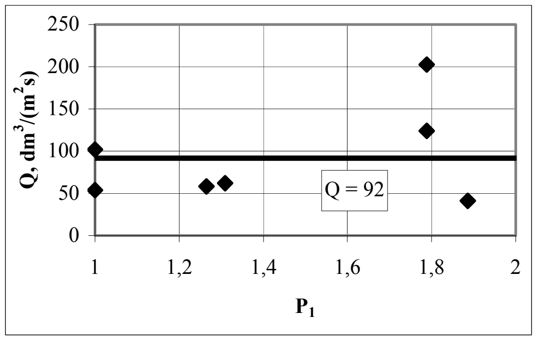


d

**Fig. 3.** Dependence of fabric air permeability $Q$ on weave factor $P_1$ at constant fabric structure factors: a) $\varphi$ = 61.6; b) *MS/MD* = 61.6; c) $T_{Galuszynski}$ = 61.6; d) $O_{Galceran}$ = 66.1

As can be seen in Fig. 3 in all these cases (a) $\varphi$ =const; b) *MS/MD* = const; c) $T_{Galuszynski}$ = const; d) $O_{Galceran}$ = const) point dispersal is similar. However, if in Milašius (a) and Galuszynski (c) cases the greatest deviation from the mean value is obtained in the case of weft rib 2/2 ($P_1 = 1$, $Q = 199.8$ dm$^3$/(m$^2$s) and $P_1 = 1$, $Q = 185.6$ dm$^3$/(m$^2$s)), that in the case of Galceran (d) the greatest noncorrespondence to the mean value is obtained to the weaves the both systems of which are woven by long floats and the weave factor of which is $P_1 = 1.7 \div 1.9$.

The smallest air permeability dispersal is in the case of Brierley, however, according to Brierley and Galuszynski proposed structure factors we cannot evaluate those weaves as the empirical factor $m$ is unknown (in our case such a weave was rib basket weave 2/4) and it is an essential drawback of these factors.

The fabric structure factor suggested by Milašius can evaluate all weaves, however, in the case of weft ribs 2/2 the value of air permeability in this point differed distinctly from the mean air permeability value of all weaves. This cannot be noticed both in the case of Galceran ($P_1 = 1$, $Q = 101.8$) and Brierley ($P_1 = 1$, $Q = 101.8$).

However, in the case of Galceran the weaves of which are $P_1 > 1.7$ are evaluated bad. So, it is possible to affirm that the structure factor $\varphi$ proposed by Milašius evaluates all the analyzed fabric structure factors best except weft ribs 2/2. So, while designing a fabric according to a necessary air permeability it should be used this criterion best except the weft rib 2/2 case when it is expedient to use Brierley or Galceran criterion.

## 3. CONCLUSIONS

The investigation of the fabrics woven by various weaves (plain, twill 2/2, warp rib 2/2, weft rib 2/2, 8 healds sateen, basket weave 4/4, twill 4/4 and rib-basket weave 2/4) of polyester multifilament 29.4 tex yarns was carried out.

It has been determined by experiments that although fabric air permeability depends on the weft set and weave factor $P_1$ and having calculated weft set $S_2$ for each weave when $\varphi = \text{const}$ it is possible to achieve the same air permeability for fabrics of different weaves, i.e. in this case when the integrated structure factor $\varphi$ is constant, the influence of weft set and fabric weave factor on air permeability is very low. It means that it is possible to design a fabric conformable to air permeability according to the fabric firmness factor $\varphi$.

Out of fabric structure factors (Milašius, Brierley, Galuszynski and Galceran) the structure factor $\varphi$ suggested by Milašius evaluates all the weaves except weft ribs 2/2 best, therefore while designing a fabric according to the necessary air permeability this criterion should be used best (except the case of weft ribs 2/2, when it is expedient to use either Brierley or Galceran criterion).

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