

## Quality of clothing fabrics in terms of their comfort properties

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Quality of various clothing woven fabrics with respect to their comfort properties, such as electro-physical properties, air permeability, and compression properties has been studied. Fabrics are produced from cotton and cotton/polyester fibre blends in plain, twill, satin and basket weave. Results show that cotton fabrics have lower values of the volume resistivity, air permeability and compressive resilience but higher values of effective relative dielectric permeability and compressibility as compared to fabrics that have been produced from cotton/PES fibre blends. Regression analysis shows a strong linear correlative relationship between the air permeability and the porosity of the woven fabrics with very high coefficient of linear correlation (0.9807). It is also observed that comfort properties are determined by the structure of woven fabrics (raw material composition, type of weave) as well as by the fabrics surface condition. Findings of the studies have been used for estimating the quality of woven fabrics in terms of their comfort properties by the application of ranking method. It is concluded that the group of cotton fabrics exhibits better quality of comfort as compared to the group of cotton/PES blend fabrics.

**Keywords:** Air permeability, Compression, Cotton, Cotton/polyester fibre, Electro-physical properties, Fabric quality, Fabric comfort

### 1 Introduction

Intensive growth of world population indicates the need of making clothing fabrics that comply with the requirements of a large number of consumers. It is not enough for clothing fabrics to have only a good painting, colorful solution and durability. The fabrics should also have good comfort properties. According to the literature<sup>1</sup>, there are two aspects of clothing comfort, viz sensorial and non-sensorial. Sensorial properties such as fabric handle, compression properties, electro-physical properties and frictional properties describe the performance of a fabric on skin contact. Non-sensorial comfort is not only comprised thermal and moisture transmission but also includes air permeability, water repellency and water resistance. From the survey of literature<sup>1-10</sup>, it is evident that a large number of studies are devoted to determining both sensorial and non-sensorial properties of fabrics.

Although the electrical properties of woven fabrics have been studied for a long period of time, this topic still leaves many opportunities for various researches,

especially when it covers the comfort of clothing fabrics. Since textile materials are in continuous contact with consumer bodies during their use, it would be necessary to investigate an appearance of static electricity which creates unfavorable effects like increased dirt, cleaning problems and increased tendency of materials to form the rolled-up ends of fibres on their surface. Created static electricity in textile material may also lead to sticking to textile fabrics for the consumer bodies or other textile materials, creating an unpleasant sensation when wearing these clothes<sup>11</sup>. These unfavorable effects are especially pronounced in synthetic textile fabrics with extremely high electric resistances<sup>12-15</sup>, and low values of relative dielectric permeability<sup>14-17</sup>. For these reasons, the tendency of textile materials to produce static electricity might be considered the most important single criterion of comfort.

The sensory aspect of textile comfort, like handle of clothing material, is getting more priority in the quality evaluation of fabric<sup>18,19</sup>. One of the most important indicators of fabric handle is softness which can be judged through the change of fabric thickness under the influence of compression load. Magnitude of compression load generated in the textile material

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and how it is distributed on the skin influence human perception of fabric softness and fabric comfort quality.

In addition to the above, air permeability is also considered as an important comfort property of the fabric. It determines the ability of air to flow through a given area of the fabric<sup>5,8,20,21</sup>. Air flow through textiles is mainly affected by the pore characteristics of fabrics. If there is no possibility of air flow through the pores of the fabric or the flow is difficult, very soon it will cause feeling of discomfort. For this reason, air permeability might be considered as a feature of fabric which has a great contribution in overall clothing comfort.

Due to the well known tendency of textile materials to produce static electricity, which causes unpleasant sensation on the skin, an attempt has been made to study the quality of clothing woven fabrics primarily through their electro-physical properties, such as volume resistivity, effective relative dielectric permeability. In order to get a complete picture of the comfort quality of investigated fabrics, compression properties such as compressibility, compressive resilience, and air permeability have been studied. Values of monitored characteristics were used for establishing the level of quality of clothing woven fabrics with regard to their comfort properties by the application of ranking method.

## 2 Materials and Methods

### 2.1 Materials

The experiment was conducted on six commercially produced woven clothing fabrics (cotton and cotton/polyester blend) with different weaves [plain (Sample 1 and Sample 4), twill 2/2 (Sample 2), twill 3/1 (Sample 5), satin (Sample 3), and basket 2/2 (Sample 6)]. The characterization of examined samples was done through determination of the fabric properties, such as yarn fineness, weave

density, warp and weft crimp, fabric weight, and thickness. Since the fabrics are quite different considering the structural parameters, the coefficient of yarn fineness ( $C_F$ ) and coefficient of weave density ( $C_g$ ) were also introduced into the analysis of test results. In such way, the two variables are reduced to, relatively speaking, one variable, allowing easier comparison of the fabrics based on the structural parameters as well as easier observation of the influence of structural parameters on comfort characteristics of woven fabrics. Basic characteristics and structure coefficients of investigated fabrics are given in Table 1.

Images of woven fabrics are shown in Fig. 1 ( $\times 65$ ). All samples are mono-coloured except Sample 4 which has printed pattern in the form of black spots on a white background.

All the samples were conditioned for 24 h at the standard atmospheric conditions of  $20 \pm 2$  °C temperature and  $65 \pm 2$  % relative humidity before tests.

### 2.2 Determination of Electro-physical Properties

The electro-physical properties of woven fabrics were characterized considering the changes in volume resistivity and effective relative dielectric permeability. The volume resistivity was calculated considering the volume resistance of the samples. Volume resistances of the tested woven fabrics were determined at room temperature (21°C) using the apparatus developed at the Department of Textile Engineering of the Faculty of Technology and Metallurgy, University of Belgrade<sup>13,14,22</sup>. The same apparatus can be used for the determination of volume resistance of yarns, knitted fabrics as well as nonwoven fabrics. Schematic diagram of the apparatus used for the measurement of volume resistance of woven fabrics using the voltage method is shown in Fig. 2.

Table 1 — Structural characteristics of woven fabrics

Material	Weave	$T_o$ , tex	$T_p$ , tex	$C_F = \frac{T_o}{T_p}$	$g_o$ , dm <sup>-1</sup>	$g_p$ , dm <sup>-1</sup>	$C_g = \frac{g_o}{g_p}$	$u_o$ , %	$u_p$ , %	$T$ , mm	$M$ , g·m <sup>-2</sup>
Cotton	Plain	36	30	1.2	240	180	1.33	7.8	4.7	0.442	136
Cotton	Twill 2/2	25×2	25×2	1	320	220	1.45	10.8	4.6	0.665	287
Cotton	Satin	26	26	1	362	310	1.17	3.2	3.1	0.536	191
Cotton/PES <sup>a</sup> (22/78)	Plain	9	23	0.39	355	249	1.42	1.3	7.0	0.234	93
Cotton/PES <sup>b</sup> (34/66)	Twill 3/1	27	29	0.93	460	226	2.03	1.96	3.50	0.375	195
Cotton/PES <sup>b</sup> (67/33)	Basket 2/2	18×2	18×2	1	320	250	1.28	8.1	3.5	0.534	215

<sup>a</sup> Warp – PES & weft – Cotton + PES.

<sup>b</sup> Warp & weft – Cotton+PES.

$T_o$  &  $T_p$  — warp & weft fineness,  $C_F$  — coefficient of yarn fineness,  $g_o$  &  $g_p$  — warp ends & weft picks,  $C_g$  — coefficient of weave density,  $u_o$  &  $u_p$  — warp & weft crimp,  $T$  — fabric thickness and  $M$  — fabric weight.

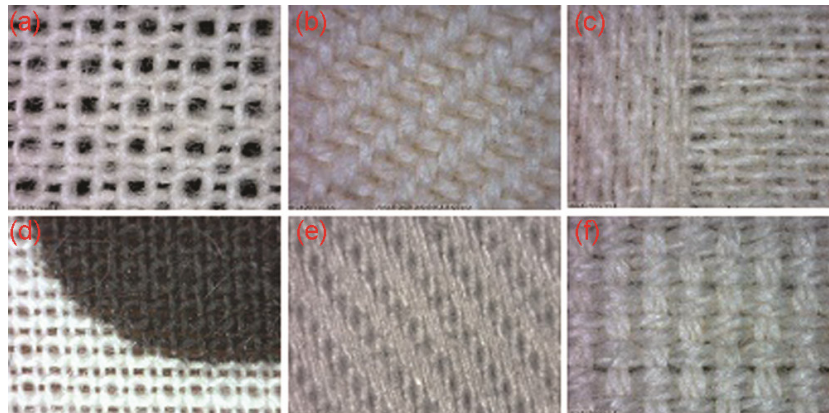


Fig. 1 – Images of investigated woven fabrics [(a) Sample 1 (plain), (b) Sample 2 (twill 2/2), (c) Sample 3 (satin), (d) Sample 4 (plain), (e) Sample 5 (twill 3/1) and (f) Sample 6 (basket 2/2)]

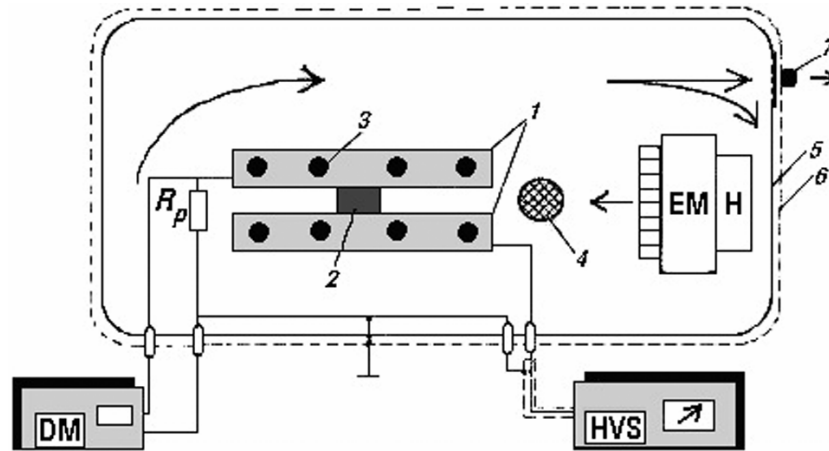


Fig. 2 –Schematic diagram of apparatus for measuring the volume resistance of woven fabrics[1 - electrodes, 2 - woven fabric, 3 - screws, 4 - sensors, 5 - chamber, 6 - Faraday's cage and 7 - aperture]

The woven fabric of unknown volume resistance ( $R_x$ ) was clamped between the electrodes and tightened with screws. The adjustable silver-plated electrodes were connected to the high voltage source (HVS). Air humidity and temperature in the chamber were registered by the sensors of the digital-measuring device. Electrodes, placed into a transparent chamber that provides controlled measurement conditions, were fixed at distance of 1 cm. The shield from external electric fields, which could produce unfavourable effects on the precision of the measurement, was realized by Faraday's cage. Air humidity change in the chamber was established by humidifier (H) as well as by adjusting the aperture which provides a connection between the chamber and the external atmosphere. An electromotor (EM), with a compression circuit, provides air circulation inside the chamber. The voltage fall was registered

using a Philips digital multi-meter Model PM 2528 (DM). The values of volume resistance of investigated samples were determined by the same dynamics of moisture desorption from all samples.

The voltage method is based on measuring a voltage fall ( $U_m$ ) on the protective known resistor ( $R_p$ ). The resistor ( $R_p$ ) was serially connected to the woven sample of unknown volume resistance. The volume resistance of the woven sample ( $R_x$ ,  $G\Omega$ ) was determined using the following formula<sup>13,22</sup>:

$$R_x = \frac{R_p R_i}{R_p + R_i} \cdot \frac{E}{U_m} \quad \dots (1)$$

where  $E$  is the applied voltage (1200 V);  $R_p$ , the resistance of the protective resistor (1.64  $M\Omega$ ); and  $R_i$ , the resistance of the digital multi-meter (10  $M\Omega$ ).

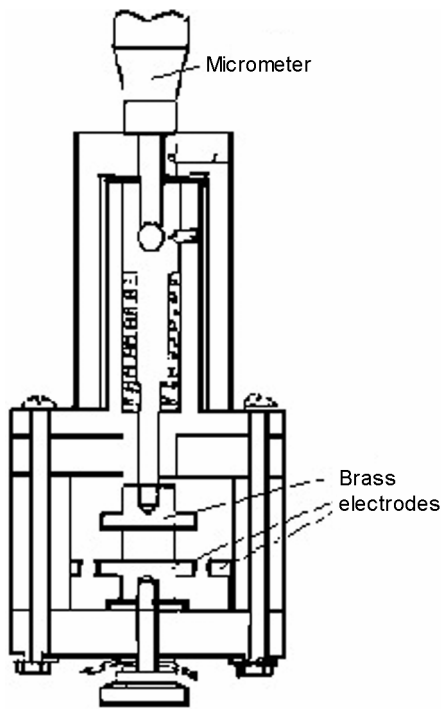


Fig. 3 – Schematic diagram of capacitance cells

Volume resistivity ( $\rho$ ,  $G\Omega \cdot \text{cm}$ ) was calculated according to the following formula<sup>13,22</sup>:

$$\rho = \frac{R_x \cdot S_F}{l} \quad \dots (2)$$

where  $R_x$  is the volume resistance of the sample ( $G\Omega$ );  $S_F$ , the surface of the sample's cross-section ( $\text{cm}^2$ ); and  $l$ , the length of the sample (1 cm).

Effective relative dielectric permeability was determined at room temperature (21°C) using a capacitance cells (Fig. 3) developed at the Faculty of Physics, University of Belgrade<sup>23</sup>. The specimens of woven fabrics were cut into circular pieces (25 mm diameter) which is equal to the diameter of used cell electrodes. The capacitance cell consisted of two measuring brass electrodes and a guard ring. Spacing of the electrodes was controlled by a micrometer. The measurement cell was connected to the bridge Agilent 4285A (frequencies 75 kHz - 30 MHz). Measurements were performed at a relative humidity of 40 % and 80 %, and frequency of 1 MHz. Textile materials can be considered as a mixture of fibres, air and moisture<sup>24</sup>. So, the value of dielectric permeability calculated based on measured capacities represents the overall effect of fibre-air-moisture system, and can be termed as effective relative

dielectric permeability ( $\epsilon_m$ ). Effective relative dielectric permeability ( $\epsilon_m$ ) was obtained from the capacitance using the following formula<sup>17</sup>:

$$\epsilon_m = \frac{(C - C_0)}{\epsilon_0 S_u} d + 1 \quad \dots (3)$$

where  $C$  is the capacity of a condenser with the woven fabric between the electrodes (F);  $C_0$ , the capacity of the same condenser with air between the electrodes (F);  $d$ , the distance between electrodes (m);  $S_u$ , the area of the sample ( $\text{m}^2$ ); and  $\epsilon_0$ , the dielectric permeability of free space ( $\epsilon_0 = 8,85 \cdot 10^{-12} \text{ F} \cdot \text{m}^{-1}$ ).

### 2.3 Determination of Air Permeability and Porosity

Air permeability tests of the woven fabrics were conducted according to the Standard EN ISO 9237:1995 using test area of  $20 \text{ cm}^2$  and pressure difference of 100 Pa. Air permeability was determined at room temperature (21°C) from back to face side of the woven material. The test was repeated 10 times at different locations on each sample. The air permeability ( $R$ ,  $\text{mm} \cdot \text{s}^{-1}$ ) was determined according to the following formula:

$$R = \frac{q_v}{A} \cdot 167 \quad \dots (4)$$

where  $q_v$  is the arithmetic mean of air flow rate ( $\text{dm}^3 \cdot \text{min}^{-1}$ );  $A$ , the woven fabric area of  $20 \text{ cm}^2$ ; and 167, the conversion factor from cubic decimeters per minute per square centimeter to millimeters per second.

Since the air permeability of fabrics is primarily determined by their porosity, it was necessary to study the porosity of samples. The porosity ( $P$ , %) was calculated according to the following formula<sup>25</sup>:

$$P = 100 - 100(d_o g_o + d_p g_p - d_o g_o d_p g_p) \quad \dots (5)$$

where  $d_o$ ,  $d_p$  are the diameters of the warp and weft yarns (cm); and  $g_o$ ,  $g_p$ , the warp and weft densities of the investigated woven fabrics ( $\text{cm}^{-1}$ ).

### 2.4 Determination of Compression Properties

A thickness tester (AMES, type 414-10, USA) was used for the investigation of compression properties of woven fabrics. The pressure-foot area for the test was  $64 \text{ mm}^2$ . By using this thickness tester, it was possible to measure the fabric thickness ( $T$ , mm) at

different pressures ( $P$ ,  $\text{cN}\cdot\text{cm}^{-2}$ ). The samples were compressed starting with the initial pressure of  $100 \text{ cN}\cdot\text{cm}^{-2}$ , through the progressively increased pressure in steps of 175, 440, 590, 745 and  $1050 \text{ cN}\cdot\text{cm}^{-2}$ . After attaining the maximum pressure, the test was reversed in the same way till the recovery of the complete sample. Compression properties of the woven fabrics were determined at room temperature ( $21^\circ\text{C}$ ). The relative compressibility ( $C$ , %) of the woven fabrics was determined using the following formula<sup>26</sup>:

$$C = \frac{T_{0c} - T_{\max}}{T_{0c}} \cdot 100 \quad \dots (6)$$

where  $T_{0c}$  is the initial thickness (mm) of woven fabric at the pressure of  $100 \text{ cN}\cdot\text{cm}^{-2}$ ; and  $T_{\max}$ , the fabric thickness (mm) of woven fabric under the maximum pressure of  $1050 \text{ cN}\cdot\text{cm}^{-2}$ .

Compressive resilience ( $RC$ , %), was calculated using the following formula<sup>26</sup>:

$$RC = \frac{W'_c}{W_c} \cdot 100 \quad \dots (7)$$

where  $W_c$  is the compression work per unit area of the sample in the direction of the pressure ( $\text{cN}\cdot\text{cm}\cdot\text{cm}^{-2}$ ); and  $W'_c$ , the compression work recovery per unit area of the sample in the direction of the pressure ( $\text{cN}\cdot\text{cm}\cdot\text{cm}^{-2}$ ). Compression work ( $W_c$ ,  $\text{cN}\cdot\text{cm}\cdot\text{cm}^{-2}$ ) was calculated according to the following formula<sup>26</sup>:

$$W_c = \int_{T_{0c}}^{T_{\max}} P_c \cdot dT_c \quad \dots (8)$$

where  $P_c$  is the magnitude of pressure which causes compression of the sample ( $\text{cN}\cdot\text{cm}^{-2}$ ). The compression work recovery ( $W'_c$ ,  $\text{cN}\cdot\text{cm}\cdot\text{cm}^{-2}$ ) was calculated using the following formula<sup>26</sup>:

$$W'_c = \int_{T_{\max}}^{T_{0r}} P_r \cdot dT_r \quad \dots (9)$$

where  $P_r$  is the magnitude of pressure under recovery conditions ( $\text{cN}\cdot\text{cm}^{-2}$ ); and  $T_{0r}$ , the final fabric thickness under the recovery condition (i.e. under decompression of the sample) (mm).

### 2.5 Determination of Comfort Quality

Aimed at estimating the quality of tested fabrics, ranking method was applied. Ranking method<sup>27</sup> consisted of providing each characteristic with the grading from '1' to 'n', where 'n' represents the total number of fabrics (in this paper 'n' = 6). Grade '1' indicates the best quality of fabric from the aspect of monitored characteristic and grade '6' means the poorest quality. In this experiment, the less value of volume resistivity, and higher values of effective relative dielectric permeability, air permeability, compressibility and compressive resilience mean the better quality of fabric. Based on the average values of grades, the rank order of each fabric in terms of its comfort properties has been established.

## 3 Results and Discussion

### 3.1 Electro-physical Properties

The volume resistivities of fabrics determined during desorption of moisture from textile material at 40% of air humidity in the chamber are shown in Table 2. An estimate of the significance of mean values differences ( $t_{s \text{ warp,weft}}$ ) between the results of volume resistivity of the tested fabrics is also presented in Table 2.

The results (Table 2) show that the cotton fabrics (Samples 1 - 3) have lower volume resistivities compared to samples obtained from cotton/PES fibre blends (Samples 4-6). It is obvious that the amount of PES fibres in the yarn structure influences the electrical resistivity of the fabrics. Higher values of volume resistivities is attributed to the presence of

Table 2 — Volume resistivity of woven fabrics at air humidity of 40 % in the chamber

Fabric	Material	Weave	Warp		Weft		$t_{s \text{ warp,weft}}$
			$\rho$ , $\text{G}\Omega\cdot\text{cm}$	CV %	$\rho$ , $\text{G}\Omega\cdot\text{cm}$	CV %	
Sample 1	Cotton	Plain	0.200	15.0	0.464	12.1	9.24
Sample 2		Twill 2/2	0.453	12.4	0.616	17.1	3.07
Sample 3		Satin	0.356	11.4	0.502	15.9	3.67
Sample 4	Cotton/PES	Plain	31.9	9.72	1.40	10.5	22.0
Sample 5		Twill 3/1	0.945	10.1	1.71	9.14	9.33
Sample 6		Basket 2/2	0.715	16.5	1.03	12.1	4.10

PES fibres which are, compared to the cotton fibres, characterized by high values of volume resistance<sup>14,15</sup>. The influence of PES component is particularly observed in Sample 4 and Sample 6. Sample 4 was made from PES warp threads and cotton/PES blend weft yarns, while Sample 6 with cotton/PES blend yarns for both warp and weft has the highest percentage of cotton content among three woven mixtures. The resistance of the samples, obtained from blends of fibres, is mostly dictated by less electrical resistance component, in this case of cotton, which takes upon itself transfer of greater part of directional movement of charge<sup>13,28</sup>. This is the reason why Sample 6 exhibits the lowest value of volume resistivity among three woven mixtures studied as well as why Sample 4 has lower value of volume resistivity in weft direction.

Cotton fabrics made of plain and satin weave have lower value of volume resistivity in relation to the twill 2/2 weave fabric. This may be due to the fact that twill fabric is made of folded yarns both in warp and weft directions. The electric flow in folded yarns can be disturbed because the close contact between the adjacent fibres may be lost. For this reason the number of electrical conduction path for electrons comes down and this fabric (Sample 2) shows higher values of volume resistivities compared to Samples 1 and 3 (made of single yarns), where exists better contact between fibres and easier flow of charge<sup>29,30</sup>.

Some differences in volume resistivities may be observed between warp and weft direction measurements of woven fabrics of the same material composition. Smaller volume resistivities in the warp direction, as compared to that in weft direction, could be due to the greater number of parallel threads able to conduct current. It has been noted that volume resistivities of all investigated samples in warp direction are significantly different from those in weft direction at the level of significance of 0.05 (Table 2).

Air humidity influences the volume resistivity of the woven fabric, as can be seen for plain woven fabrics (Sample 1 and Sample 4) (Fig. 4). With the decrease in air humidity in the chamber, the volume resistivity of the tested fabric increases. Owing to higher velocity of moisture desorption of PES than that of cotton<sup>31</sup>, change in volume resistivity is found to be greater in warp direction with the decrease of relative humidity. This observation is valid for Sample 4. In other samples studied, the same

depending trend concerning volume resistivity increasing and air humidity decreasing is observed, such as registered for Sample 1 and Sample 4 in weft direction (Fig. 4).

Values of effective relative dielectric permeability of clothing fabrics determined at relative humidities of 40 % and 80 % in the chamber are presented in Fig. 5. Since fabrics can be considered heterogenic three - phase system composed of fibre - air -

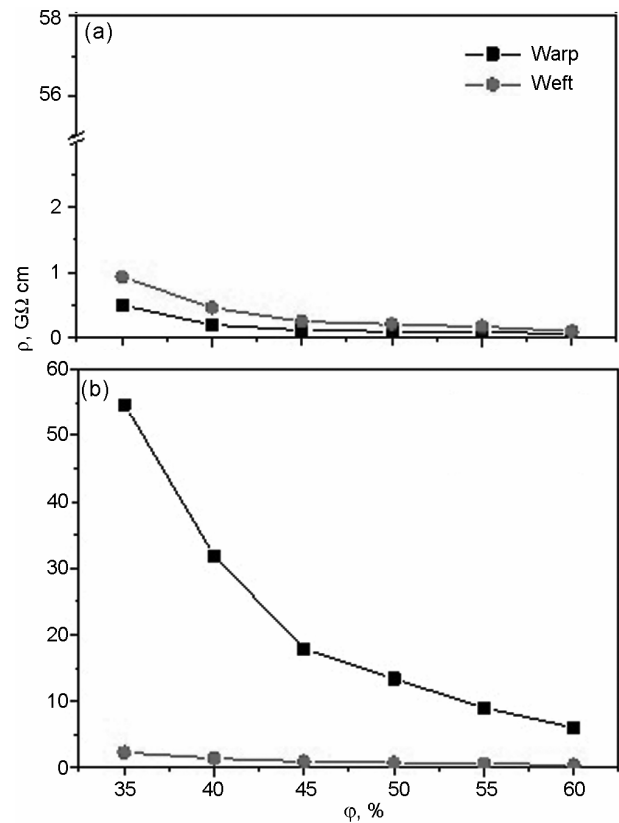


Fig. 4 – Volume resistivity of plain weave fabrics at various air humidities in the chamber, (a) Sample 1, and (b) Sample 4

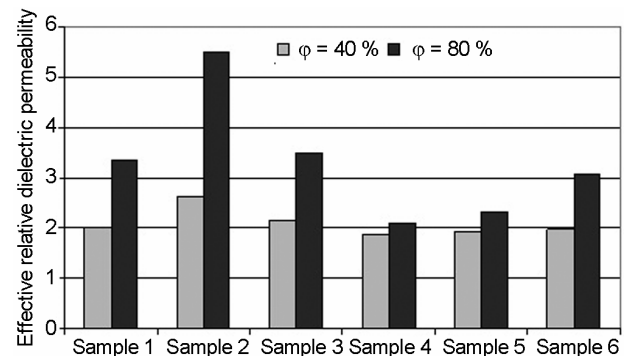


Fig. 5 – Influence of relative humidity on effective relative dielectric permeability of woven fabrics

moisture<sup>24</sup>, relative dielectric permeability values are gross values of the mixture.

Figure 5 shows that the increase in relative air humidity leads to an increase in effective relative dielectric permeability of fabrics, which can be attributed to the fact that room temperature water has much higher value of dielectric permeability ( $\epsilon_r = 81$ ), as compared to the textile material. Also, cotton/PES blend fabrics, compared to cotton woven samples, show lower values of effective relative dielectric permeability at both values of relative humidity as well as less change in the observed parameter with an increase in air humidity. The influence of increase in relative humidity on effective relative dielectric permeability of the sample with higher content of PES component in a blend (Sample 4 compared to Samples 5 and 6) is less pronounced. The absence of polar functional groups in PES fibres, capable of forming hydrogen bonds with molecules of water<sup>32</sup>, causes the minimal moisture absorption by the PES fibres<sup>33</sup>, which is reflected by the minor change in effective relative dielectric permeability.

**3.2 Air Permeability and Porosity**

Table 3 shows that the highest air permeability is attributed to the plain weave cotton/PES blend fabric (Sample 4), while the lowest air permeability is recorded for 3/1 twill weave cotton/PES blend fabric (Sample 5). Sample 4 is made of fine yarns, especially warp yarns, with the lowest coefficient of fineness as compared to other fabrics ( $C_F = 0.39$ ). Also, this fabric has a lower density (density ratio  $C_g=1.42$ ) compared to Sample 5, whose density ratio ( $C_g = 2.03$ ) is the highest among all fabrics. A finer

yarn and lower fabric density means increasing the space between the yarns (macropores) and thus the air permeability of fabric. In other words, values of air permeability are consistent with the values of porosity. The higher the value of porosity of the fabric, the higher is the value of air permeability and vice versa. Regression analysis shows a strong linear correlative relationship between the air permeability and the porosity of woven fabrics with very high coefficient of linear correlation ( $r = 0.9807$ ).

**3.3 Compression Properties**

One of the very important parameters of the sensorial comfort of textile materials is the ability to alter their thickness at relatively low compression loads. Within the proposed mechanical model of compression, de Jong observed the woven fabrics as a three-layered structure. Middle or inner part is relatively incompressible dense core which consists of small amount of air and fibre bundles organized in the yarns. Fibres that protrude from the surface of woven or knitted fabric along with plenty of air form the two outer layers, which are compared with the inner layer to a considerable extent subject to compression<sup>7,34</sup>.

Compression characteristics of woven fabrics estimated through the value of their compressibility ( $C$ ), the compression work ( $W_C$ ), the compression work recovery ( $W'_C$ ) as well as compressive resilience ( $RC$ ), are shown in Table 4.

Table 4 shows that the greatest value of compressibility ( $C$ ) among cotton fabrics is recorded for satin weave fabric which is due to its greater softness in relation to plain and twill 2/2 weave fabrics. Satin weave fabric has a less compact structure with clearly defined binding points which do not touch each other as well as interlacing points arranged so as to allow the great length floating threads to slip and move much easier in relation to plain and 2/2 twill weave fabrics. In addition, satin weave fabric has more distinct hairiness of the surface (Sample 3, Fig. 1). The influence of hairiness on the fabric surface is in agreement with the explanations as reported earlier<sup>7</sup>, according to which the sample with

Table 3 — Air permeability and porosity of woven fabrics

Fabric	$R, \text{mm}\cdot\text{s}^{-1}$	CV %	$P, \%$
Sample 1	733.4	4.90	26.7
Sample 2	66.80	5.20	4.41
Sample 3	204.6	3.29	10.5
Sample 4	1009	2.49	29.8
Sample 5	64.39	3.08	2.22
Sample 6	142.9	11.5	9.81

Table 4 — Compression characteristics of woven fabrics

Fabric	$C, \%$	CV %	$W_C, \text{cN}\cdot\text{cm}\cdot\text{cm}^{-2}$	CV %	$W'_C, \text{cN}\cdot\text{cm}\cdot\text{cm}^{-2}$	CV %	$RC, \%$	CV %
Sample 1	12.2	7.15	1.99	5.98	0.702	8.46	35.4	8.93
Sample 2	11.9	8.68	3.49	9.18	1.44	9.25	41.3	5.09
Sample 3	16.6	5.60	3.40	7.31	1.27	8.69	37.2	6.22
Sample 4	13.9	14.4	1.33	15.2	0.569	15.6	42.6	6.53
Sample 5	13.2	8.34	1.95	8.23	0.821	7.75	42.1	6.62
Sample 6	12.1	8.53	2.92	5.53	1.22	5.44	42.0	5.28

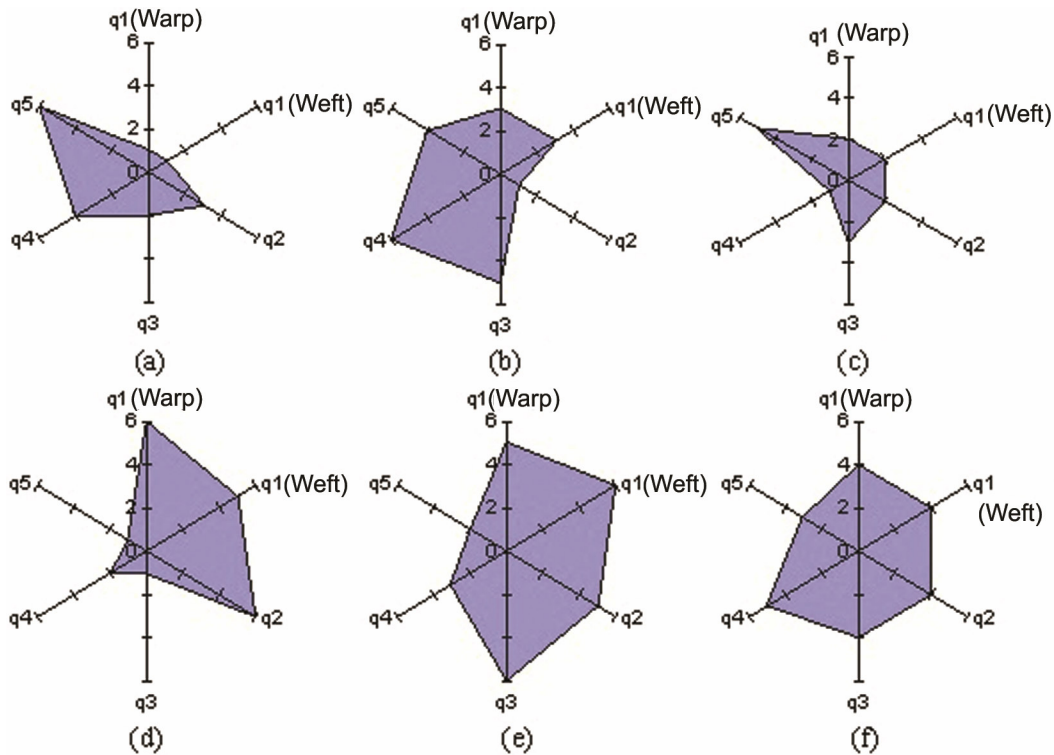


Fig. 6 – Grades of investigated characteristics (a) Sample 1, (b) Sample 2, (c) Sample 3, (d) Sample 4, (e) Sample 5, and (f) Sample 6 [q<sub>1</sub> – grade of volume resistivity, q<sub>2</sub> – grade of effective relative dielectric permeability, q<sub>3</sub> – grade of air permeability, q<sub>4</sub> – grade of compressibility and q<sub>5</sub> – grade of compressive resilience]

more pronounced hairiness on the surface will be softer, i.e. it will have higher compressibility. Statistical analysis using *t*-test shows a statistically significant difference between the compressibility of some samples ( $t_{s\ 1,3} = 7.73$  and  $t_{s\ 2,3} = 7.57$ ) at the level of significance of 0.05.

Concerning fabrics that have been obtained from cotton/PES blends, there is no significant difference in compressibility among Samples 4 - 6, which is confirmed by statistical analysis at the level of significance of 0.05. However, plain weave fabric (Sample 4) exhibits slightly higher compressibility than twill and basket weave fabric. This can be explained by the largest percentage share of PES fibres in a given blend which is characterized by good elasticity as well as the lowest value of fabric thickness<sup>25</sup>.

The elastic recovery of woven fabric is of great importance for the preservation of material softness during its exploitation. Observing the results of compressive resilience (*RC*) of cotton woven fabrics (Samples 1 - 3) as shown in Table 4, it is possible to notice that twill 2/2 weave fabric has a higher value of compressive resilience in regard to plain and satin

weave fabric. This indicates its better recovery after the cessation of the compression load<sup>35</sup>. Based on statistical analysis using *t*-test, a statistically significant difference is observed between the compressive resilience values  $t_{s\ 1,2} = 3.46$  and  $t_{s\ 2,3} = 2.90$  at the level of significance of 0.05. Compared to cotton fabrics, statistically significant difference is not found between the values of compressive resilience of cotton/PES blend woven fabrics at the level of significance of 0.05. Also, Table 4 indicates that the Samples 4 - 6 have better recovery after compression compared to Samples 1 - 3, which can be explained by the presence of PES component with good elasticity<sup>25</sup>.

### 3.4 Comfort Quality

Grades of investigated characteristics are presented through radar diagram (Fig. 6). Smaller surface on the diagram indicates better comfort quality of the fabric.

Average value of grades for each fabric was used for establishing rank order of the tested clothing fabrics (Table 5). Aimed at determining whether a group of cotton fabrics or cotton/PES blend fabrics has better quality in terms of investigated comfort properties, the grade and the rank of each group was calculated and presented in Table 5.



Table 5 — Rank order of woven fabrics

Fabric	Average value of grades	Rank of fabric	Grade of group of fabrics	Rank of group of fabrics
Sample 1	2.83	II		
Sample 2	3.67	IV	3.0	I
Sample 3	2.50	I		
Sample 4	3.50	III		
Sample 5	4.50	VI	4.0	II
Sample 6	4.00	V		

Table 5 shows that the rank of fabrics decreases according to the following sequence: Sample 3 > Sample 1 > Sample 4 > Sample 2 > Sample 6 > Sample 5. In other words, cotton woven fabric in satin weave (Sample 3) shows the best characteristics of comfort, followed by cotton plain weave fabric (Sample 1), while the worst characteristics of comfort is observed for Sample 5 made of cotton/PES blend in 3/1 twill weave. Obtained results also show that cotton fabrics with the grade '3' have better comfort quality in regard to the group of cotton/PES blend fabrics with the grade '4'.

#### 4 Conclusion

Findings of the study show that the cotton fabrics are characterized by lower values of the volume resistivity as compared to fabrics that have been produced from cotton/PES fibre blends. Also, it is found that the volume resistivity increases with the decrease in humidity, that can be ascribed to decrease in the moisture content of the textile samples. The effective relative dielectric permeability increases with the increase in relative humidity, hence woven fabrics with the highest moisture contents generally have the highest values of effective relative dielectric permeability.

The results show that the air permeability depends on the porosity of fabrics with very high coefficient of linear correlation (0.9807) between the air permeability and the porosity. Concerning compression properties, cotton fabrics exhibit better compressibility but worse compressive resilience compared to cotton/PES fabrics. Besides, it has been noticed that all investigated comfort properties of woven fabrics are determined by the raw material composition, type of weave as well as fabrics surface condition.

Application of ranking method indicates the fact that the cotton woven fabric in satin weave has the best comfort properties and cotton/PES woven fabric in twill 3/1 weave has the poorest. Also, the group of

cotton fabrics has better characteristics of comfort in regard to the group of cotton/PES blend fabrics. Studying the relationship between fabric structure and clothing comfort as well as variation in parameters of fabric's structure enables to obtain a woven material as per the demand of textile market in terms of required comfort properties.

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