AIR PERMEABILITY AND STRUCTURAL PARAMETERS OF SINGLE JERSEY KNITTED FABRIC

Marie Havlová

Technical University of Liberec, Department of Textile Evaluation, Liberec, Czech Republic
marie.havlova@tul.cz

Abstract: *The main aim of our study is to investigate the influence of the basic structural parameters on the air permeability value of single jersey weft knitted fabric. A specific experimental set of knitted fabrics was used for this purpose – the yarns of two materials (viscose and polyester) and two yarn counts (20 tex and 29.5 tex) were used, each of these four yarns was used to manufacture a set of single jersey knitted fabric samples of several different densities. Altogether 22 different knitted samples were prepared and used for investigation the basic relationships between air permeability and the structural parameters of the knitted fabrics. Primary and secondary structural parameters such as area of unit cell, thickness, planar weight or porosity were investigated. Porosity was calculated according to three different theoretical models. Our results showed that as the thickness and planar weight of the knitted fabric increase, its air permeability decreases. As the porosity of the knitted fabric increases, its air permeability increases, with the value of air permeability responding most sensitively to the porosity expressed as a proportion of the open area of the knitted fabric. The results also showed that the relationship between air permeability and porosity as well as the relationship between air permeability and planar weight are not completely linear. Linear relationship was found between the air permeability of the knitted fabric and the ratio of its porosity and its planar weight.*

Keywords: *air permeability, knitted fabric, structural parameters, porosity, planar weight.*

1 INTRODUCTION

Due to the method of construction, textile materials in general are a porous structure. Therefore, a large part of their total volume is airspace. This porous character determines all physical properties of textile materials. The size of the pores in textile as well as their shape, arrangement and distribution are one of the crucial characteristics for a number of fabric properties including comfort parameters. One of them is the ability of the fabric to transmit air.

Air permeability is one of the fundamental textile properties and it is an important factor in the comfort of a fabric [1, 10], together with the water vapour permeability and thermal insulation properties as well as the tactile characteristics of the fabric. All these comfort properties are very closely related to the porosity of the fabric. A number of authors have researched the relationship between the structure and comfort parameters of the textile fabrics [1-3, 5, 6]. The property usually given by the description of the structure of the fabric is just the porosity. The pore dimension and distribution are functions of the geometric structure of the fabric. Understanding the relationships between the structural parameters and physical properties of the textile materials is very important for the ability to simulate and design these properties before the fabric is made. It is necessary to focus on knitted fabrics, because they provide excellent comfort qualities and have preferred in many types of clothing. They are increasingly used in clothing production. Today, many knitted fabrics are made that imitate the original traditional woven fabrics – such as denim, corduroy, tweed, bouclé, brocade etc. Air permeability is very important for these fabrics because it allows to ventilate the space under the garment. Some authors have investigated the relationship between the structural parameters (primary or secondary) of a knitted fabric and its comfort parameters, including air permeability. For example, Ogulata [1] conducted an experimental study in order to develop a theoretical model to predict air permeability values for plain knitted fabric and used D'Arcy's formulation for expressing the relationship between the air permeability of knitted fabrics and fabric structure parameters. In this paper, the porosity ε_V based on the proportion of volumes was used and the pore was considered to have a circular cross section. The set of 18 knitted samples was made for this experiment and for these samples the near linear relationship between predicted and experimental values of air permeability was shown. Coruh [2] investigated the influence of different loop lengths and different fibre blend ratios of single jersey knitted fabrics on the mechanical and comfort properties and found that an increase in the loop length increases the air permeability, while an increase in the thickness of knits decreases the air permeability. Twelve variants of fabrics were prepared from cotton, viscose and polyester blend yarns. Wilbik-Halgas [3] examined relationship between air permeability and water vapour permeability using a set of double-layered knitted fabrics. The surface porosity was measured by image analysis method. Their results showed that air permeability is a function of the thickness and porosity of the knitted fabric. Benltoufa [4] ranks air permeability among the methods of porosity determination together with image analysis method and geometry modelling and concluded that the most suitable and easiest method to determine porosity is the geometrical model based on the proportion of volumes ε_V. Bivainyte [5] concluded that the air permeability of double-layered knitted fabrics with different patterns can be predicted by the area linear filling rate. 16 variants of knits were used for this experiment and porosity value ε_A was calculated on the base of proportion of areas. The conclusion was that if the knitted fabrics are made with the same pattern the air permeability depends on the loop length. Maheswaran [6] investigated the properties of plain jersey knitted fabrics produced from blended yarns. 18 samples were obtained for this experiment. It was found that main factors influencing the air permeability of knitted fabrics are fabric thickness and yarn hairiness. Other authors try to describe in detail the geometry of the loop in the knitted fabric - for example Suh [7], Munden [8] or Peirce [9]. However, these models are complex and requires many parameters to characterise the loop shape geometry and in addition, they usually also require a number of simplifying assumptions. Benltoufa [4] compared porosity values calculated using Suh's geometrical model and using much simpler model of porosity based on the proportion of volumes ε_V below and for 60 samples of knitted fabrics obtained very similar results.

The aim of our study is not to find a generally valid model for predicting the air permeability value of a knitted fabric, but to examine the influence of basic and in practice easily detectable structural parameters such as thickness, planar weight or density of the knitted fabric on the value of its air permeability and also to compare the relationships between air permeability and porosity values calculated according to three different theoretical models. A specific experimental set of knitted fabrics with defined structural parameters is to be used for this purpose.

2 RESEARCH METODOLOGY

2.1 Air permeability

Air permeability *AP* [m/s] of textile materials is generally understood as the ability of fabric to transmit air. Permeability measurement is carried out according to the standard ISO 9237 and air permeability is expressed as the speed of air flowing through the sample of fabric given (under defined measurement conditions – clamping area *S* [cm^2] and the pressure difference Δ*p* [Pa]). Standard measurement devices create a negative pressure inside the device, which leads to sucking air through the tested fabric.

2.2 Structural parameters of plain jersey weft knitted fabrics

Analogous to woven fabrics [10, 11], the basic structure of the knitted fabric may be described as follows: the method of yarn interlacing, yarn diameter or the linear mass of this yarn, wale spacing and course spacing, the thickness of the fabric or its surface mass. The fabric structure parameters can be divided into primary and secondary parameters. Primary parameters of fabric structure are dependent variables, where the choice of one parameter influences the effect of the others. All others fabric structure parameters depend on primary parameters. These are secondary parameters [12].

The jersey based plain structure is the simplest, but at the same time the most used structure of the weft knitted fabric. Dimensional characteristics of unit cell of this fabric are illustrated in Figure 1:

- wale spacing *W* [m] (or loop width); the number of wales per meter *w* [1/m], while *W*=1/*w*,
- course spacing *C* [m] (or loop height); the number of courses per meter *c* [1/m], while *C*=1/*c*,
- yarn diameter *d* [m],
- loop length *l* [m].

The primary structural parameters are yarn diameter, plain jersey structure, wale spacing and course spacing. However, it is very important to note that the wale spacing *W* [m] is defined by the knitting machine gauge and course spacing *C* [m] is changed by the sinking depth [13]. So for samples knitted on one machine: in the first phase we change the course spacing. Removing the knitted fabric from the machine is followed by relaxation, after which the length of the loop is the same, but wale spacing and course spacing change nonlinearly [14].

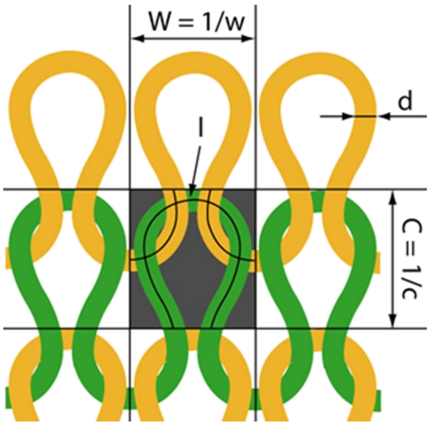

Figure 1 Scheme of unit cell of a plain knitted fabric

Very important parameter of a knitted structure is the loop length *l* [m]. The loop length is usually mentioned as the primary knitted structure parameter [8, 13], which is changed by the machine used and its settings. The loop length can be determined experimentally. However, if the value of loop length is calculated theoretically, it would be more logical to consider this parameter as a secondary structural parameter, because it is calculated from the primary structural parameters. For example, the geometrical model by Dalidovic [15] calculates the loop length as a function of yarn diameter, wale spacing and course spacing:

$$l = \frac{\pi}{2} \times W + \pi \times d + 2C \tag{1}$$

This model is one of the most used due to its simplicity. The yarn diameter *d* [m] can be determined experimentally or calculated as:

$$d = \sqrt{\frac{4T}{10^{-6}\pi \times \mu \times \rho_F}} \tag{2}$$

where: ρ_F [kg/m^3] is the density of fibres, *T* [tex] is the count of yarn and *μ* [-] is the packing density of yarn [16]. In this case, a free yarn diameter is involved. It means considerable simplification, because the yarn cross section is deformed at the interlacing points in the textile structure.

The two-dimensional Figure 1 does not show the thickness of the fabric *t* [m]. The thickness of the knitted fabric, as its secondary structural parameter, is results of its primary structural parameters and can be easily determined experimentally. According to some authors [2, 3, 6], the thickness of a knitted fabric is one of the most important parameters for its air permeability. Finally, the planar weight of the knitted fabric W_T [kg/m^2] is a secondary structural parameter, which is also the result of its primary structural parameters. The planar weight (or surface mass) is the weight per unit area of the fabric and can be easily determined experimentally. Based on the structural parameters above, a porosity of the knitted fabric can be calculated. There exist generally three basic techniques for characterization of idealized fabric porosity [17]:

- Porosity based on the proportion of densities ε_D [-] is computed from the equation:

$$\varepsilon_D = 1 - \frac{\rho_T}{\rho_F} \tag{3}$$

where: ρ_F [kg/m^3] is the density of fibres and ρ_T [kg/m^3] is the volumetric density of the fabric defined by the relation:

$$\rho_T = \frac{W_T}{t} \tag{4}$$

where: W_T [kg/m^2] is the planar weight and *t* [m] is the thickness of the fabric. Then density based porosity can be calculated as:

$$\varepsilon_D = 1 - \frac{W_T}{(\rho_F \times t)} \tag{5}$$

Dias [18] refers this method as the experimental evaluation of porosity. This method is simplest and applicable for all fabrics regardless of their construction.

- Porosity based on the proportion of areas ε_A is defined as [5]:

$$\varepsilon_A = 1 - \frac{A_Y}{A_T} \tag{6}$$

where A_Y [m^2] is the area of projection of the yarn in unit cell of the knitted structure:

$$A_Y = d \times l - 4d^2 \tag{7}$$

and A_T [m^2] is the total area of projection of this unit cell:

$$A_T = C \times W \tag{8}$$

Then the porosity ε_A can be calculated as:

$$\varepsilon_A = 1 - \frac{d \times l - 4d^2}{C \times W} \tag{9}$$

- Porosity based on the proportion of volumes ε_V is defined as [1, 4]:

$$\varepsilon_V = 1 - \frac{V_Y}{V_T} \tag{10}$$

where: V_Y [m^3] is the yarn volume in unit cell of the fabric calculated as:

$$V_Y = \left(\frac{\pi d^2}{4}\right) \times l \tag{11}$$

and V_T [m^3] is the total volume of unit cell of the fabric:

$$V_T = C \times W \times t \tag{12}$$

Then the porosity ε_V can be calculated as:

$$\varepsilon_V = 1 - \frac{\pi d^2 \times l}{4C \times W \times t} \tag{13}$$

All discussed structural parameters are summarised in affinity diagram on Figure 2.

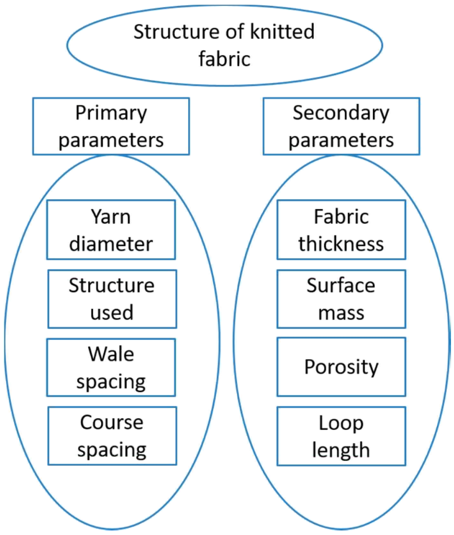

Figure 2 Affinity diagram of basic structural parameters of a knitted fabric

3 MATERIALS AND EXPERIMENT

Knitted fabrics of single jersey structure were used for the experiment. The samples were specially made for the research purpose on a small-diameter circular knitting machine – Rius-Protex (Spain) from polyester and viscose ring-spun yarns, which have always been of two linear densities 20 tex and 29.5 tex. Samples of the fabrics with different densities were knitted from each yarn – altogether 22 different knitted samples were prepared (Figure 3 and Table 1). Figure 4 shows images of knitted fabric made of viscose yarn 29.5 tex.

Table 1 Knitted fabrics structural parameters

sample	W_T [kg/m^2]	*t* [mm]	A_T [mm^2]	ε_D [-]	ε_A [-]	ε_V [-]
VI_20	0.084	0.44	0.98	0.870	0.431	0.797
	0.099	0.45	0.74	0.852	0.349	0.772
	0.105	0.46	0.66	0.846	0.315	0.762
	0.117	0.47	0.56	0.832	0.258	0.742
	0.134	0.48	0.42	0.809	0.151	0.697
PL_20	0.085	0.43	0.92	0.858	0.447	0.812
	0.100	0.46	0.70	0.843	0.366	0.793
	0.119	0.49	0.52	0.824	0.269	0.769
	0.133	0.52	0.47	0.814	0.240	0.770
VI_29.5	0.108	0.47	1.20	0.844	0.506	0.770
	0.115	0.48	1.08	0.838	0.374	0.761
	0.126	0.49	0.97	0.825	0.340	0.749
	0.138	0.52	0.77	0.821	0.264	0.731
	0.149	0.54	0.68	0.812	0.219	0.718
	0.165	0.55	0.58	0.797	0.164	0.701
	0.181	0.57	0.51	0.784	0.110	0.686
	0.201	0.58	0.45	0.765	0.058	0.669
PL_29.5	0.120	0.54	0.98	0.851	0.319	0.759
	0.147	0.56	0.67	0.810	0.191	0.709
	0.172	0.56	0.58	0.779	0.135	0.685
	0.185	0.58	0.52	0.771	0.094	0.677
	0.187	0.58	0.50	0.769	0.075	0.670

Primary and secondary structural parameters of all knitted fabric samples were determined with laboratory tests. The planar weight of the fabrics W_T was measured according to Standard EN 12127 and the thickness of the fabrics *t* according to Standard EN ISO 5084. The number of courses per mm *c* and wales per mm *w* was measured according to Standard EN 14971.

The loop length *l* was calculated according to (1), with the yarn diameter value *d* calculated according to (2). The porosity values ε_D, ε_A and ε_V were calculated according to (5), (9) and (13). The parameters of the knitted fabrics are summarized in Table 1.

The air permeability of the fabrics *AP* [m/s] was measured according to Standard EN ISO 9237 using a Textest FX 3300 air permeability tester. The measurements were performed with a constant pressure difference of 50 Pa and 20 cm^2 test area.

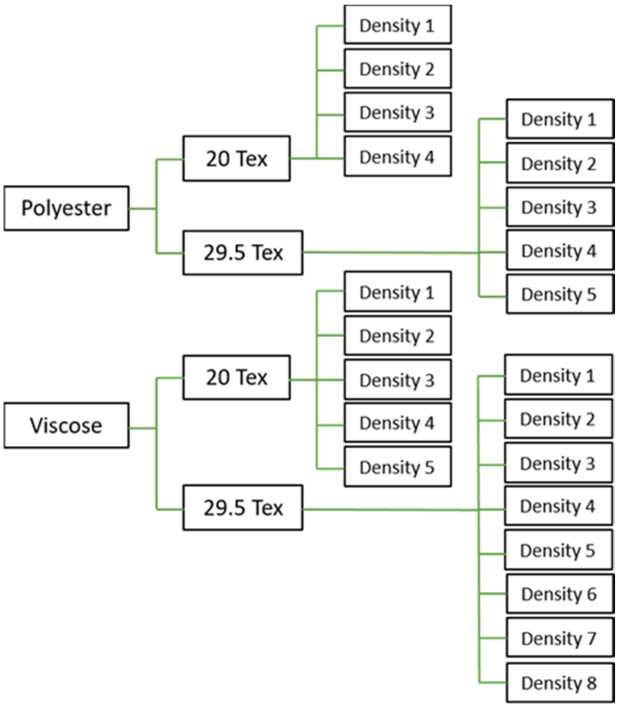

Figure 3 Knitted samples preparation diagram

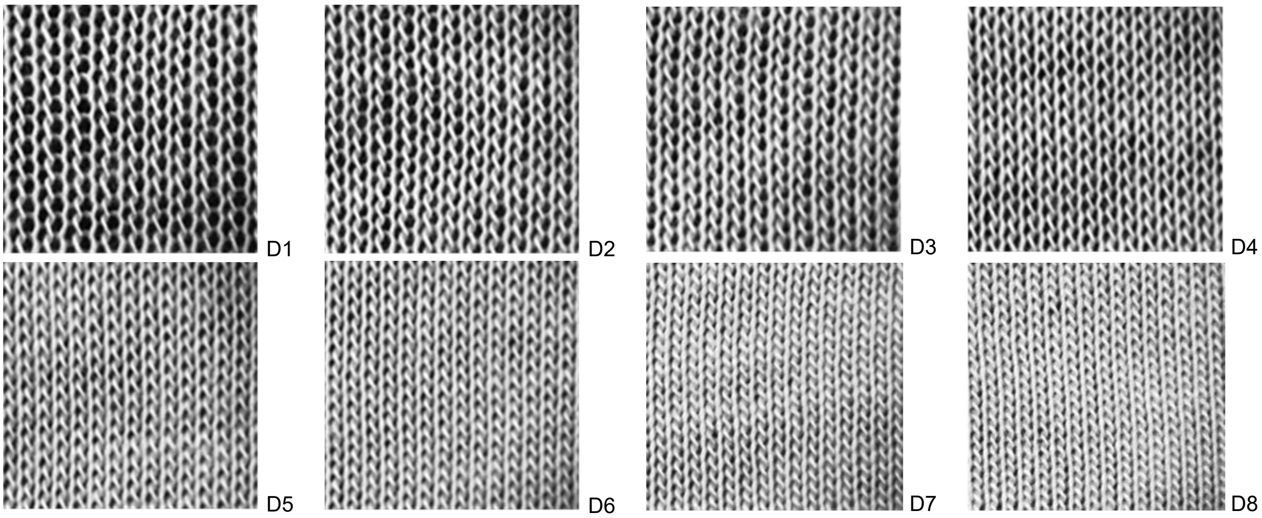

Figure 4 Microscopic views of the knitted fabric samples Viscose_29.5 tex with different densities (D)

4 RESULTS AND DISCUSSION

According to some authors [2, 3, 6], the thickness of the knitted fabric is an important structural parameter for the value of its air permeability. Figure 5 and the correlation coefficients in Table 2 show that when the knitted fabric samples are made from the same yarn, the data show a strong negative linear dependence (e.g. VI_29.5: R=-0.98). If the thickness of the fabric increases, then its air permeability decreases. However, the correlation coefficient is lower when the knitted fabric samples are made of different yarns (R=-0.81). In this case the linear relationship is not so strong.

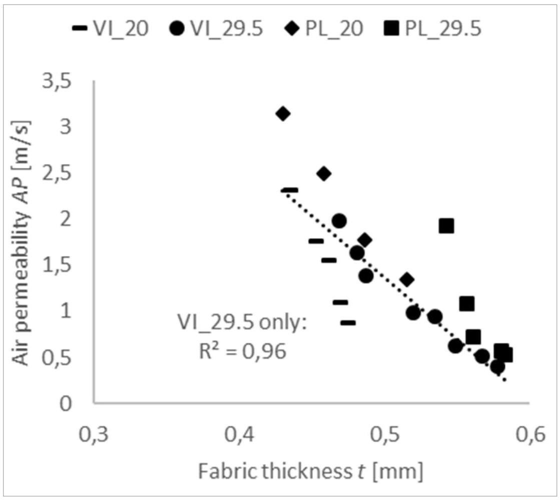

Figure 5 Relationship between thickness and air permeability of knitted fabrics

Table 2 Correlation coefficients for relationships between air permeability and selected structural parameters of knitted fabrics

	t [mm]	W_T [kg/m^2]	A_T [mm^2]	ε_D [-]	ε_A [-]	ε_V [-]
All data	-0.81	-0.90	0.64	0.88	0.92	0.94
VI_29.5	-0.98	-0.95	0.996	0.94	0.97	0.97

Another important structural parameter of the knitted fabric is the loop length. This parameter also affects the value of air permeability of knitted fabric [1, 2, 5]. Since in our paper the loop length is calculated theoretically according to (1) as a function f (W, C, d), the dependence of the air permeability of the knitted fabric on the area of its unit cell A_T calculated according to (8) is shown in Figure 6.

Figure 6 and Table 2 show that if the knitted fabric samples are made from the same yarn (material and yarn count), the dependence is strongly linear (e.g. VI_29.5: R=0.996). This must be so, because the area of unit cell A_T in this is exactly the parameter of the knitted fabric that changes. Only in this case it is possible to evaluate that if the area of the pore cell of the knitted fabric increases, its air permeability also increases. Figure 6 also shows that for sets of knitted fabrics made of different yarns, the parameters a and b of the linear dependence in the form $y=a*x+b$ change. Thus, the slope of the line and the displacement of the line on the y-axis are different.

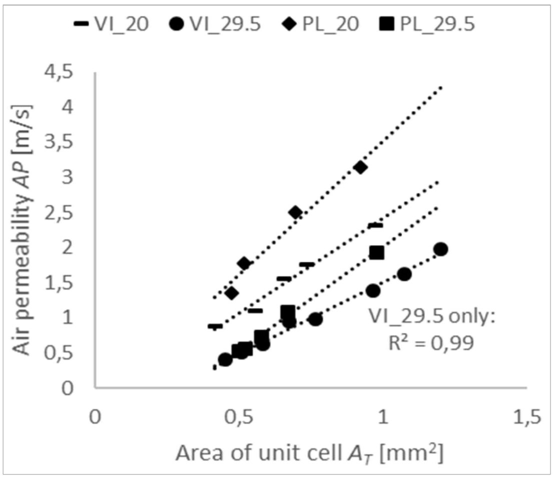

Figure 6 Relationship between area of unit cell and air permeability of knitted fabrics

The planar weight of the knitted fabric is a parameter that is easily measurable and in practice is usually known for a fabric given. Table 2 shows that the relationship between the planar weight and the air permeability of the knitted fabric shows a strong negative linear dependence, even if it is a set of all knitted fabrics – made of different yarns (R=-0.90). This means that as the planar weight of the knitted fabric increases, its air permeability decreases. However, from Figure 7, the data correspond better to nonlinear dependence than the linear one. That is, the air permeability of the knitted fabric decreases nonlinearly depending on its planar weight.

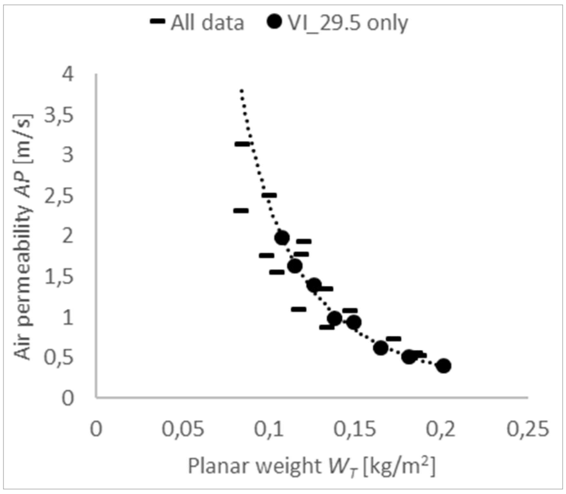

Figure 7 Relationship between planar weight and air permeability of knitted fabrics

In the case of knitted fabrics with a higher planar weight, a relatively large change in planar weight will cause only small change in air permeability. Conversely, in the case of knitted fabrics with a lower planar weight, a relatively small change in the planar weight can cause a large change in the air permeability value – the sensitivity of air permeability to planar weight varies. This means that it is necessary to find another structural parameter that will be significant for the air permeability value of the knitted fabric.

Figure 8 shows relationships between air permeability of the knitted fabric and its porosity values calculated according to 3 different models - (5), (9) and (13): ε_D = f (W_T, t, ρ_F), ε_A = f (C, W, d), ε_V = f (C, W, d, t).

From Table 2 it is evident that all three relationships show a strong positive linear dependence. If the knitted fabric samples are made of the same yarn, the correlation coefficients range in 0.94-0.97. If the knitted fabric samples are made of different yarns, the correlation coefficients range in 0.88-0.94. However, Figure 8 shows that air permeability value responds most sensitively to the porosity based on the proportion of areas ε_A.

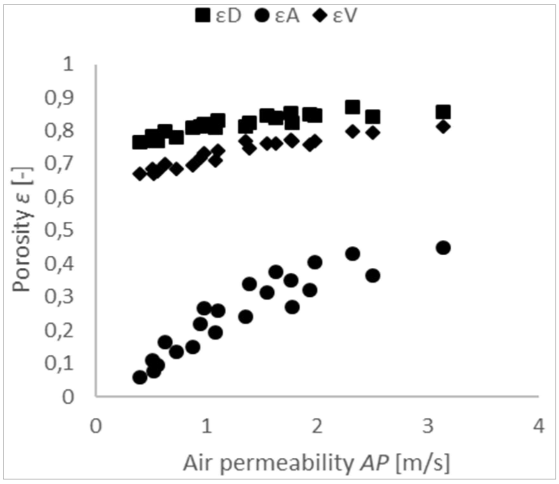

Figure 8 Relationship between air permeability and porosity of knitted fabrics

Figure 9 shows the relationship between porosity ε_A and air permeability of knitted fabrics only. It is evident that this dependence is not completely linear. If the porosity ε_A of the fabric increases, the air permeability value also increases. However, in the case of knitted fabrics with lower porosity, a relatively large change in the porosity value will cause a small change in the air permeability, and conversely, in the case of knitted fabrics with higher porosity, a relatively small change in the porosity will cause a large change in the air permeability value. Therefore, the sensitivity of the air permeability value to the porosity value of the fabric varies.

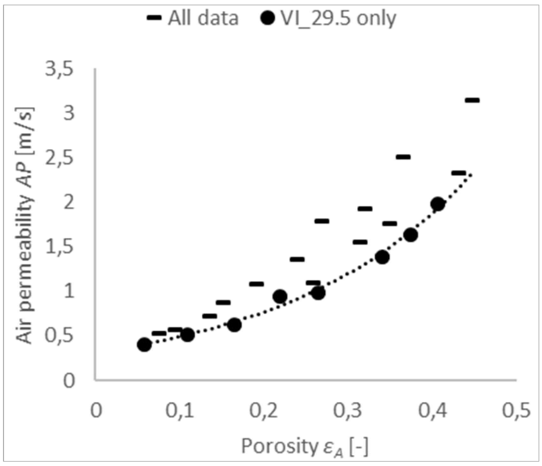

Figure 9 Relationship between porosity ε_A and air permeability of knitted fabrics

Therefore, if the air permeability value increases depending on the porosity ε_A and decreases depending on the planar weight W_T, the air permeability value should depend on the ratio ε_A/W_T. Figure 10 shows a strong positive linear dependence between air permeability values and values of the ratio ε_A/W_T in the case when the knitted fabric samples are made from yarns of the same material.

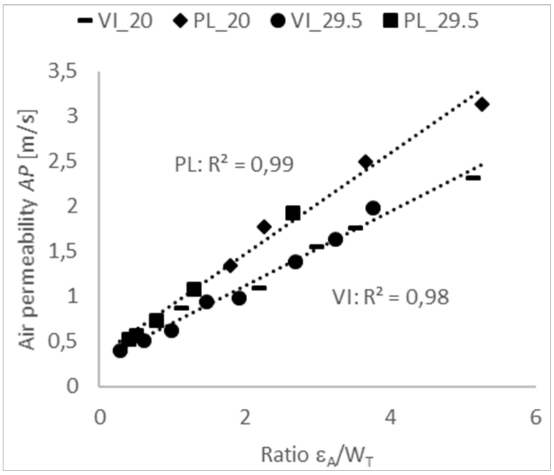

Figure 10 Relationship between ε_A/W_T ratio and air permeability of knitted fabrics

5 CONCLUSSIONS

Four sets of knitted samples were used for the experiment. In one set of samples only one primary structural parameter - density of knitted fabric - was changed, while the other primary structural parameters - material, yarn count, structure - remained unchanged.

The change in the primary structural parameter was reflected in the changes in the secondary structural parameters - thickness, planar weight and porosity of fabrics.

According to experimental results:

- The air permeability of knitted fabric decreases when its thickness increases. In the case of fabrics made of the same yarn, the relationship shows the strong negative linear dependence with the correlation coefficient value R=-0.98. In the case that the fabrics are made of different yarns, the correlation coefficient value decreases (R=-0.81).
- The air permeability of knitted fabric increases when its area of unit cell increases. However, only in the case of fabrics made of the same yarn, the relationship shows strong linear dependence. The slope of the line and the displacement of the line on the y-axis are different for sets of fabrics made of different yarns. Therefore, the values of *a* and *b* parameters of the linear dependence in the form *y=a*x+b* are probably to be dependent on the structural parameters of yarns (material, yarn count, yarn diameter, …). However, a larger set of experimental knitted fabrics will need to be used to investigate such dependencies.
- The air permeability of knitted fabric decreases nonlinearly when its planar weight increases. The relationship shows that the significance of the planar weight of the knitted fabric for its air permeability varies and is relatively higher for knitted fabrics with lower planar weight value.
- The air permeability of knitted fabric increases nonlinearly when its porosity increases. The relationship shows that the significance of the porosity of the knitted fabric for its air permeability varies and is relatively higher for knitted fabrics with higher porosity value. The air permeability value responds most sensitively to the porosity, which is calculated as the proportion of the open area of the knitted fabric.
- Our data also showed that the air permeability value of the knitted fabric increases linearly when the proportion of its porosity and planar weight increases. This applies if the knitted fabrics are made of the same material (polyester or viscose).

The aim of our study was not to find a generally valid model for predicting the air permeability value of a knitted fabric. Due to the narrow spectrum of experimental fabrics used, the results cannot be generalized. However, on the contrary, thanks to the precisely defined structural parameters of the knitted fabric samples used, it was possible to investigate the elementary relationships between these structural parameters and the air permeability value. Consequently, our study can serve as a basis for exploring a wider range of common clothing knits.

ACKNOWLEDGEMENT: *This work was supported by the Ministry of Education, Youth and Sports of the Czech Republic and the European Union - European Structural and Investment Funds in the frames of Operational Programme Research, Development and Education - project Hybrid Materials for Hierarchical Structures (Hyhi, Reg. No. CZ.02.1.01/0.0/0.0/16_0000843).*

6 REFERENCES

1. Ogulata R.T., Mavruz S.: Investigation of porosity and air permeability values of plain knitted fabrics, Fibres & Textiles in Eastern Europe 18(5), 2010, pp. 71-75
2. Coruh E.: Optimization of comfort properties of single jersey knitted fabrics, Fibres & Textiles in Eastern Europe 4(112), 2015, pp. 66-72, DOI: 10.5604/12303666.1152728
3. Wilbik-Halgas B., Danych R., Wiecek B., Kowalski K.: Air and water vapour permeability in double-layered knitted fabrics with different raw materials, Fibres & Textiles in Eastern Europe 14(3), 2006, pp. 77-80
4. Benltoufa S., Fayala F., Cheikhrouhou M., Ben Nasrallah S.: Porosity determination of Jersey structure, Autex Research Journal 7(1), 2007, pp. 63-69, http://www.autexrj.org/No1-2007/0209.pdf
5. Bivainyte A., Mikučioniene D.: Investigation on the air and water vapour permeability of double-layered weft knitted fabrics, Fibres & Textiles in Eastern Europe 19(3), 2011, pp. 69-73
6. Maheswaran R., Srinivasan V., Muralikrishnan A.: Prediction and experimental investigation of knitted fabric thickness and its influence on single jersey fabric properties, Fibres & Textiles in Eastern Europe 28(3), 2020, pp. 38-43, DOI: 10.5604/01.3001.0013.901
7. Suh M.W.: A study of the shrinkage of plain knitted cotton fabric, based on the structural changes of the loop geometry due to yarn swelling and deswelling, Textile Research Journal 37(5), 1967, pp. 417-431, https://doi.org/10.1177/004051756703700513
8. Munden D.L.: The geometry and dimensional properties of plain-knit fabrics, Journal of the Textile Institute Transactions 50(7), 1959, pp. 448-471, https://doi.org/10.1080/19447025908659923
9. Peirce F.T.: Geometrical principles applicable to the design of functional fabrics, Textile Research Journal 17(3), 1947, pp.123-147, https://doi.org/10.1177/004051754701700301
10. Polipowski M., Wiecek P., Wiecek B., Pinar A.: Analysis of the effect of chanel parameters between filaments and single fabric parameters on air permeability, water vapour resistence and thermal resistence, Fibres & Textiles in Eastern Europe 25(5), 2017, pp. 79-86, DOI: 10.5604/01.3001.0010.4632
11. Szosland, J.: Identification of structure of inter-thread channels in models of woven fabric, Fibres & Textiles in Eastern Europe 7(2), 1999, pp. 41-45
12. Dubrovski P.D., Žiberna-Šujica M.: The connection between woven fabric construction parameters and air permeability, Fibres & Textiles in Eastern Europe 11(4), 1995, pp. 37-41

13. Pavko-Cuden A., Hladnik A., Sluga F.: Loop length of plain single weft knitted structure with elastane, Journal of Engineered Fibers and Fabrics 8(2), 2013, pp. 110-120
14. Havlová M., Špánková J.: Porosity of knitted fabrics in the aspect of air permeability – discussion of selected assumptions, Fibres & Textiles in Eastern Europe 25(3), 2017, pp. 86-91
15. Dalidovic A.S.: Knitting Theory Basics (Osnovy teorii vjazanija), Light Industry, Moscow 1971, 432 p. (in Russian)
16. Neckář B., Vyšanská M.: Simulation of fibrous structures and yarns. Simulation in textile technology – Theory and applications, Woodhead publishing. 2012, DOI: 10.1533/9780857097088.222
17. Militký J., Havrdová M.: Porosity and air permeability of composite clean room textiles, International Journal of Clothing Science and Technology 13(3/4), 2001, pp. 280-288, https://doi.org/10.1108/09556220110396533
18. Dias T., Delkumburewatte G.B.: Changing porosity of knitted structures by changing tightness, Fibers and Polymers 9(1), 2008, pp. 76-79, DOI:10.1007/s12221-008-0012-6