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# Analysis of geometric structure of woven fabrics surface

**Gabriela Kosiuk, Małgorzata Matusiak**

*Lodz University of Technology, Faculty of Material Technologies and Textile Design, Institute of Architecture of Textiles, Lodz, Poland*
*Corresponding author *E-mail address:* gabriela.kosiuk@dokt.p.lodz.pl

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## ABSTRACT

*The geometric structure of the surface of textile materials is of significant functional, operational and aesthetic importance. The basic parameters of the woven fabrics' structure are the following: weave, warp and weft density as well as warp and weft linear density. Roughness is one of the surface quality features most often assessed by quantitative indicators called surface roughness parameters. The aim of the presented research was to analyze the parameters characterizing the geometric structure of the surface of cotton woven fabrics with different weaves. Surface topography measurements were performed using the MicroSpy® Profile profilometer by FRT the art of metrology™. Using the Mark III software cooperating with the profilometer, a number of indices characterizing the geometric structure of the fabric surface and histograms illustrating the frequency of occurrence of points of a certain height on the tested surface were determined. The research confirmed that, on the basis of the results obtained with the profilometer, it is possible to analyze comprehensively the topography of the fabric surface.*

**Keywords**
roughness,
profilometer,
weave,
fabric,
surface



## 1 Introduction

There are many features that characterize the quality of fabrics. Żyliński [1] divided them into 3 main groups:

- features significant from the point of view of the possibility of formatting the desired product,
- features affecting the performance of the manufactured product,
- features determining the durability of products.

The shaping of particular properties of fabrics depends on their structure. The basic structural parameters of woven fabrics are:

- weave,
- the density of warp and weft,
- the linear density of warp and weft.

The weaving pattern determines the way the warp and weft are interlaced. The plain weave is considered as the simplest weave of the woven fabrics. In plain weave, the weft thread runs successively under one and then over one warp thread (Fig. 1).

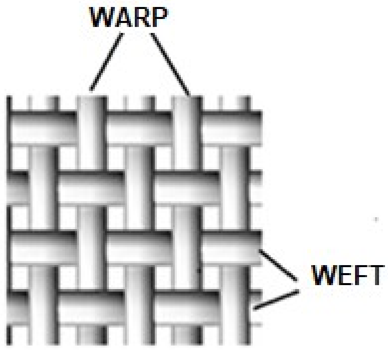


*Fig. 1 Interweaving of warp and weft threads in a plain weave fabric.*

The density of threads determines the number of threads per unit length. It reflects the density (compactness) of the fabric structure. A distinction is made between the density of warp and density of weft.

The linear density of yarn is a parameter characterizing the thickness of the yarn and it is most often expressed in the unit tex. 1 tex corresponds to the mass of 1 km (1000 m) yarn length.

Numerous studies have shown that the above-mentioned parameters of the fabric structure affect their properties: mechanical, technological, aesthetic and functional [2-7]. One of the important quality features of fabrics is the quality of their surface. It affects both the appearance of fabrics and their performance properties. This applies especially to fabrics used in direct contact with human skin [8]. In contact with human skin, as well as in the mutual contact of fabrics, an important role is played by the surface topography characterizing the shape of the surface as well as the presence and mutual position of characteristic objects and points. There are many methods of studying the surface topography of objects. Generally, these methods can be divided into contact and non-contact methods [9]. In the textile industry, the most popular and most frequently used method is the measurement of the surface parameters of textiles using the KES (Kawabata Evaluation System) system module – KES – FB 4 [10]. It is a contact method with which the surface roughness is determined. The disadvantage of contact methods is the possibility of deformation of the surface of the textiles due to the movement of the sensor of the measuring instrument on the measured surface. This can lead to measurement errors.

The aim of the presented work is to characterize the surface topography of the woven fabrics of different weaves by using a contactless method of measurement. The influence of weave on the selected roughness parameters of the investigated fabrics was also analyzed and discussed.

## 2 Materials and method

In order to analyze the influence of weave on the surface properties of woven fabrics, 12 variants of cotton woven fabrics have been manufactured. Cotton OE yarns of different linear density were used for manufacturing the fabrics: 50 tex as the warp as well as 60 tex and 100 tex as the weft. The fabrics were made of the same warp yarn and density of warp and weft. Weaves applied in the woven fabric variants being investigated are presented in Fig. 2.

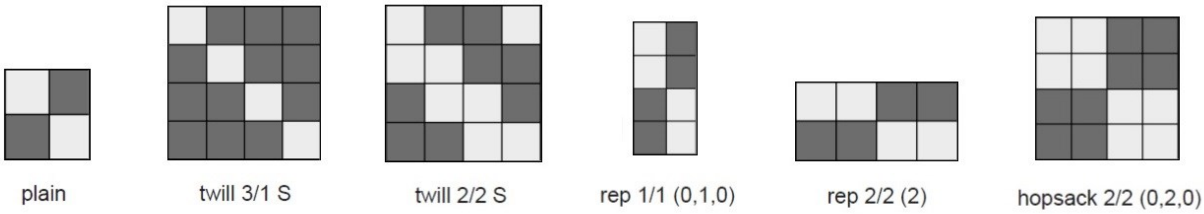


*Fig. 2 Weaves applied in the fabric variants manufactured.*

The fabric surface topography tests were performed using the MicroSpy® Profile profilometer by FRT the art of metrology™ (Fig. 3). For each fabric variant, a sample scanning was performed on the right side of the fabrics. The scanning area was 49 mm x 49 mm. The obtained fabric scans were processed in a specialized Mark III software.

First, the obtained images were modified in order to remove defective and missing data. Based on the scan results obtained, the surface topography of the tested fabrics was analyzed. The parameters characterizing the geometric structure of the fabric surface were determined according to the PN EN ISO 4287: 1993 standard [11].

*Fig. 3 MicroSpy® Profile profilometer by the FRT the art of metrology™.*

In order to assess an influence of weave on the parameters characterizing the geometric structure of the fabric surface, a statistical analysis has been performed using ANOVA.

## 3 Results

Figure 4 shows an example of the obtained images of the tested fabrics. Next to the images on the right side there is a scale for the *z* (height) value. Fabrics are flexible materials. They show a certain shape memory. Therefore, it is impossible to arrange the fabric samples in such a way that they perfectly adhere to the measuring table of the profilometer. Due to this fact the phenomenon of waviness has been observed. It does not result from the waviness of the fabric surface, but from the inaccurate adherence of the samples to the table, and thus the position of the samples slightly deviating from the horizontal plane. To eliminate this, when determining the roughness parameters, appropriate filters (cut-off filters) were used to eliminate the waviness phenomenon. The surface image of the tested fabric after eliminating the waviness is shown in Fig. 5. It is clearly visible that the height distribution (*z* value) is more even, and the range of *z*-value is significantly smaller than that recorded for the images of fabrics before the filter was applied (Fig. 4).

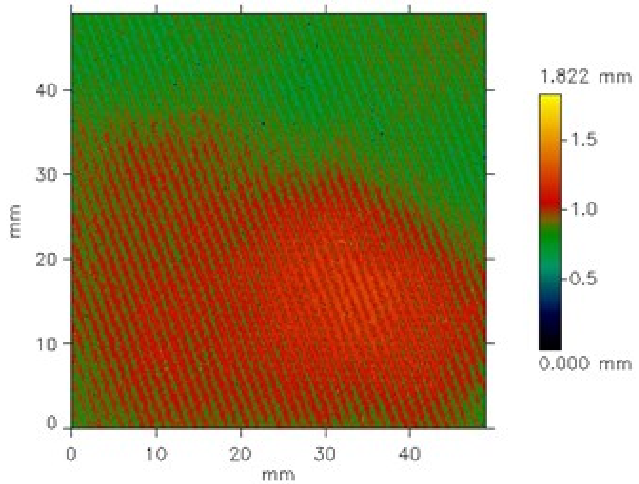


*Fig. 4 Image of the fabric before applying the filter.*

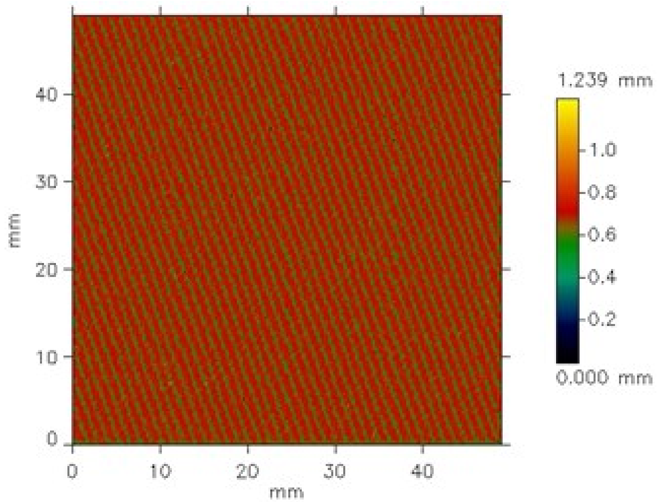


*Fig. 5 Image of the surface of the tested fabrics after eliminating waviness.*

Filtered data have been applied in further analysis. Using the Mark III software, it is possible to determine the values of a number of parameters characterizing the surface topography of fabrics. In Table 1, only the selected parameters described below are presented. According to the standard [11], the surface roughness parameters were determined using the profile method. The “s” prefix denotes the value of the parameters determined by the profile method calculated for the analyzed s – surface.

sRa – arithmetic mean height indicates the average of the absolute value along the sampling length;

sRq – root mean square deviation indicates the root mean square along the sampling length;

sRz – mean roughness depth; it is the mean of 5 maximum peak-to-valley roughness depths in 5 successive sampling lengths;

sRt – represents the sum of the maximum peak height and the maximum valley depth of a profile within the evaluation length, not sampling length;

sRsk – skewness – the parameters represent the degree of bias of the roughness shape (asperity); parameter Rsk is used to evaluate deviations in the height distribution. An interpretation is following:

sRsk = 0: the height distribution symmetric against the mean line,

sRsk > 0: deviation beneath the mean line,

sRsk < 0: deviation above the mean line

Rku – kurtosis, its value is a measure of the sharpness of the roughness profile.

Table 1. *Parameters characterizing the surface topography of the investigated fabrics.*

| Weave | $sR_a$ (mm) | $sR_q$ (mm) | $sR_z$ (mm) | $sR_t$ (mm) | $sR_{sk}$ | $sR_{ku}$ |
|---|---|---|---|---|---|---|
| **PLAIN [A]** | 0.044 | 0.056 | 1.191 | 1.399 | 0.202 | 7.087 |
| **PLAIN [B]** | 0.039 | 0.048 | 0.958 | 0.338 | 0.149 | 6.284 |
| **TWILL 3/1 S [A]** | 0.053 | 0.068 | 1.273 | 1.524 | -0.388 | 6.338 |
| **TWILL 3/1 S [B]** | 0.054 | 0.069 | 1.251 | 1.410 | -0.769 | 6.781 |
| **TWILL 2/2 S [A]** | 0.058 | 0.077 | 1.050 | 1.231 | -0.965 | 5.888 |
| **TWILL 2/2 S [B]** | 0.062 | 0.080 | 1.102 | 1.387 | -0.924 | 4.530 |
| **REP 1/1 (0,1,0) [A]** | 0.060 | 0.075 | 1.275 | 1.515 | 0.094 | 5.721 |
| **REP 1/1 (0,1,0) [B]** | 0.062 | 0.075 | 1.120 | 1.357 | -0.207 | 3.883 |
| **REP 2/2 (2) [A]** | 0.036 | 0.047 | 1.002 | 1.259 | 0.790 | 12.117 |
| **REP 2/2 (2) [B]** | 0.035 | 0.046 | 1.290 | 1.574 | -0.228 | 17.554 |
| **HOPSACK 2/2 (0,2,0) [A]** | 0.050 | 0.063 | 0.948 | 1.326 | -0.123 | 5.521 |
| **HOPSACK 2/2 (0,2,0) [B]** | 0.047 | 0.059 | 0.777 | 1.174 | -0.203 | 5.326 |

*A – 60 tex weft yarn, B – 100 tex weft yarn*

On the basis of these results, it is clearly seen that the fabrics differ from each other in the aspect of all presented parameters characterizing the geometric structure of surface. The highest roughness was observed for the twill 2/2 S fabric with the 60 tex weft yarn, the lowest for the rep 2/2 (2) fabric also with the 60 tex weft yarn. Statistical analysis confirmed that weave influences the values of all presented surface parameters in statistically significant way at the significance level 0.05.

Figure 6 presents the $sR_a$ parameter in a function of weave. The highest $sR_a$ values were observed for the twill 2/2 and rep 1/1 weaves, the lowest for the plain and rep 2/2 weaves. It was also stated that linear density influences the parameters characterizing the surface geometry of the investigated fabrics. However, statistically significant influence was stated only in the case of the $sR_{sk}$ parameter, the skewness (Fig. 7). For all analyzed surface parameters, a statistically significant interaction between the main factors weave and linear density of the weft yarn was observed (Fig. 8).

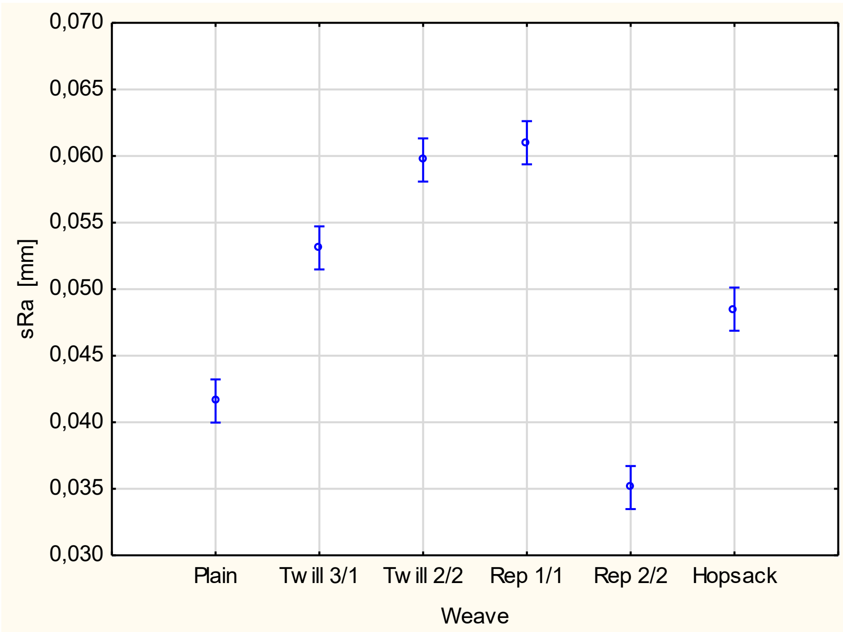


*Fig. 6 $sR_a$ parameter as a function of fabrics' weave.*

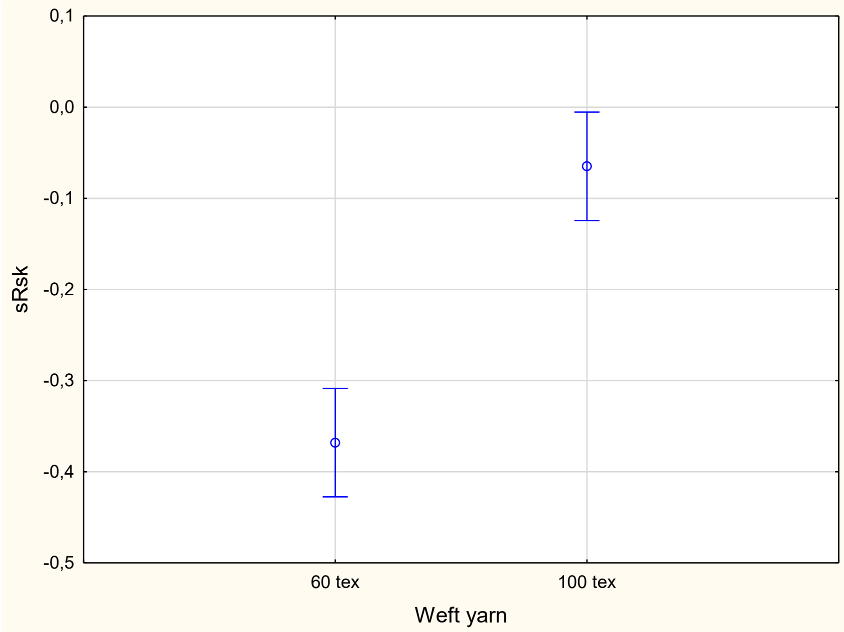


*Fig. 7 $sR_{sk}$ parameter as a function of linear density of weft yarn.*

In the majority of cases (all twill fabrics, rep 1/1 [weft 100 tex], rep2/2 [weft 100 tex] and hopsack fabrics), negative values of the $sR_{sk}$ parameters were stated. This means that the height distribution shows a deviation above the mean line. The values of kurtosis $sR_{ku}$ are higher than 3. It means that in all cases the height distribution on the fabrics' surface is spiked.

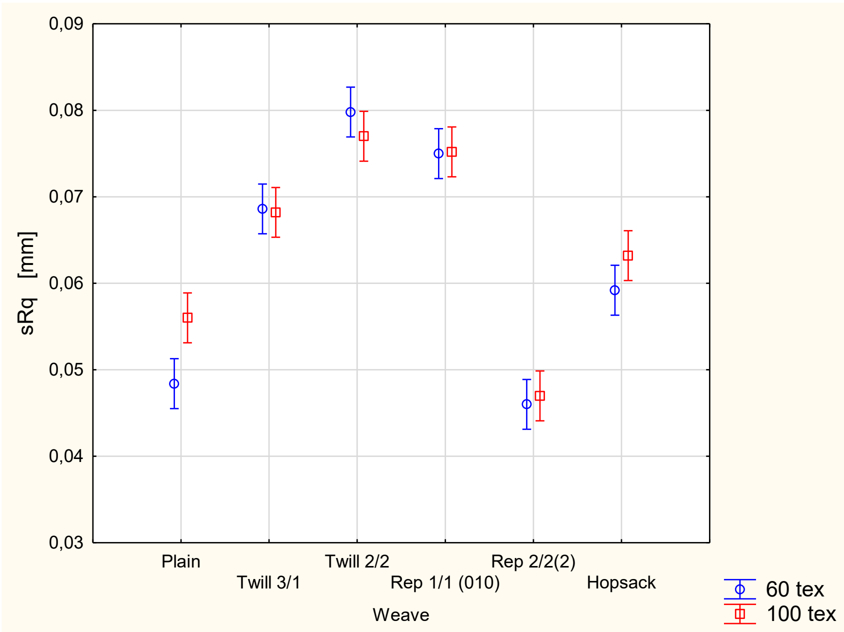


*Fig. 8 $sR_q$ parameter as a function of weave and linear density of weft yarn.*

The Mark III software makes it possible to analyze the scanning results in different ways. Based on the data from the profilometer, histograms illustrating the height distribution of the surfaces of the tested fabrics can be created. It is also possible to determine the fractal dimension, angle distribution, autocorrelation function and many others.

Figures 9 and 10 show exemplary histograms obtained for fabrics of different weaves. Histograms of the *z* value have been prepared for all fabric variants and for each specimen measured for particular variant. Based on the analysis of the histograms for all investigated fabric variants, it can be stated that weave influences the distribution of the *z* value (height) on the fabrics' surface. Differences concern both the most frequent height and histogram maximum.

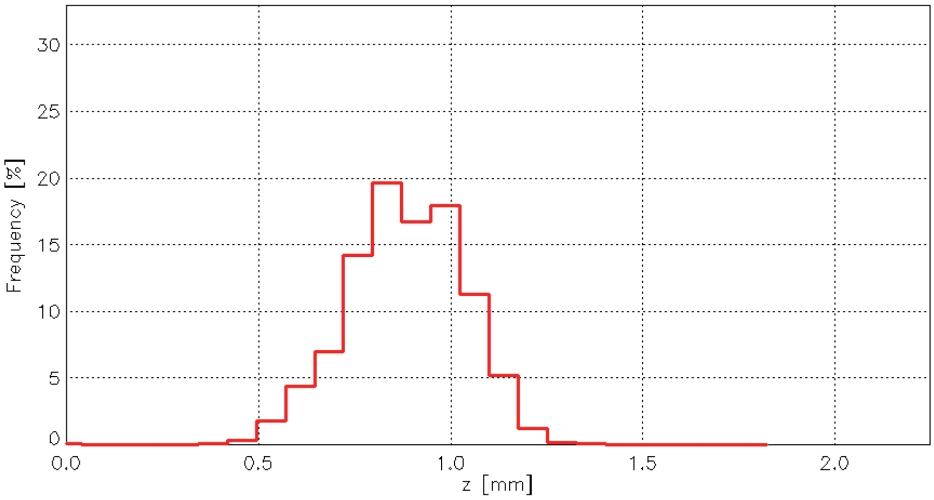


*Fig. 9 Exemplary distribution of height (z value) for the fabric of twill 3/1 S weave with the60 tex weft yarn.*

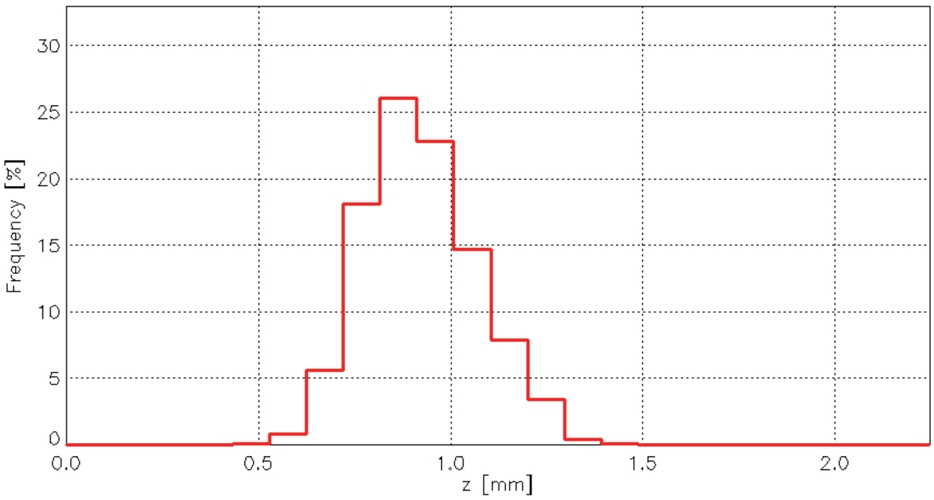


*Fig. 10 Exemplary distribution of height (z value) for the fabric of rep 2/2 (2) weave with the100 tex weft yarn.*

It is impossible to show all results and graphs which can be obtained using the Mark III software. The applied method enables determining the values of all parameters covered by appropriate standards [11,12], the autocorrelation function, fractal dimension, angle distribution and many others. The further results and their deep analysis will be the aim of future publications being in preparation.

## 4 Conclusions

Based on the performed investigations and obtained results it can be concluded that:

- the MicroSpy® Profile profilometer by FRT and the Mark III software enable comprehensive studies of the geometrical structure of the textile surface,
- investigated cotton fabrics of different weave differ between each other in the range of all presented surface topography parameters,
- statistical analysis by means of the ANOVA confirmed that influence of weave on the fabrics' surface parameters is statistically significant at the significance level 0.05,

- a change in the linear density of the weft yarn while maintaining the same other parameters of the fabric structure affects the surface topography; however, the influence of the linear density of the weft yarn on the roughness parameters is not always statistically significant,
- there is statistically significant interaction between the main factors weave and linear density of weft yarn. This means that the influence of one factor on the surface parameters is modified by the influence of the second factor.

## Author Contributions

G. Kosiuk: investigation, data curation, visualization, writing – original draft preparation; M. Matusiak: conceptualization, methodology, supervision, writing – review and editing, project administration, funding acquisition. All authors have read and agreed to the published version of the manuscript.


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## Conflicts of Interest

The authors declare no conflict of interest.

## References


1. Żyliński, T. *Textile metrology III* (in Polish); WNT; Warsaw, 1969.
2. Matusiak, M. Influence of the Structural Parameters of Woven Fabrics on their Drapeability. *Fibres & Textiles in Eastern Europe* **2017**, *25*(1), 56-64.
3. Backer, S. The relationship between the Structural Geometry of a Textile Fabric and Its Physical Properties, Part IV.: Interstice Geometry and Air Permeability. *Textile Research Journal* **1951**, *21*(10), 703-714.
4. Nofitoska, M.; Demboski, G.; Carvalho, M. A. F. Effect of Fabric Structure Variation on Garment Aesthetic Properties. *Tekstie ve Konfeksiyon* **2014**, *24*(2), 132-136.
5. Kumpikaitė, E. Analysis of Dependencies of Woven Fabric's Breaking Force and Elongation at Break on its Structure Parameters. *Fibres & Textiles in Eastern Europe* **2007**, *1*(60), 35-38.
6. Milašius, V.; Milašius, R.; Kumpikaité, E.; Olšauskiené, A. Influence of Fabric Structure on Some Technological and End-use Properties, *Fibres and Textiles in Eastern Europe* **2003**, *11*(2), 48-51.
7. Matusiak, M.; Sikorski, K. Influence of the structure of woven fabrics on their thermal insulation properties. *Fibres and Textiles in Eastern Europe* **2011**, *88*(5), 46-53.
8. Żurek, W.; Kopias, K. *Structure of fabrics* (in Polish); WNT; Warsaw, 1977.
9. Calvimontes, A.; Dutschk, V.; Stamm, M. Advances in Topographic Characterization of Textile Materials. *Textile Research Journal* **2010**, *80*(1), 1004-1015.
10. Krucińska, I.; Konecki, W.; Michalak, M. *Measuring systems in textiles* (in Polish); ISBN 83-7283-148-3. Lodz 2006; pp. 252-329.
11. Polish Standard PN-EN ISO 4287: 1993 Specifications of product geometry – Geometric structure of the surface: profile method – Terms, definitions and parameters of the geometric structure of the surface.
12. International Standard ISO 25178: 2012 Geometrical product specifications (GPS) – Surface texture: Areal – Part 2: Terms, definitions and surface texture parameters.