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# Investigation of 3D Woven Fabric Topography Using Laser-Scanning

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**Abstract**
*Among the different features of fabrics, surface properties play an important role, especially in the case of fabrics used near human skin. The effect of fabric on human skin in direct contact influences the sensorial comfort of clothing usage. The appropriate designing of woven fabrics from the point of view of their stiffness and surface properties can create new possibilities for their application. Particularly 3-dimensional woven fabrics of small-scale evenly distributed three-dimensionality can be applied in therapeutic clothing ensuring micro-massage. At the moment there is a lack of methods enabling the assessment of 3D woven fabrics with a textured surface from the point of view of the geometric structure of the surface. The paper presents preliminary investigations of the surface topography of 3D woven fabrics by means of a laser-scanner for precise 3D measurements.*

**Key words:** *woven fabrics, seersucker woven fabrics, surface properties, fabric topography, laser scanning.*

## Introduction

A basic common definition of 3D fabrics is that these types of fabrics have a third dimension in the thickness layer [1]. 3D fabrics can be manufactured using both knitting and weaving technologies. In the case of woven fabrics, there are several classifications based on the shedding mechanisms, weaving process, geometries and configurations of interlacements and the fibre axis [2]. 3D woven fabrics can be manufactured both with 2D and 3D weaving. Depending on the way of manufacturing, the surface properties of 3D woven fabrics can be different [3]. There are 3D fabrics with a smooth surface. Some kinds of spacer fabrics or two-layer woven fabrics can be included in this group. There are also 3D woven fabrics with a textured surface created from different elements, such as plisse or pleated fabrics, terry fabrics, velvet fabrics, seersucker fabrics, etc.

Seersucker woven fabrics can be achieved by an appropriate combination of warp yarns of different tension as well as by the application of weft yarns of different elasticity [4]. The puckered elements create the special topography of the fabric surface and influence the parameters of the fabric, especially the surface properties.

The special texture of 3D woven fabrics with puckered elements on their surface (***Figure 1***) leads to the greater roughness of fabrics and higher friction between the fabric and other surfaces.

The surface irregularity of flat textiles can be measured by means of contact and contactless techniques [5-11]. Generally the surface properties of fabrics are measured by the KES-FB 4 device. It is a module of the KES-FB (Kawabata Evaluation System for Fabrics) system developed for the complex evaluation of textile materials. By means of the KES FB 4 module, the following surface properties can be measured [5-8]:

- coefficient of friction (MIU),
- mean deviation of the coefficient of friction (MMD),
- geometrical roughness (SMD).

KES-FB4 belongs to the contact methods and measures the height variation. A similar approach is applied with a Shirley step thickness meter [5]. A profile of the fabric surface can be obtained using contactless techniques by means of the analysis of fabric images. Militky et al. [9] described the RCM system, allowing to obtain a set of fabric surface profile images. The high-resolution 3D surface profiling system TALYSURF CLI-500 is also a contactless method applied to investigate the topography of fibrous materials [12]. Mohri et al. [11] applied the image analysis technique using the radon transform (RT) and texture analysis in the assessment of fabric wrinkle. Objective results from the RT and texture analysis were compared with subjective ones from human experts. The study reveals a linear relationship between the RT as an objective evaluation and subjective evaluation.

The majority of research works carried out so far in the area of the surface properties of textile materials have focused on the development of new, precise methods of measurement of surface properties. In the case of surface roughness, the papers were mostly aimed at comparison of the results from contact and non-contact methods. Different attempts at image data processing have also been studied. Nevertheless on the basis of the data published, it can be stated that the investigations carried out so far concern mainly flat (2D) woven fabrics of basic and derivative weaves. Militky [11] successfully applied a special arrangement of a textile bend around a sharp edge combined with a CCD camera to characterise the surface of cord fabric with visible rows. However, the fabric investigated can be rather classified as 2D material. Calvimontes et al. investigated the surface topography of fabrics and its influence on fabric functionality [13]. They stated that the cut-off length ($L_m$), defined as the length of one side of the square sampling area, and res-

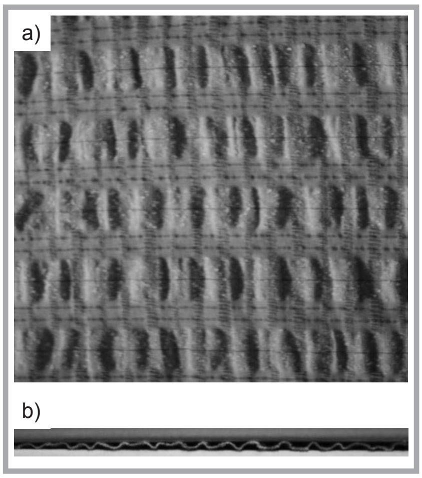


***Figure 1.*** *Convex surface of goffer fabric with elastomeric and fancy yarns [4]: a) surface image, b) profile of cross-section.*

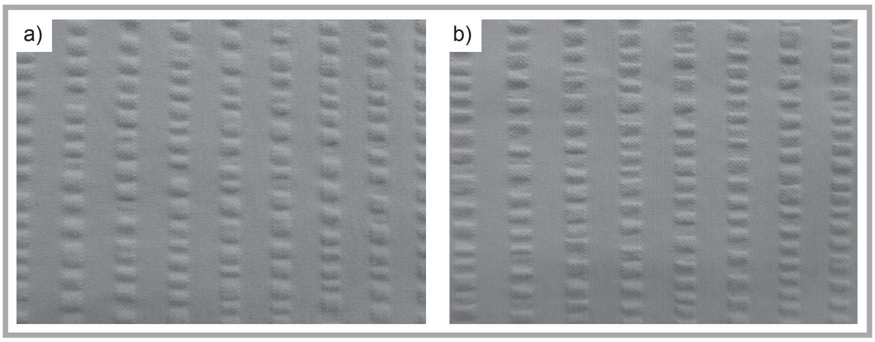


*Figure 2. Pictures of goffer fabrics investigated: a) sample I, b) sample II.*

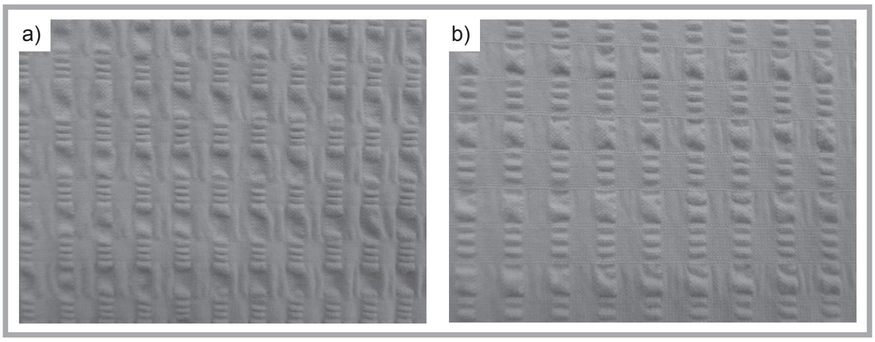


*Figure 3. Pictures of investigated goffer fabrics with elastomeric yarn in the weft: a) sample III, b) sample IV.*


*Figure 4. Romer CimCore Ininity 2 measuring arm with scanning head contour probe.*

olution are the most important sampling parameters which have to be optimally defined before characterising the fabric topography of fabrics. They analysed the parameter called the total height of the profile $W_z$ – one of the main parameters characterising surface irregularity. It is defined in the standard [14]. The total height of the profile $W_z$ means the height between the deepest valley and the highest peak inside each extracted sub-area of the sampling length on the evaluated line. It is determined as the sum of the height of the largest profile peak height and the largest profile valley depth within a sampling length [13-15].

*Table 1. Characteristic of woven fabrics applied in the experiment.*

| Parameter | Unit | Value | | | |
|---|---|---|---|---|---|
| | | Fabric I | Fabric II | Fabric III | Fabric IV |
| Raw material – warp I | – | CO | CO | CO | CO |
| Raw material – warp II | – | CO | CO | CO | CO |
| Raw material – weft I | – | CO | Dacron ThermoCool Fresh 156/94/2 (Conti Fibre, Italy) | CO | Dacron ThermoCool Fresh 156/94/2 (Conti Fibre, Italy) |
| Raw material – weft II | – | – | – | PU57/PES43 | PU57/PES43 |
| Warp I linear density | tex | 20 x 2 | 20 x 2 | 20 x 2 | 20 x 2 |
| Warp II linear density | tex | 20 x 2 | 20 x 2 | 20 x 2 | 20 x 2 |
| Weft I linear density | tex | 20 x 2 | 15.6 x 2 | 20 x 2 | 15.6 x 2 |
| Weft II linear density | tex | – | – | 37 | 37 |
| Weave – warp I | – | plain | plain | plain | plain |
| Weave – warp II | – | rep 2/2 | rep 2/2 | rep 2/2 | rep 2/2 |
| Warp density | $dm^{-1}$ | 278 | 284 | 341 | 359 |
| Weft density | $dm^{-1}$ | 221 | 290 | 269 | 264 |
| Mass per square meter | $gm^{-2}$ | 241 | 201 | 365 | 332 |
| Warp I take up | % | 5.12 | 1.85 | 6.55 | 6.73 |
| Warp II take up | % | 70.6 | 60.0 | 91.2 | 64.1 |
| Weft I take up | % | 13.7 | 15.9 | 38.2 | 44.7 |
| Weft II take up | % | – | – | 92.4 | 95.9 |
| Thickness | mm | 1.64 | 1.31 | 1.90 | 1.69 |

The aim of present work was to investigate the topography of 3D woven fabrics of small-scale anisotropic three-dimensionality using a laser-scanner for precise 3D measurements. Seersucker woven fabrics were the objects of the investigation.

## Materials and methods

The investigations presented are aimed at characterisation of the topography of seersucker woven fabrics, which belong to the group of 3D woven fabrics of small-scale evenly distributed three-dimensionality. Such a 3D structure of fabrics was achieved by an appropriate combination of warp and weft yarns. Four kinds of seersucker woven fabrics were the objects of the investigation, manufactured on an industrial loom – MAV 206 (Wifama, Poland) with two beams. All fabric variants were produced on the basis of the same warp and made of 20 x 2 tex cotton yarn. In samples I and II, two warps of different tension and one kind of weft yarn were applied, creating a typical goffer structure with puckered strips in the warp direction (***Figure 2***). In fabric samples III and IV, two warps of different tension were applied similarly to samples I and II. Additionally two kinds of yarns of different elasticity were used in the weft, which gave a seersucker effect in the weft direction (***Figure 3***).

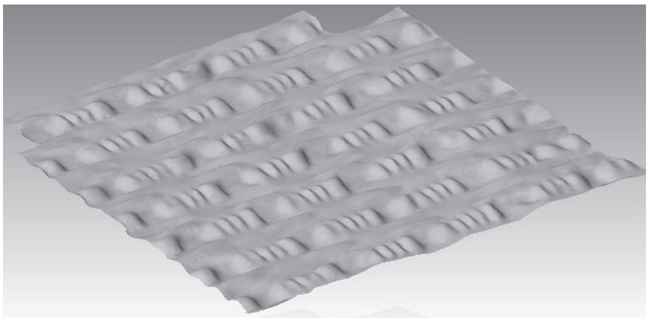

*Figure 5. Example of a picture of fabric III's surface obtained using laser scanning.*

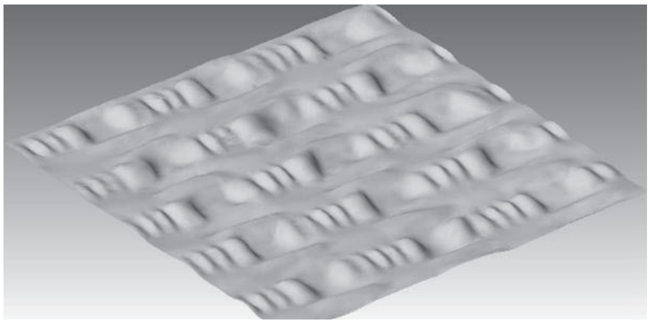

*Figure 6. Square of 50 mm side cut from the sample image (fabric III).*

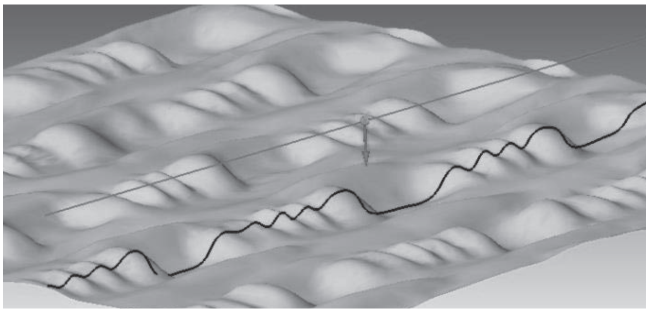

*Figure 7. Line created in the plane of fabric III.*

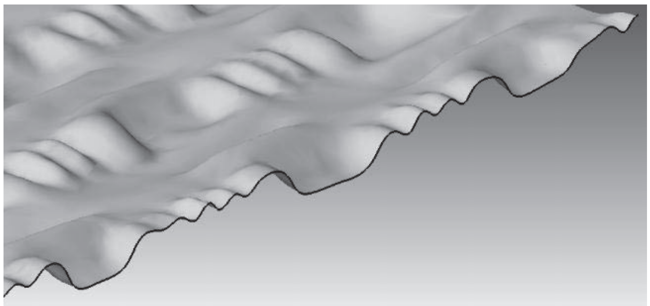

*Figure 8. Example of section of the seersucker woven fabric III.*

The basic structural parameters of the fabrics investigated are presented in ***Table 1***.

In the work presented, a Romer CimCore Ininity 2 (CimCrome Hexagon Metrology, US) measuring arm with a contour probe scanning head (***Figure 4***) was applied to assess the profile of the fabrics investigated.

The measuring set allows to scan the surface of fabrics with an accuracy of 0.02 mm. The measuring arm was placed on a granite table, on which further fabric samples were also placed. The samples were placed on the table in such a way as to provide their natural, smooth setting and to avoid their shifting, which would have falsified the results.

Before testing, the measuring head was calibrated at the following measurement parameters:

- scanning frequency – 30 Hz,
- number of measurement points in one scan – 640 points (19200 pts/ sec),
- width of scanning – 70 mm (distance between points 0.1 mm),
- scanning speed – ca. 10 mm/s (longitudinal distance of about 0.3 mm).

In order to avoid errors of scanning, the measuring head was kept so that the measuring laser beam was perpendicular to the fabric scanned. The surface of each sample was scanned four times: two times along the warp direction, scanning from the left to the right side, from the right side to the left, and next two times along the weft, scanning from the top to the bottom and opposite. In total, after scanning, a point cloud count of about 250 to 300 thousand points was obtained for each fabric sample. Then each point cloud was converted in Geomagic software (3D Systems, US) as follows:

- Removing the most protruding points from the average value in the population of points (in the surrounding area of 1 mm radius). The limit value for removing the protruding points was established at 0.05 mm.
- From the point clouds a surface consisting of triangles was created in such a way that each point in the cloud was a vertex (end point) of not less than one triangle and not more than three.
- Then the protruding vertices of the triangles were removed by moving them "into" or "out" of the fabric. The relocation value did not exceed 0.05 mm.
- On the basis of these triangles, the surface of the fabric measured was determined (***Figure 5***).

Created in such a way, the surface of the fabric was inputted into SolidEdge ST7 (Siemens, Germany) software. In the software a square with a side of 50 mm (***Figure 6***) was cut for each sample. Next a line parallel to the warp was created in the plane of the sample. The line was placed on one side of the sample surface. Then the line was projected on the surface of the fabric (***Figure 7***). It allows to measure particular fragments of the projected line. These measurements reflect the geometric parameters of the fabric in the place of cutting (***Figure 8***).

In order to avoid chance in the selection of the line placement created, a series of parallel lines spaced exactly every 1 mm was generated in such a way as to cover at least the full pattern repeat defined along the warp (***Figure 9***). Then a series of parallel lines spaced every 1 mm was created in the weft direction. Subsequently these lines were projected onto the surface of the fabric. The number of lines and their location were chosen in such a way as to cover the full pattern repeat defined along the weft.

Created in such a way, the projections of lines on the fabric surface contain full information about the geometry of the fabric surface under the line. This can be seen in ***Figure 8***, showing the edge of the fabric in the cross-section of the projected line. An example of an extracted line representing the edge of the fabric in the place of cutting by the surface

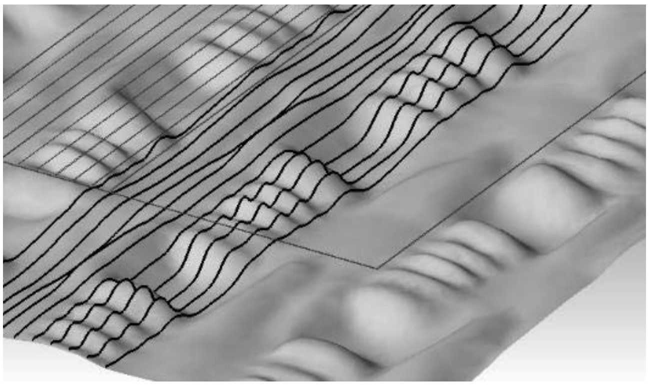

Figure 9. *Series of lines created in the warp direction of fabric III.*

***Figure 10.*** *Example of line extracted from the fabric image.*

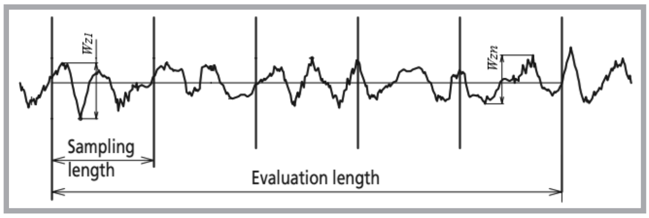


***Figure 11.*** *Exemplary division of the evaluation length into 5 sampling lengths.*

***Table 2.*** *Results of the determination of the total height of the profile for lines created in the warp directions of the fabrics investigated.*

| No. of line | $W_z$ in mm | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | Fabric I | | Fabric II | | Fabric III | | Fabric IV | |
| | Average | SD | Average | SD | Average | SD | Average | SD |
| 1 | 0.688 | 0.127 | 0.286 | 0.059 | 0.794 | 0.292 | 0.230 | 0.106 |
| 2 | 0.254 | 0.078 | 0.140 | 0.074 | 1.442 | 0.108 | 0.178 | 0.101 |
| 3 | 0.174 | 0.096 | 0.124 | 0.098 | 1.722 | 0.173 | 0.142 | 0.034 |
| 4 | 0.206 | 0.052 | 0.146 | 0.064 | 1.650 | 0.204 | 0.188 | 0.061 |
| 5 | 0.180 | 0.060 | 0.128 | 0.060 | 0.786 | 0.145 | 0.142 | 0.081 |
| 6 | 0.140 | 0.080 | 0.134 | 0.071 | 0.246 | 0.046 | 0.366 | 0.152 |
| 7 | 0.122 | 0.118 | 0.146 | 0.054 | 0.542 | 0.155 | 1.076 | 0.304 |
| 8 | 0.168 | 0.126 | 0.288 | 0.045 | 0.654 | 0.322 | 1.192 | 0.351 |
| 9 | 0.414 | 0.056 | 0.114 | 0.048 | 0.534 | 0.353 | 0.974 | 0.284 |
| 10 | 0.928 | 0.030 | 0.230 | 0.072 | 0.602 | 0.234 | 0.436 | 0.208 |
| 11 | 1.198 | 0.061 | 0.698 | 0.080 | 0.702 | 0.388 | 0.192 | 0.091 |
| 12 | 1.170 | 0.067 | 0.976 | 0.081 | – | – | 0.136 | 0.076 |
| 13 | 0.832 | 0.099 | 0.998 | 0.090 | – | – | – | – |
| 14 | 0.350 | 0.115 | 0.750 | 0.100 | – | – | – | – |
| Av. | 0.487 | | 0.368 | | 0.879 | | 0.438 | |
| SD | 0.395 | | 0.333 | | 0.493 | | 0.401 | |

***Table 3.*** *Results of the determination of the total height of the profile for lines created in the weft directions of the fabrics investigated.*

| No. of line | $W_z$ in mm | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | Fabric I | | Fabric II | | Fabric III | | Fabric IV | |
| | Average | SD | Average | SD | Average | SD | Average | SD |
| 1 | 0.382 | 0.121 | 0.424 | 0.114 | 0.440 | 0.032 | 0.254 | 0.142 |
| 2 | 0.454 | 0.177 | 0.426 | 0.181 | 0.322 | 0.129 | 0.532 | 0.241 |
| 3 | 0.638 | 0.216 | 0.216 | 0.043 | 0.944 | 0.253 | 0.646 | 0.182 |
| 4 | 0.600 | 0.203 | 0.372 | 0.171 | 1.148 | 0.347 | 0.696 | 0.095 |
| 5 | 0.302 | 0.139 | 0.378 | 0.141 | 1.172 | 0.382 | 0.696 | 0.229 |
| 6 | 0.430 | 0.185 | 0.418 | 0.056 | 1.322 | 0.248 | 0.806 | 0.080 |
| 7 | 0.264 | 0.126 | 0.338 | 0.092 | 1.364 | 0.194 | 0.602 | 0.305 |
| 8 | 0.646 | 0.162 | 0.348 | 0.166 | 1.242 | 0.185 | 0.468 | 0.149 |
| 9 | 0.382 | 0.167 | 0.360 | 0.161 | 1.310 | 0.189 | 0.244 | 0.068 |
| 10 | 0.310 | 0.244 | 0.416 | 0.144 | 1.310 | 0.249 | 0.236 | 0.055 |
| 11 | 0.512 | 0.135 | 0.372 | 0.228 | 0.926 | 0.188 | 0.384 | 0.100 |
| 12 | 0.518 | 0.220 | 0.294 | 0.186 | 0.714 | 0.113 | 0.452 | 0.189 |
| 13 | 0.482 | 0.191 | 0.366 | 0.049 | 0.704 | 0.164 | 0.386 | 0.077 |
| 14 | 0.554 | 0.115 | – | | 0.672 | 0.122 | 0.442 | 0.163 |
| Av. | 0.462 | | 0.364 | | 0.971 | | 0.489 | |
| SD | 0.124 | | 0.059 | | 0.349 | | 0.182 | |

perpendicular to the fabric is presented in ***Figure 10***.

Each projection of the line was divided into five sections of 10 mm in length. Next the total height of the profile $W_z$ [13, 14] was measured for each section (***Figure 11***). For each line the evaluation length was divided equally into 5 sampling lengths, and next the total height of the profile $W_z$ was determined for each sampling length.

A measurement was performed for each fabric in both directions: warp and weft. The software applied (the SolidEdge ST7) enables measurement with an accuracy of ± 0.01 mm. Next for each line the average total height of the profile was calculated as the arithmetic mean from the results of the measurement of 5 sampling lengths.

## Results and discussion

Results of the determination of the total height of the profile are presented in ***Tables 2*** and ***3***, containing the following:

- average values of parameter $W_z$ for each line created in both directions,
- average values for the warp and weft direction, calculated as the arithmetic mean from results obtained for all lines in the pattern repeat created in the given direction,
- standard deviation of the total height of the profile for each direction of the fabrics investigated.

On the basis of the results presented, it can be seen that the fabrics differ significantly from each other in the aspect of the total height of the profile in both directions and in the disperse of parameter $W_z$.

Sample No. I is a typical seersucker woven fabric, characterised by the exist-

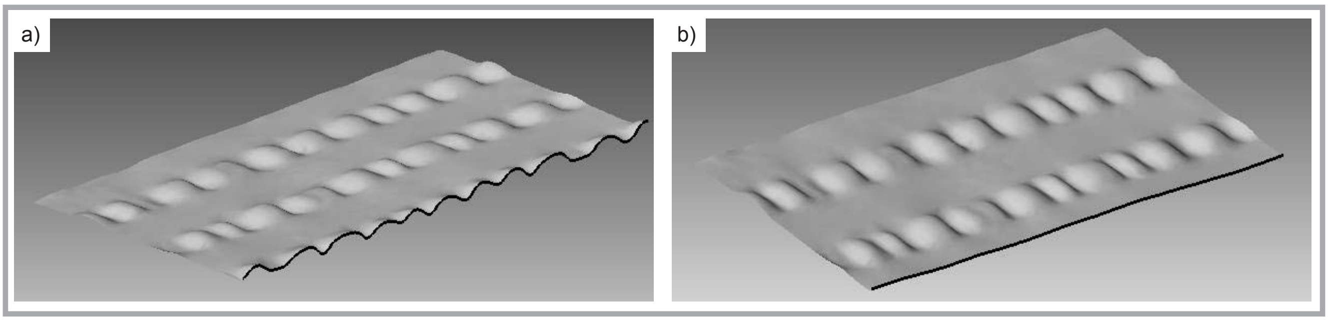


***Figure 12.*** *Edges of fabric I cut parallel to the warp: a) along the goffered strip, b) along the flat strip.*

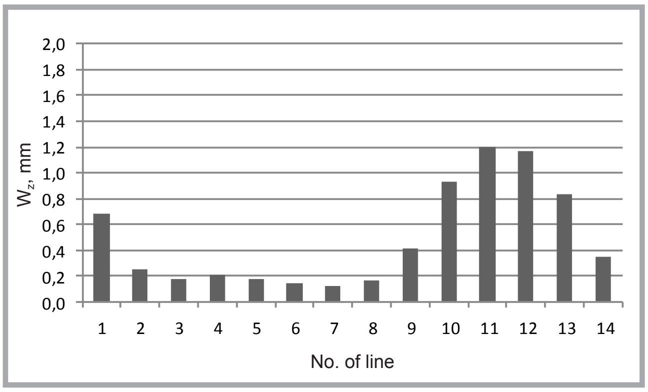


***Figure 13.*** *Average values of the total height of the profile ($W_z$) for the lines created parallel to the warp of fabric I.*

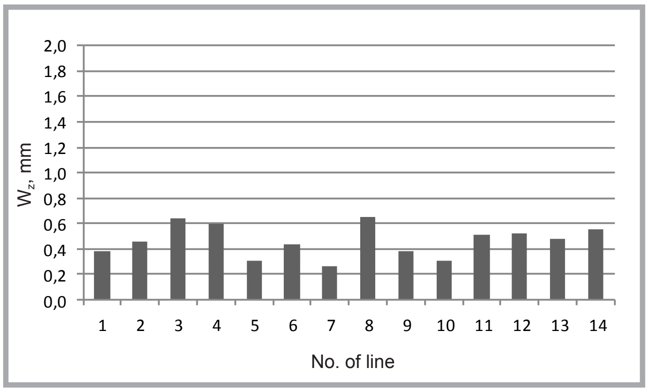


***Figure 14.*** *Average values of the total height of the profile ($W_z$) for the lines created parallel to the weft of fabric I.*

ence of two kinds of strips in the warp direction: basic flat strips and puckered strips (***Figure 2.a***). Due to this fact, the lines created parallel to the warp can be divided into two groups: lines along the flat strip and those along the puckered (goffered) strip.

***Figure 12*** presents the edges of fabric No. I created parallel to the warp both along the puckered strip (***Figure 12.a***) and flat strip (***Figure 12.b***). It is visible that the lines parallel to the warp from both groups are different in shape. Values of the total height of the profile $W_z$ are also different for both groups of lines.

The average values of parameter $W_z$ for 14 lines created parallel to the warp of sample I are presented in ***Figure 13***. It can be seen that there is a significant difference between the particular lines in the aspect of the average total height of the profile. Lines No. 10-13 correspond to the puckered strip. The lines created were every 1 mm; four lines were of 4 mm, corresponding to the width of the goffered strip – 4 mm. The average total height of the profile is in the range 0.8 mm – 1.2 mm. However, the value of parameter $W_z$ is different for each line created along the puckered strip of the fabric. The highest value of the total height of the profile was stated for the lines in the centre of the puckered strip, e.g. for lines No. 11 and No. 12.

Lines No. 2-8 correspond to the flat strip of the fabric. The total height of their profile is low, being at a similar level, and in the majority of cases it is lower than 0.2 mm. Lines No. 1, No. and No. 14 should be considered as the border lines between the puckered and flat strips. Their average values of the total height of the profile are between the values of this parameter obtained for the lines created along the flat strip and for those along the puckered strip.

In the weft direction we can observe a different situation. The lines created parallel to the weft are characterised by the average total height of the profile in the range from 0.26 mm to 0.65 mm (***Figue 14***).

The dispersion of $W_z$ values is lower than in the case of the lines parallel to the warp. However, values of the total height of the profile $W_z$ determined do not characterise the shape of the lines parallel to the weft in a sufficient way. According to the methodology described in the previous section, the sampling length is 10 mm, whereas the shape of the lines parallel to the weft changes every 8 mm and 4 mm according to the repeat of the flat and puckered warp strips (***Figure 15***).

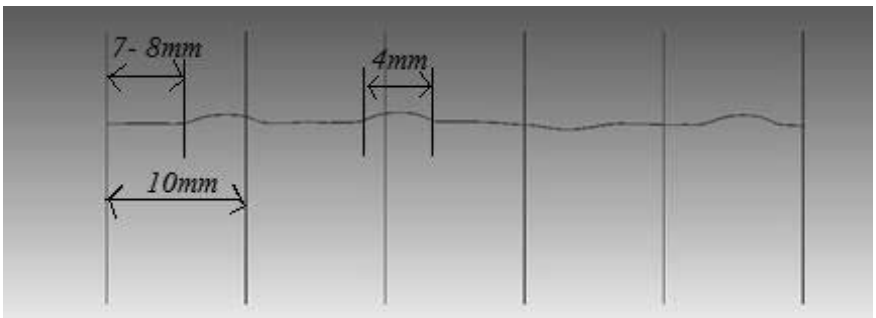


***Figure 15.*** *Line extracted in the weft direction of fabric I.*

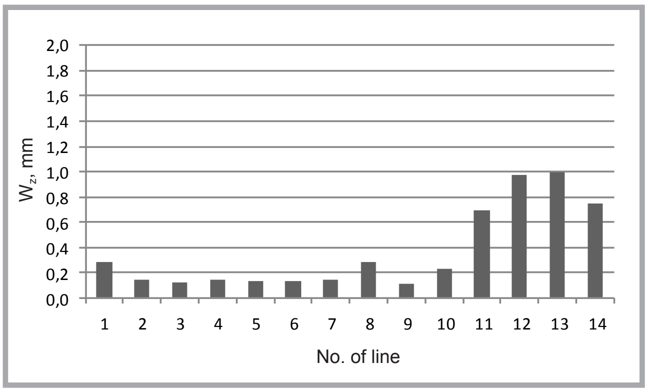


*Figure 16. Average values of the total height of the profile ($W_z$) for the lines created parallel to the warp of fabric II.*

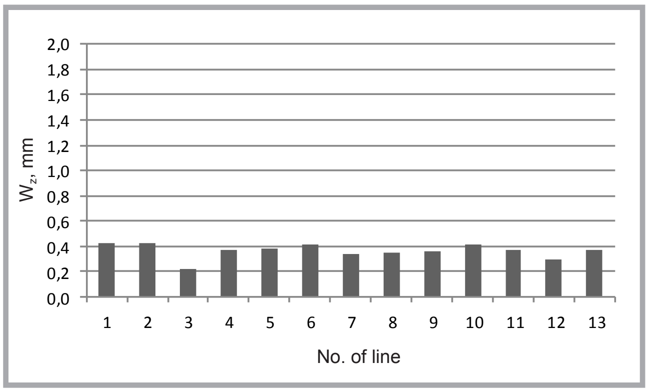


*Figure 17. Average values of the total height of the profile ($W_z$) for the lines created parallel to the weft of fabric II.*

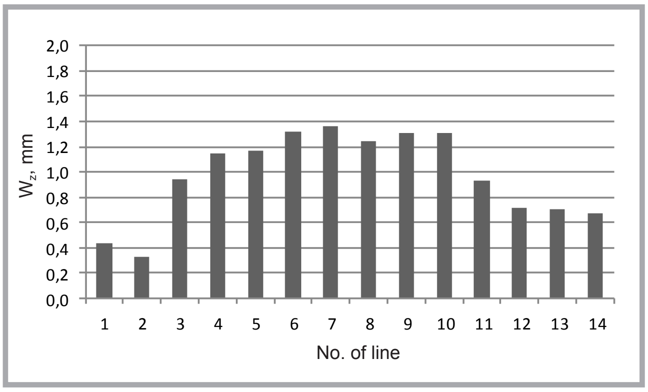


*Figure 18. Average values of the total height of the profile ($W_z$) for the lines created parallel to the warp of fabric III.*

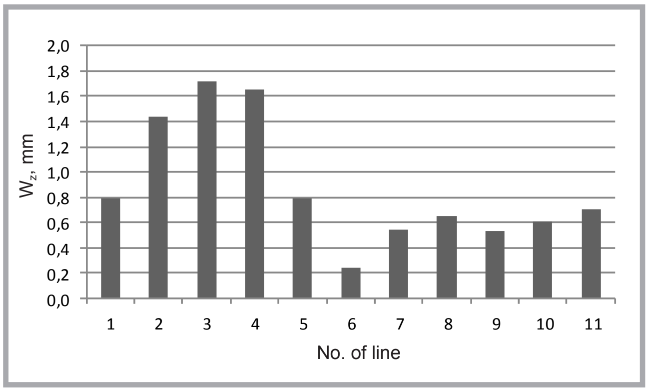


*Figure 19. Average values of the total height of the profile ($W_z$) for the lines created parallel to the weft of fabric III.*

This situation confirms that in the case of the patterned fabrics, for instance the seersucker woven fabrics, the sampling length is very important and should be adjusted according to the structure of the fabric, especially the repeat of the pattern. In the case of sample I, its structure is rather straight. The value of parameter $W_z$ of the lines parallel to the weft also approximately expresses the total height of the profile of the segments corresponding to the puckered warp strip. For more complicated structures of 3D patterned woven fabrics, the application of different sampling lengths depending on the repeat of the pattern may be a more suitable solution. However, in such a situation it is difficult to compare the results for fabrics of different patterns. Taking the above into consideration, in our opinion the elaboration of a procedure for determining the surface properties of 3D patterned fabrics is an open problem and needs further investigations.

Fabric sample No. II is also a seersucker woven fabric (***Figure 2.b***) and manufactured on the basis of the same warp set as fabric I. In the weft the fabric is created from filament yarn 15.6 x 2 tex PES yarn – Dacron ThermoCool Fresh 156/94/2. The application of thinner yarn made of polyester in the weft direction caused changes in the basic parameters of the fabric, especially the crimp of warp yarns, the mass per square meter, weft density and fabric thickness (***Table 1***).

The appearance of fabric II, especially the structure of puckered strips, is slightly different than that of fabric I (***Figure 2***). The values of the total height of the profile in both directions (***Figure 16***, ***17***) also confirm the difference between the structures of both seersucker fabrics: sample I and II.

Fabric II is characterised by lower values of the total height of the profile than fabric I. In the warp direction (***Figure 16***), the maximal value of parameter $W_z$ is 1 mm, whereas the lowest is 0.14 mm. In the weft direction (***Figure 17***), the total height of the profile is at a similar level for all lines created, and it is lower than the value of the parameter noted in the weft direction of fabric I.

In comparison to fabric I, fabric II is characterised by significantly lower standard deviation of the total height of the profile in both directions (***Table 2***), confirming a more uniform structure of fabric II compared to that of fabric I.

Fabric III is characterised by the strips in both directions: warp and weft. Such a structure was achieved from fabric I thanks to the application of an additional yarn in the weft direction – elastomeric yarn 37 tex PU57/PES43. Two kinds of weft yarns were introduced in the weft direction in the following order: 20 threads of 20 x 2 tex CO cotton yarn and 20 threads of elastomeric yarn (***Figure 3.a***). It caused the occurrence of goffer strips in the weft direction. The investigations carried out confirmed the difference between the structure of fabric III and that of fabrics I and II.

***Figure 18*** shows values of the average total height of the profile $W_z$ of the lines created along the warp of the fabric III. In the repeat of the pattern, only 11 lines could be created, due to the application of elastomeric yarn in the weft. It caused the thickening of the fabric structure in the warp direction. Lines No. 2-4 correspond to the puckered strip. Their values

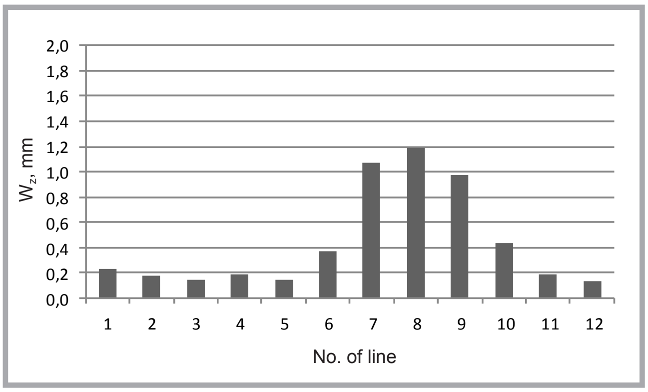


***Figure 20.*** *Average values of the total height of the profile ($W_z$) for the lines created parallel to the warp of fabric IV.*

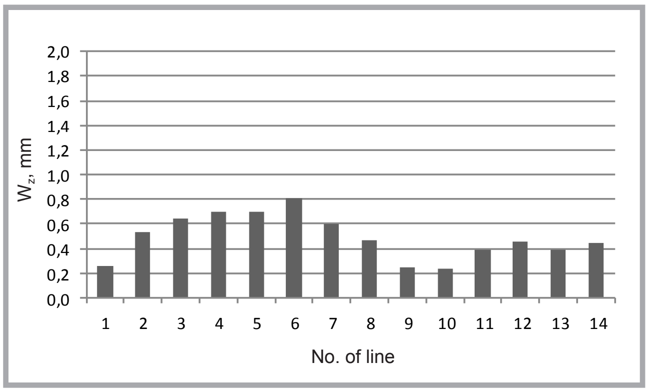


***Figure 21.*** *Average values of the total height of the profile ($W_z$) for the lines created parallel to the weft of fabric IV.*

of parameter $W_z$ are very high, much higher than in the case of the values of parameter $W_z$ for the previously presented fabrics – samples I and II. Lines No. 6-11 created along the flat strip in the warp direction are also characterised by a much higher value of the total height of the profile than the analogical lines created for fabrics I and II. Values of parameter $W_z$ for lines corresponding to the flat strip of fabric III are at a similar level to those of parameter $W_z$ for lines 11 and 14 (***Figure 16***) created along the puckered warp strip of fabric II.

The total height of the profile is high for the majority of lines created parallel do the weft of fabric III (***Figure 19***). The values of parameter $W_z$ for lines No. 3-11 correspond to the level characteristic for the lines created along the goffered warp strips of fabrics I and II.

In comparison to fabrics I and II. fabric III is characterised by the highest average value and standard deviation of the total height of the profile $W_z$ in both directions: warp and weft (***Table 2***).

***Figure 20*** presents average values of the total height of the profile of the lines created along the warp of fabric IV. Similar to fabric III, the number of lines is lower than in the case of fabrics I and II, due to the application of elastomeric yarn in the weft direction, which caused that the warp strips are thinner than in the case of fabrics without elastomeric yarn. In fabric IV the puckered strip is represented by lines No. 7, 8 and 9. Similar to fabric I, the maximal value of parameter $W_z$ in the warp direction of fabric IV is ca. 1.2 mm.

Due to the elastomeric threads occurring alternately with the non-elastomeric multifilament PES threads, the seersucker effect can also be observed in the weft direction (***Figure 21***). In the weft direction the puckered strips are broader than those in the warp direction. The goffered strips are represented by 7 lines: No. 2-8. The highest value of parameter $W_z$ in the weft direction is 0.8 mm. It is noted that line No. 6 corresponds to the puckered weft strip.

Fabric IV is characterised by higher standard deviation of the total height of the profile in both directions: warp and weft in comparison to fabrics I and II, but is lower than that for fabric III (***Table 2***).

## Conslusions

The investigation presented confirmed that 3D laser scanning can be applied to characterise the surface topography of patterned 3D woven fabrics. By means of a 3D laser scanner and appropriate software, it is possible to simulate the surface of patterned fabrics and next to create lines expressing the fabric edges in a particular direction. The lines derived can be used for determination of the parameters characterising the profile of the fabric surface.

In the investigations presented the total height of the profile $W_z$ was applied to quantify the geometric structure of the surface of the seersucker woven fabrics investigated. The values of parameter $W_z$ were determined on the basis of lines created exactly every 1 mm in the warp and weft directions in the range of the pattern repeat. The standard deviation of parameter $W_z$ for lines created in the warp and weft directions can also be used for an assessment of the structure of patterned woven fabrics. Additionally the width of the strips can be determined from the number of lines belonging to a particular strip, due to the fact that the lines are created exactly every 1 mm.

The results obtained confirmed that the average values of the total height of the profile $W_z$ together with the standard deviation of the total height of the profile and the number of lines corresponding to particular strips of the patterned fabrics investigated can be applied to characterise the topography of patterned fabrics in a quantitative way.

However, it is necessary to continue the investigation. First of all, it would be well advised to compare the results with those obtained be means of another method of assessment of the surface topography of fabrics. 3D laser scanning techniques have been used for fabric assessment since the late 1980s. However, till now neither seersucker woven fabrics nor any other patterned woven fabrics have been investigated in the aspect of their geometric structure. It is also important to analyse the influence of the pattern repeat on the sampling length, and on the results. On the basis of the results from the 3D laser scanning, it is possible to determine other surface texture parameters described in ISO [14]. It would be justified to check which parameter characterises the geometric structure of patterned woven fabrics in the best way.


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