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SEERSUCKER WOVEN FABRICS – EXCELLENT MATERIAL FOR COMFORTABLE CLOTHING

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ABSTRACT

Seersucker woven fabrics are characterized by a unique three-dimensional (3D) structure determining their properties, functionality and possibility of measurement. Especially, the comfort-related properties of the seersucker woven fabrics are strongly affected by their structure. Measurement of seersucker woven fabrics needs some modification of methods usually applied in measurement of standard woven fabrics and sometimes, an elaboration of procedure of laboratory sample preparation. The paper provides information concerning the unique structure of the seersucker woven fabrics, an influence of a kind of weft yarn on the fabric properties, measurements of their comfort-related properties such as thermal resistance, thermal absorptivity, water-vapor resistance and liquid moisture transport. The measurements were performed by means of such instruments as: Alambeta, Permetets, Moisture Management Tester. A surface geometry is also a very important feature of the seersucker woven fabrics. Due to the presence of puckered stripes in the warp direction, the topography of the seersucker fabrics is specifically structured, especially in the puckered area. The surface geometry of fabrics was measured using the optical method with a MicroSpy® Profile profilometer. The paper presents and explains some selected surface geometry characteristics important from the point of view of sensorial comfort of clothing usage.

KEYWORDS: Comfort; Measurement; Seersucker Fabrics; Structure; Topography.

2. INTRODUCTION

The basic – primary functions of clothing are the following: protective, aesthetic and organizational. Depending on the function, purpose and conditions of usage, clothing should be characterized by an adequate set of functional features. The properties and functionality of clothing can be shaped through appropriate cut, technology of manufacturing and, above all, selection of appropriate materials and clothing accessories. The seersucker woven fabrics are characterized by a unique structure and properties, especially those related to comfort, which makes them an excellent clothing material allowing the production of clothes that are both interesting in terms of design and at the same time functional. The paper presents shortly the basic structural and comfort-related properties of seersucker woven fabrics to show their potential for use in clothing applications.

3. LITERATURE REVIEW

The seersucker woven fabrics are a specific type of fabrics with a characteristically shaped surface. These fabrics feature alternating smooth stripes and convex-concave stripes, called puckered stripes, in the warp direction (Fig. 1).

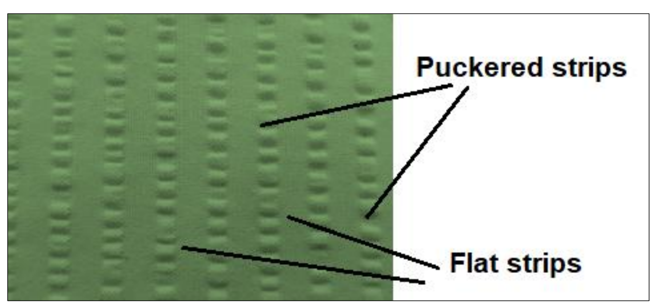


Figure 1. Example seersucker woven fabric

The seersucker woven fabrics are classified as fabrics with a relief (Matusiak, 2020; Matusiak and Frączczak, 2021; Szosland, 2007). The seersucker (puckered) effect, can be achieved using various methods: weaving, finishing, and thermal (Szosland, 2007;

Wilk, 1997). The most common method is the weaving method. This is a mechanical method in which the seersucker effect is achieved directly on the loom during the weaving process. This method allows for four ways of achieving zonal variation in fabric structure:

- varying the number of warp threads in the zones forming the base and puckered areas of fabric,
- varying the linear density of the base and puckering warp threads,
- varying the weave patterns in the base and puckered fabric zones,
- varying all the above-mentioned fabric structural elements (Wilk, 1997).

The finishing method involves embossing patterns onto the fabric surface using shaped rollers under appropriate conditions (chemical and thermal action), and then fixing them. In the thermal method, yarns with varying degrees of shrinkage under temperature are used to create seersucker fabric. Depending on the direction of high-shrinkage yarns, the seersucker effect can be achieved in the warp, weft, or both directions. (Wilk, 1997).

The seersucker woven fabrics are classified as 3D (three-dimensional) or 2.5D fabrics, sometimes referred to as 2D+. This is because their thickness is significantly greater than that of standard 2D (two-dimensional) fabrics and cannot be ignored (Matusiak, 2020; Matusiak and Frączczak, 2021). This surface structure of seersucker woven fabrics influences their appearance and also properties both mechanical and comfort-related.

Studies on the seersucker woven fabrics have confirmed that their structure, and especially the puckered stripe repeat (defined by the width of the puckered stripes and the distance between these stripes), influences the following biophysical properties of the fabrics: thermal conductivity, thermal resistance, thermal absorptivity, water-vapor resistance, and liquid moisture transport (Matusiak, 2020; Matusiak and Frączczak 2017). It has also been shown that the puckered stripe repeat and the linear density of the weft yarn influence the following mechanical properties of seersucker woven fabrics: maximum breaking force and elongation at maximum breaking force (Matusiak and Frączczak, 2016; Matusiak et al., 2019), bending stiffness, drapeability (Matusiak, 2021), and the coefficient of friction (Fracczak and Matusiak, 2017). Matusiak and Bajzik (Matusiak and Bajzik, 2021) conducted surface roughness tests on seersucker woven fabrics using the KES-FB4 device. They determined the surface roughness separately along smooth and rough stripes. They demonstrated that the puckered stripe pattern affects the surface roughness value and there are certain limitations to the use of the KES-FB4 device for measuring the surface properties of such kind of fabrics. They concluded that measurements of the geometric structure of seersucker woven fabric surface should be performed using a non-contact method.

Matusiak and Frączczak conducted research on the surface topography of seersucker woven fabrics using three-dimensional laser scanning. They analyzed the cross-section lines along the puckered and flat stripes, determining, among other parameters, so-called total waviness profile height (Fracczak and Matusiak, 2017; Matusiak and Frączczak 2017).

Seersucker woven fabrics are very interesting textile materials in terms of appearance and properties, which is quite often used in clothing, especially intended for use in warm microclimates. Figures below present the women's blouse (Fig. 2) and men's shirt (Fig. 3) made of seersucker woven fabrics, from the current offers of well-known retail chains – spring/summer 2026 season collections.

Figure 2. Women’s blouse made of seersucker fabric

Figure 3. Man shirt made of seersucker woven fabric

Although the seersucker woven fabrics have been known and used for a long time, studies of their structure and properties are rarely published. This is because testing such fabrics using methods applied to standard flat textile materials requires certain modifications. It is not always possible to perform tests precisely according to the procedures described in the relevant standards. Detailed studies of the geometric surface structure of seersucker woven fabrics require the use of non-contact, usually optical methods, enabling an examination of the entire surface, not just profiles. These methods and the instruments used are expensive and, to date, rarely applied to textile materials.

The aim of presented work was to investigate the surface geometry and comfort-related properties of the sample seersucker woven fabrics made of cotton.

4. MATERIALS

Three variants of the seersucker woven fabrics were the objects of the investigations. They were the fabrics made of cotton yarns both in warp and weft directions. In order to obtain the seersucker effect using the weaving method, two warps with different tension were used on the loom: the basic warp which forms the background and the puckering warp (with higher tension) which creates the puckered stripes. The 20 tex x 2 cotton yarn was applied both in the basic and puckering warps. Different cotton yarns were applied in the weft: 20 tex x 2, 25 tex x 2 and 30 tex x 2. The width of puckered stripes was 4 mm, whereas the flat stripes – 8 mm. The basic structural parameters of the investigated seersucker woven fabrics are presented in Table 1.

Table 1. The basic structural parameters of the investigated seersucker woven fabrics

Parameter	Unit	Variant No. 1	Variant No. 2	Variant No. 3
Weft yarn	-	20 tex 2	25 tex x 2	30 tex x 2
Mass per square meter	g/m^2	221.9	253.0	262.6
Warp density	threads/cm	13.8	13.5	13.8
Weft density	threads/cm	12.0	11.6	10.8
Basic warp take-up	%	6.2	6.4	10.1
Puckered warp take-up	%	53.8	62.4	60.4
Weft take-up	%	14.7	15.8	13.5
Thickness	mm	1.38	1.40	1.46

The fabrics differ between each other in the values of the basic structural parameters. It is due to the fact that weft yarns are characterized by different linear density. It influences the structural parameters of the seersucker woven fabrics. The weft density in particular could not be the same in given fabric variants while weaving. Different linear density o weft yarn requires different weft density to ensure intense and stable seersucker effect.

5. METHODOLOGY

The fabrics were measured in the range of their comfort related properties by means of the Alambeta, Permetest and Moisture Management Tester (MMT). The Alambeta (Fig. 4) made by Sensora (Czech

Republic) is a two-plate instrument for measuring thermal properties of textile materials (Hes and Sluka 2005). It measures six thermal properties: thermal conductivity, thermal diffusivity, thermal absorptivity, thermal resistance, maximum heat flux density as well as the ratio of maximum and stationary heat flux density. Additionally it determines the thickness.

Figure 4. The Alambeta device

From the point of view of thermo-physiological comfort of clothing usage three parameters are the most important: thermal resistance, thermal absorptivity and thickness. Thermal resistance and thickness determine thermal insulation of fabric, or its ability to protect the wearer's body from excessive heat loss in cold microclimates. In warm microclimates, both properties determine the extent to which clothing made from a given material will protect the wearer's body from overheating. Thermal absorptivity determines whether a material feels cold or warm upon first contact with the human skin. The higher the thermal absorptivity value is, the cooler it feels to the touch.

The Permetest (Fig. 5), also made by Sensora (Czech Republic) measures thermal resistance, water-vapor resistance and relative water-vapor permeability (Hes et al., 2014). It is considered as a portable “skin model”. Both the Alambeta and Permetest are controlled by PC.

Figure 5. The Permetest device

The Moisture Management Tester m290 (Fig. 6) by SDL Atlas was also applied in measurement of the investigated seersucker woven fabrics.

Figure 6. Moisture Management Tester m290

The instrument determines ten parameters characterizing a transport of liquid moisture trough textile materials (Öner et al 2013; Çeven and Günaydin, 2018). There are parameters determined separately for the top (T) and bottom (B) surface of measured sample such as: wetting time (WTT and WTB), absorption rate (TAR and BAR), spreading speed (SST and SSB) and maximum wetted radius (MWRT, MWRB). Additionally, two calculative parameters are provided: accumulative one-way transport index (R) and Overall Moisture Management Capacity (OMMC). Both characterize the whole sample.

Analysis of the surface geometry was performed by means of the MicroSpy® Profile profilometer (Fig. 7) made by the FRT® the art of metrology™. The profilometer uses the principle of chromatic distance measurement by means of the FRT CWL (chromatic white-light) sensor. It is based on the patented method which utilizes a chromatic aberration of the optical lenses (FRT, 2016). The square-shaped samples with sides of 49 mm were tested. The data from the profilometer were processed using the Mark III software by the FRT the art of metrology™.

Figure 7. The MicroSpy® Profile profilometer

Results of measurement were analyzed using statistical tools such as analysis of variance (ANOVA) and post-hoc Tukey's test. It allowed to assess the statistical significance of differences observed between investigated fabric variants.

6. RESULTS AND DISCUSSION

6.1. Comfort-related properties

Table 2 presents the results of comfort-related properties of the investigated seersucker woven fabrics. There are presented the results from the Alambeta, Permetest and Moisture Management Tester (MMT). The MMT provides the values of ten parameters. In the Table 2 only the OMMC values are presented, because this parameter is calculated based on other parameters determined by MMT and allows for a comprehensive assessment of the fabric's ability to transport a liquid moisture.

Table 2. The comfort-related properties of the investigated seersucker woven fabrics

Parameter	**Unit**	**Method**	**Variant No. 1**	**Variant No. 2**	**Variant No. 3**
Thermal conductivity	$W\ m^{-1}K^{-1}\ 10^{-3}$	Alambeta	37.80	39.82	39.70
Thermal absorptivity	$Wm^{-2}\ s^{1/2}\ K^{-1}$	Alambeta	117.28	129.36	132.76
Thermal resistance	$W^{-1}\ Km^{2}\ 10^{-3}$	Alambeta	36.44	35.19	36.68
Water-vapor resistance	$m^{2}PaW^{-1}$	Permetest	4.53	5.30	5.37
Relative water-vapor resistance	%	Permetest	60.73	55.40	55.00
Overall Moisture Management Capacity	-	MMT	0.233	0.040	0.210

It is clearly seen that the comfort-related properties of the investigated variants of seersucker woven fabrics have different values dependably on the linear density of weft yarn. The highest thermal conductivity was stated for the variant No. 2 – with the 25 tex x 2 weft yarn, the lowest – for the variant with the 20 tex x 2 weft yarn (Fig. 8)

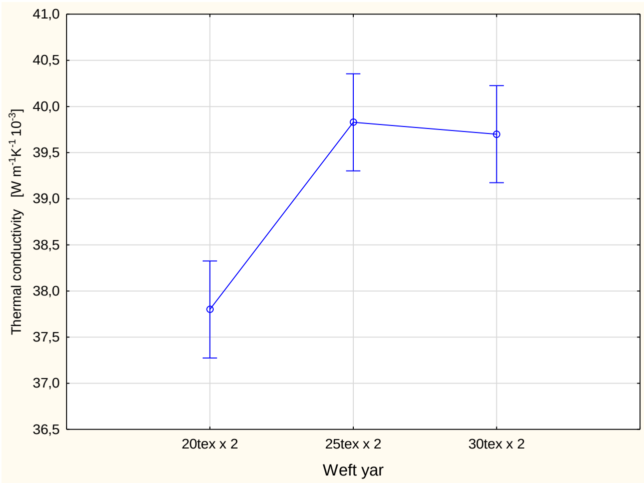


Figure 8. Thermal conductivity of investigated fabrics

In the case of thermal absorptivity the thicker weft yarn is, the greater thermal absorptivity, and in the same time the colder feeling in first contact with human skin (Fig. 9). Thermal resistance of all fabric variants is at the same level and it is high (Table 2). In comparison to the thermal resistance of standard (flat, 2D) cotton woven fabrics it is about 3 – 4 times greater. At the same time, the widespread use of seersucker fabrics in summer clothing is observed. This is only an apparent contradiction

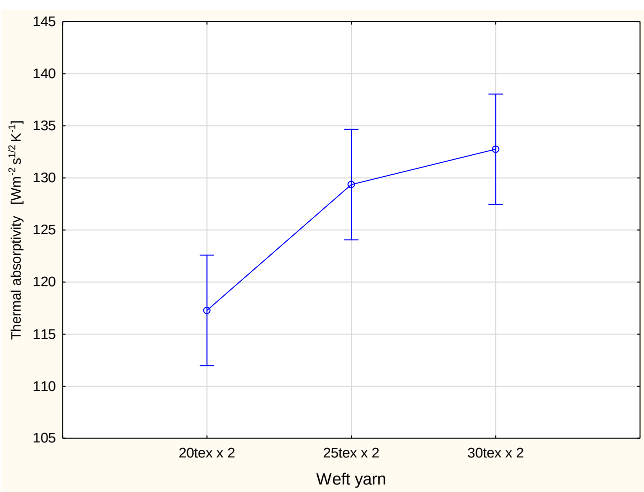


Figure 9. Thermal absorptivity of investigated fabrics

The Alambeta is a two-plate device in which the sample being measured is placed between two plates: a lower one at ambient temperature and an upper one with a temperature close to that of the human body. Due to the three-dimensional structure of seersucker woven fabrics, the sample's entire surface does not adhere to the instrument's plates. Convex areas in the puckered stripes create small, enclosed spaces filled with air between the instrument's plates and the upper and lower fabric surfaces (Fig. 10).

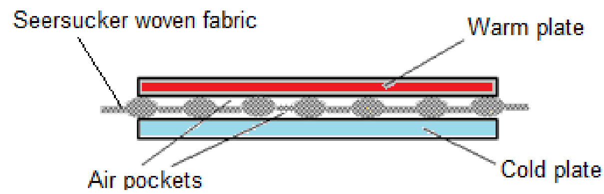


Figure 10. Scheme of measurement by means of the Alambeta

Air is a good thermal insulator, resulting in high thermal resistance recorded during measurement. However, during clothing usage, the structure of the seersucker woven fabrics plays an additional role. Due to the raised areas on the fabric surface, the clothing does not adhere tightly to the wearer's skin, thus ensuring skin ventilation. As the wearer moves, the bellows effect causes air to be expelled from the undergarment zone, thus releasing heat more quickly to the environment. This means that, despite the high thermal resistance determined instrumentally, clothing made of seersucker woven fabrics provides thermo-physiological comfort. This facilitated ventilation allows the undergarment zone to exchange air saturated with moisture and carbon dioxide released by the human skin for fresh, cooler air from the environment.

The parameters determined by the Permetest are used to evaluate textile materials in terms of their ability to wick away sweat vapor. Water-vapor resistance measures the resistance a material offers to water-vapor moving from the undergarment zone to the environment. The higher the water-vapor resistance, the lower the material's ability to wick away sweat in a form of vapor. However, relative water-vapor permeability has the opposite effect. The value of this parameter ranges from 0 % to 100 %. A value of 0% indicates complete lack of water-vapor permeability, while a value of 100% is recorded by Permetest during the test without a sample, meaning without a barrier limiting the flow of water-vapor. The higher the relative water-vapor permeability value, the better the wicking of sweat from the undergarment zone. A value above 50% indicates a material's good ability to provide thermo-physiological comfort.

In the case of the investigated fabrics all of them are characterized by relative water-vapor permeability greater than 50 % (Table 2). It means that they are good from the point of view of water-vapor release from the undergarment zone to the environment. The highest value of the relative water-vapor permeability was stated for the fabric variant with the 20 tex x 2 weft yarn, the lowest – for the fabric with the 30 tex x 2 weft yarn.

Statistical analysis by means of the one-way ANOVA confirmed that in the cases of the thermal conductivity, thermal absorptivity and relative water-vapor permeability the differences are statistically significant at the 0.05 significance level. Post-hoc analysis using Tukey's test showed that the statistically significant difference exists between the variant with the 20 tex x 2 weft yarn and both other variants. The differences between the variants with the 25 tex x 2 and 30 tex x 2 weft yarns are statistically insignificant in the case of all mentioned parameters. The ANOVA also confirmed that influence of a kind of weft yarn on thermal resistance and water-vapor resistance is statistically insignificant at the 0.05 significance level.

The value of the OMMC parameter can be in the range from 0 to 1. The higher value of the OMMC parameter is, the better ability of fabric to transport the liquid moisture. In the case of the investigated fabrics the values of the OMMC are rather low. They classify the fabric variant No. 1 and variant No. 3 into the grade 2 – poor according to classification of the MMT manufacturer (). The variant No. 2 was classified into the class 1 – very poor. It practically does not transfer the liquid water. Such results are caused by great density of the investigated seersucker fabrics. Additionally, it was stated that the puckered stripes significantly disturb the liquid movement into the fabric structure (Fig. 11).

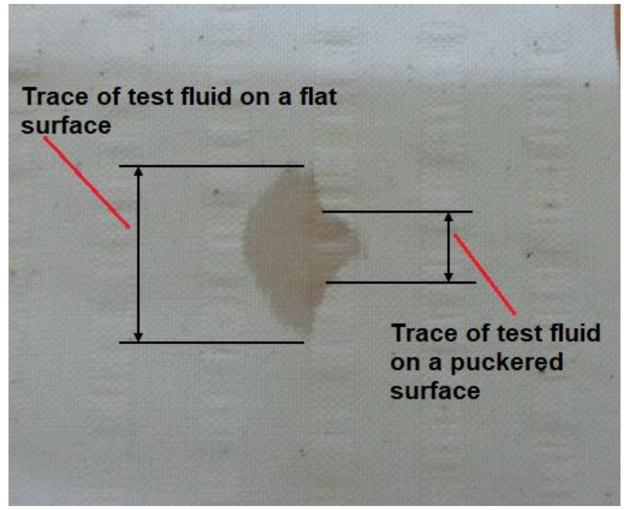
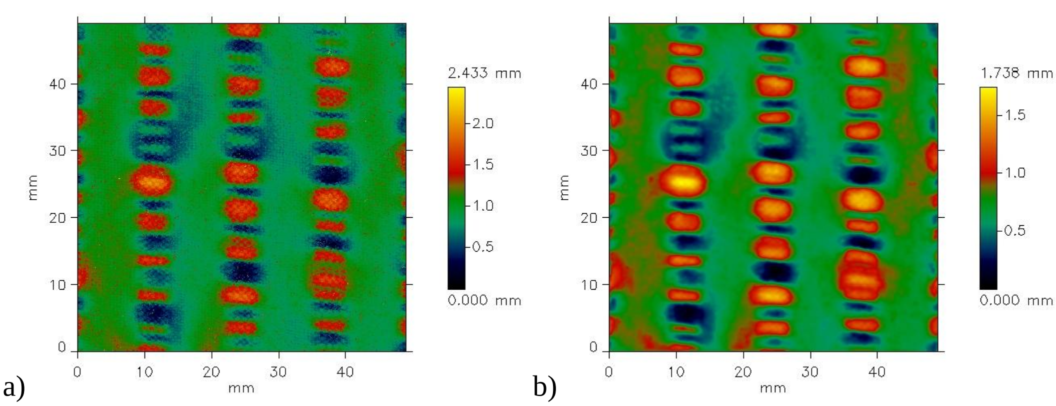
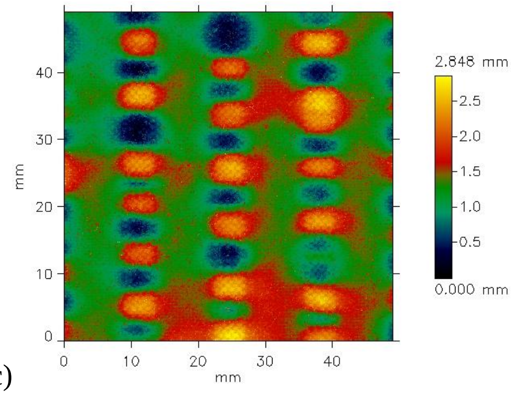


Figure 11. Comparison of liquid trace on the flat and puckered areas of seersucker woven fabric

6.2. Surface geometry of fabrics

The measurement of surface geometry was done by means of optical method using the MicroSpy® Profile profilometer. The fabric surface was tested in dimensions of 49 mm x 49 mm. Figure 12 presents the exemplary images of the investigated woven fabrics. On the right side of the surface images there is a color scale in which the color corresponds to the height of the points on the examined surface. The fabric images look very similar due to the fact that the puckered stripes' repeat (width of the puckered stripes and distance between the puckered strieps) is identical for all variants. However, differences occur in the shape of the puckered stripes and the distribution of point heights on the surface of individual fabrics.





c)

Figure 12. Example images of the seersucker woven fabric surface from the profilometer: a) variant No. 1, b) variant No. 2, c) variant No. 3

Fig. 13 presents the distribution of height of individual points on the measured surfaces. It is clearly seen that the distribution is different for different fabric variants. The histograms are characterized by two main parameters: the most frequent height and histogram maximum. The most frequent height was shaped accordingly:

- variant No. 1 – 0.811 mm,
- variant No. 2 – 1.012 mm,
- variant No. 3 – 1.187 mm.

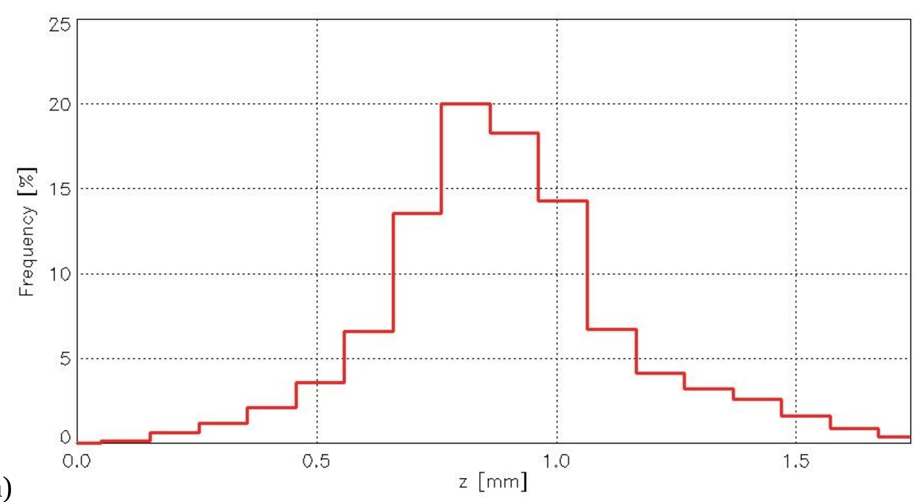
There is a clearly visible dependence of the most frequent height on the linear density of the weft yarn.

The histogram maximum was as follows:

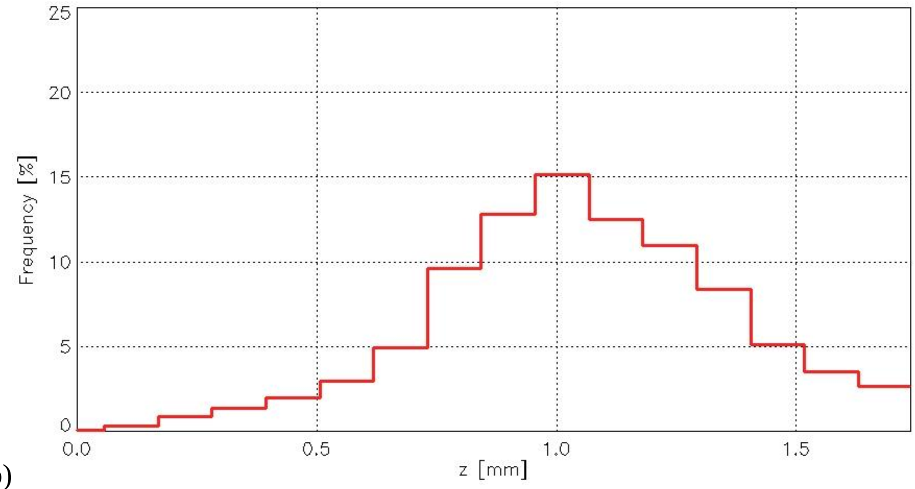
- variant No. 1 – 20.04 %,
- variant No. 2 – 15.15 %,
- variant No. 3 – 15.13 %.

The variant No. 1 has the highest value of the histogram maximum, variants No. 2 and No. 3 are very similar in terms of this parameter.

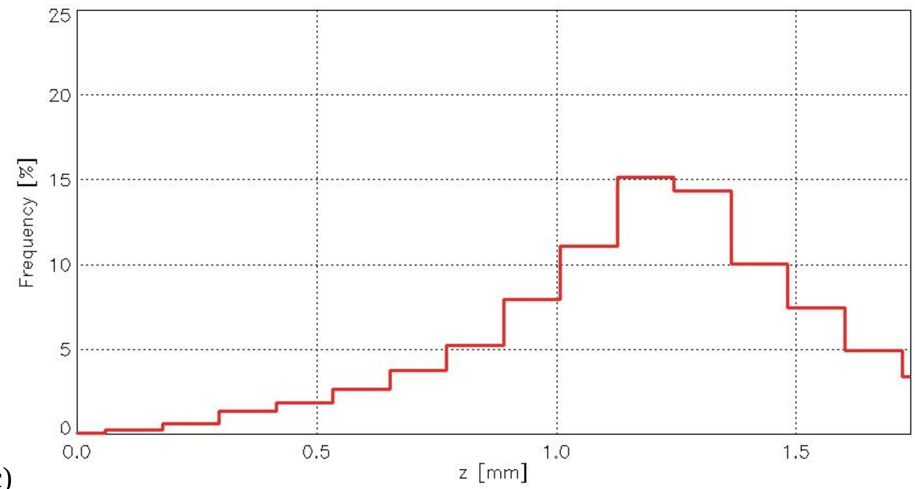
Figure 14 presents the example profiles created along the puckered stripes of each fabric variant. The profiles were created after elimination of roughness in order to show the shape of puckered stripes in particular fabric variants. Differences in the shape of the profiles concern both the distribution of convex and concave places as well as the maximum height of the profiles. In variant No. 1, there were 9 hills of different heights (Fig. 14 a) on the tested length of the profile, in the case of variant No. 2 there were 6 hills (Fig. 14 b), while in variant No. 3 there were only 5 hills (Fig. 14 c). Additionally, in the variant No. 3 the length and height of the wave is very regular, which was not found in the other two cases.



a)

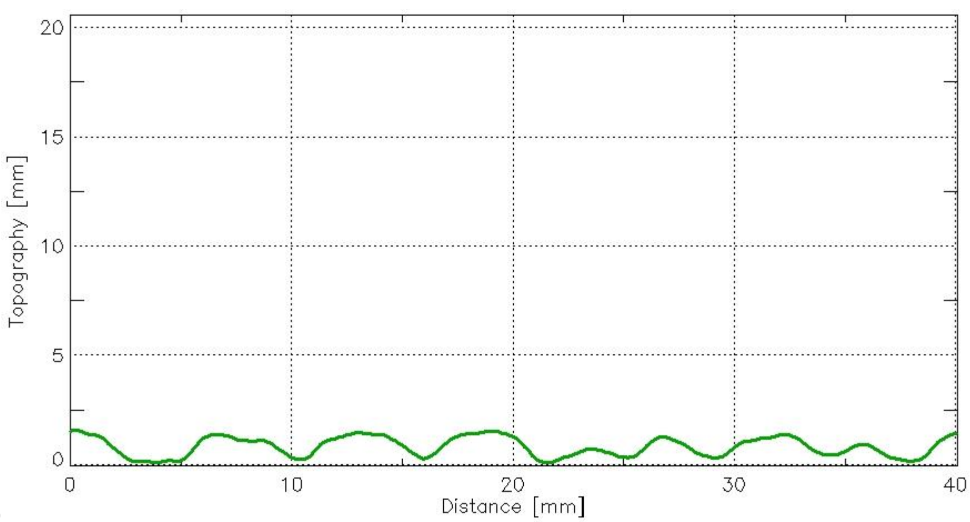


b)

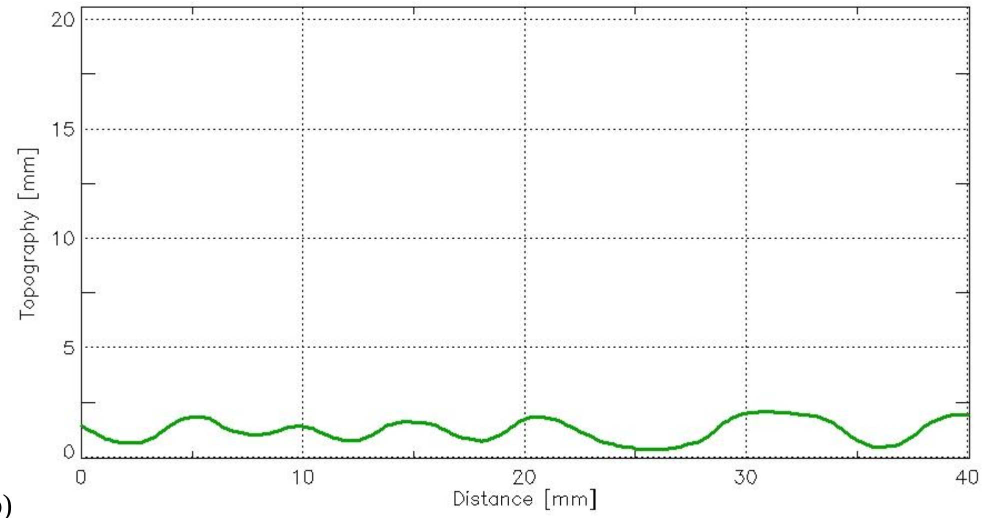


c)

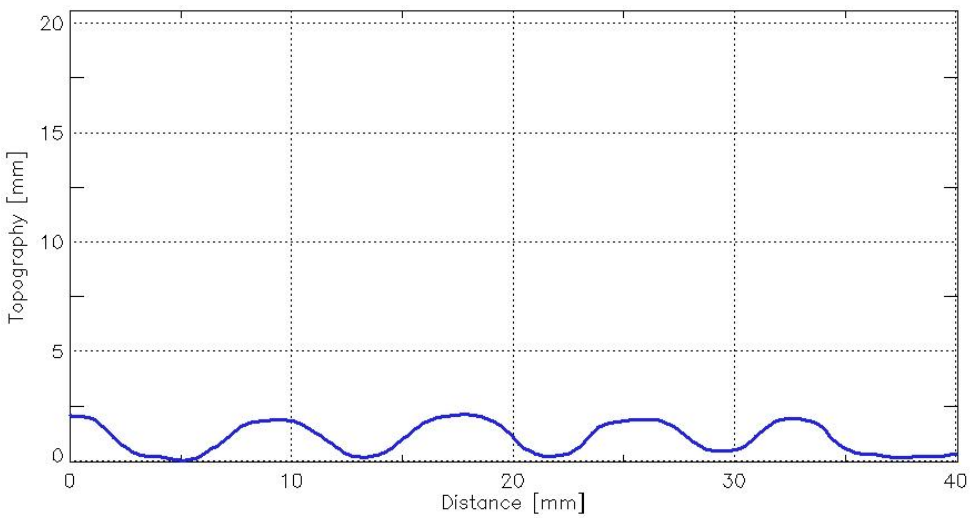
Figure 13. Example histograms of point height on the seersucker woven fabric surface: a) variant No. 1, b) variant No. 2, c) variant No. 3



a)



b)



c)

Figure 14. Example profiles along the puckered stripes on the seersucker woven fabric surface: a) variant No. 1, b) variant No. 2, c) variant No. 3

Figure 14 presents only the example profiles. They can be created anywhere on the puckered strip and along each strip on the tested surface. For each profile, parameters characterizing roughness and waviness are determined too. The article only shows sample charts for individual fabric variants. The in-depth analysis of the profile shape and its dependence on the weft yarn used or the profile location requires a separate publication. This is a very complex issue.

This article demonstrates that the seersucker woven fabrics, while visually very similar, can differ in their comfort-related properties. This variation results from the different shapes of the puckered stripes in warp direction caused by the use of different weft yarns.

7. CONCLUSION

The results of presented work confirmed that the comfort-related properties of seersucker woven fabric depend on the structure of fabrics, especially the shape of the puckered stripes occurring in the warp direction. The shape of the puckered stripes varies depending on the weft yarn used, while maintaining the same warp yarn and the same repeat of the seersucker effect. Measurement of the surface geometry by means of the non-contact optical method enables comprehensive examination of the surface structure of the seersucker woven fabrics. Especially, an ability to analyze the shape of the puckered stripes, which is the most important structural feature of these fabrics, is particularly valuable.

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