Influence of weft density on selected parameters of fabric surface

Wpływ liczności wątku na wybrane parametry powierzchni tkanin

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Abstrakt

Struktura geometryczna powierzchni materiałów tekstylnych ma duże znaczenie funkcjonalne, eksploatacyjne i estetyczne. Podstawowymi parametrami struktury tkanin są: gęstość splotu, osnowy i wątku oraz gęstość liniowa osnowy i wątku. Chropowatość jest jedną z cech jakości powierzchni najczęściej ocenianych za pomocą wskaźników ilościowych, zwanych parametrami chropowatości powierzchni. Celem prezentowanych badań była analiza parametrów charakteryzujących strukturę geometryczną powierzchni tkanin bawełnianych o splocie skośnym. Pomiary topografii powierzchni przeprowadzono przy użyciu profilometru MicroSpy® Profile firmy FRT the art of metrology™. Badania potwierdziły, że na podstawie wyników uzyskanych za pomocą profilometru można kompleksowo analizować topografię powierzchni tkaniny.

Abstract

The geometric structure of surface of textile materials have 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 twill weave. Surface topography measurements were performed using the MicroSpy® Profile profilometer by FRT the art of metrology™. 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.

Słowa kluczowe: chropowatość, profilometr, splot, tkanina, powierzchnia

Keywords: roughness, profilometer, weave, fabric, surface

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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 the woven fabrics are:

• weave,

• the density of warp and weft,

• linear density of warp and weft.

The weaving pattern determines the way the warp and weft are interlaced. The twill weave is one of the basic weaves of the woven fabrics. In twill weave, the weft thread runs successively under three and then over one warp thread (Fig. 1).

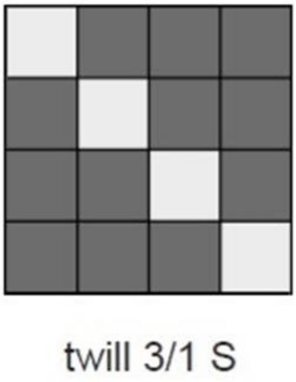


Fig. 1. The interweaving of warp and weft threads in a twill weave fabric.

Source: [own source].

The density of threads determines the number of threads per unit of 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 tex unit. 1 tex corresponds to the weight of a 1 km (1000 m) length of yarn. 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 [7]. 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 [8]. 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 [8]. It is a contact method in 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 measuring instrument on the measured surface. This can lead to measurement errors. The aim of presented work to characterize the surface topography of the woven fabrics of twill weave by using the contactless method of measurement. The influence of linear density of weft yarn on selected roughness parameters of the investigated fabrics was also analyzed and discussed.

2. Materials and methods

2.1. Materials

In order to analyze the influence of weave on the surface properties of woven fabrics, 5 variants of cotton woven twill weaves fabrics have been manufactured.

OE cotton yarns with different linear density were used for manufacturing the fabrics: 50 tex as the warp as well as 100, 60, 50, 40, 30 tex as the weft. The fabrics were made of the same warp yarn and of the same density of warp and weft. The basic parameters of the investigated fabrics are presented in table 1.

Tab. 1. The basic parameters of the investigated fabrics.

Sample	**Weft linear density [tex]**	**Mass per square meter [g/m2]**	**Warp density *Threads* [/dm]**	**Weft density *Threads* [/dm]**	**Thickness [mm]**
1	100	292	317	116	0.78
2	60	238	317	117	0.70
3	50	225	317	116	0.68
4	40	215	320	118	0.65
5	30	198	318	118	0.61

2.2. Methods

The fabric surface topography tests were performed using the MicroSpy® Profile profilometer by FRT the art of metrology™ (Figure 2). 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 [9].

Fig. 2. MicroSpy® Profile profilometer by the FRT the art of metrology™.

Source: [own source].

3. Results and Discussion

In order to assess an influence of linear density of weft yarn on the parameters characterizing the geometric structure of the fabric surface the statistical analysis has been performed using the ANOVA. Figure 3 shows the example of the obtained images of the tested fabrics.

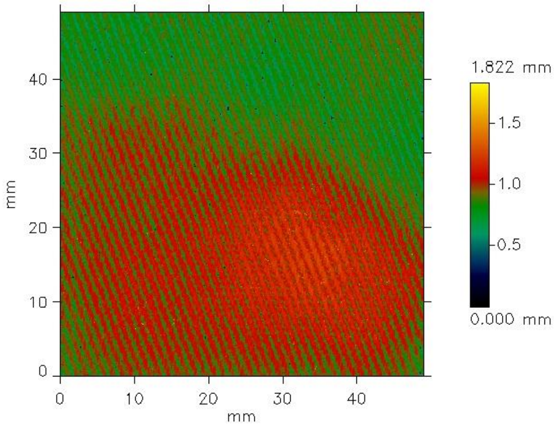


Fig. 3. Image of the fabric before applying the filter.

Source: [own source].

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, an appropriate filter (cut-off filter) was used to eliminate the waviness phenomenon. The surface image of the tested fabric after eliminating the waviness is shown in Figure 3. 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 (Figure 4).

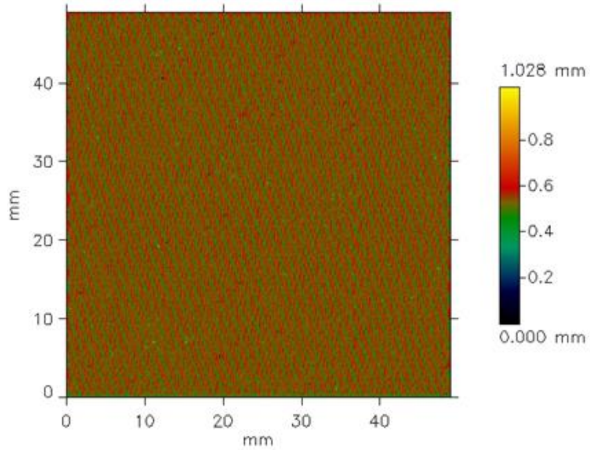


Fig. 4. Image of the fabric after applying the cut-off filter.

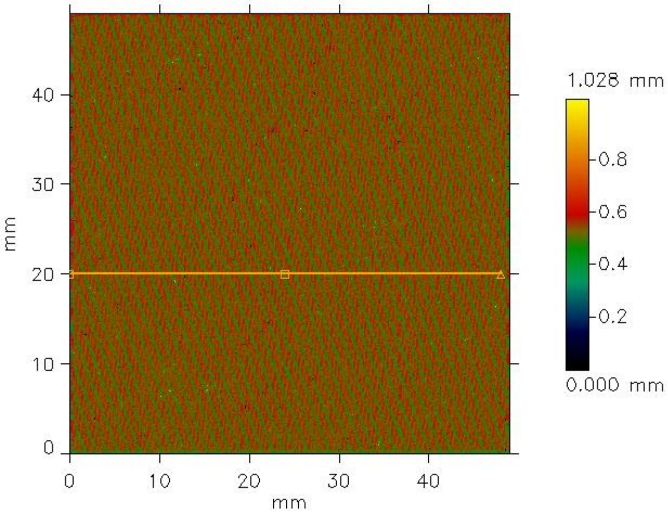
Source: [own source].

The fabrics images after removing the waviness component have been analyzed using the Mark III software. Selected parameters for the whole area of the investigated samples are presented in the table 2.

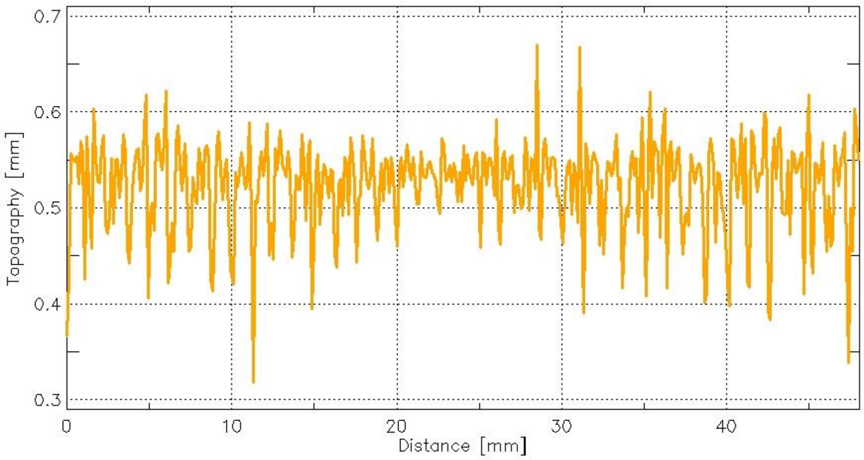
Tab. 2. Results from the MicroSpy® Profile profilometer for the sample area.

Sample	**Weft linear density [tex]**	**Ra [mm]**	**Rq [mm]**	**Rz [mm]**	**Rk [mm]**
1	100	0.034	0.047	1.060	0.079
2	60	0.034	0.046	0.931	0.076
3	50	0.032	0.045	1.036	0.075
4	40	0.032	0.045	1.069	0.073
5	30	0.029	0.040	1.034	0.069

In the table 2 there are presented the values of the following parameters: Ra, Rq, Rz and Rk. The Ra, Rq and Rz are the height parameters. The Ra is an arithmetic mean of the absolute of the ordinate values within a defined area. It is an arithmetical mean height of a line. It expresses, as an absolute value, the difference in height of each point compared to the arithmetical mean height of the surface, The Rq is a root mean square value of the ordinate values within a defined area. It is equivalent to the standard deviation of heights. Rz expresses the maximum height. It is equivalent to the sum of the maximum peak height Rp and maximum valley depth Rv. Last parameter 0 – Rk is a core height. It is functional parameter derived from the Material Ratio curve. Rk expresses the difference between the upper and lower levels of the core of the material being investigated. It is clear that the values the are different for each fabric variant. In the case of the Ra, Rq and Rk, the values of the parameters decrease with the decrease of the linear density of weft yarn. For the Rz parameter any clear tendency was observed. Due to the fact that the structure of the fabrics was changed by changing only one system of threads – weft, the influence of the structure changes on the surface parameters was analyzed separately for both directions warp and weft. In order to do it, for each fabric variant the profiles have been created in warp and weft directions. Exemplary profile and place of the profile of the fabric surface are presented in the Figure 5.



a)



b)

Fig. 5. Exemplary profile created in the weft direction: a) place of the profile on the sample surface, b) created horizontal profile; Source: [own source].

For each created profile the Mark III software provides the values of the roughness parameters. The values of the selected parameters for the profiles created in weft direction of the investigated fabrics are presented in the Table 3.

Tab. 3. Results from the MicroSpy® Profile profilometer for the horizontal profiles.

Sample	**Weft linear density [tex]**	**Ra [mm]**	**Rq [mm]**	**Rz [mm]**	**Rk [mm]**
1	100	0.035	0.048	0.261	0.085
2	60	0.033	0.044	0.215	0.072
3	50	0.036	0.048	0.240	0.077
4	40	0.030	0.041	0.215	0.086
5	30	0.027	0.035	0.161	0.068

Next, in the same way the vertical profiles – in warp direction have been created and assessed. The results for the vertical profiles are presented in the Table 4.

Tab. 4. Results from the MicroSpy® Profile profilometer for the vertical profiles.

Sample	**Weft linear density [tex]**	**Ra [mm]**	**Rq [mm]**	**Rz [mm]**	**Rk [mm]**
1	100	0.032	0.045	0.260	0.084
2	60	0.030	0.040	0.194	0.068
3	50	0.029	0.040	0.211	0.061
4	40	0.033	0.047	0.245	0.071
5	30	0.028	0.042	0.237	0.057

Figure 6 presents the comparison of the Ra parameter determined for the investigated fabrics for whole area of the sample (A symbol) as well as for the created profiles: horizontal (H symbol) and vertical (V symbol).

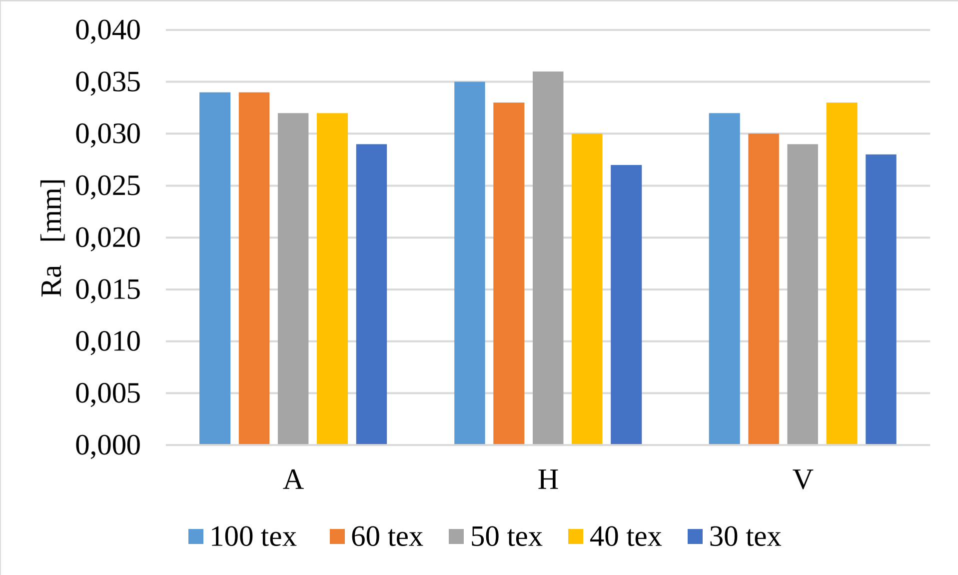


Fig. 6. The comparison of the Ra parameter determined for the investigated fabrics for whole area of the sample (A symbol) as well as for the created profiles: horizontal (H symbol) and vertical (V symbol). Source: [own source].

For the Rq parameter the tendencies are the same as for the Ra parameter (Figure 7) but the values of Rq are higher that the values of the Ra. Interesting situation is observed in the case of the Rz parameter. The values of the Rz parameter for the whole area of the sample are ca. 5 times higher that that for the profiles. The Rz parameter is the sum of the maximum peak height Rp and maximum valley depth Rv in the analyzed area. It is obvious that in the whole area it is much more points being investigated that in the case of the profiles. On the whole area are all picks and valleys present on the sample surface. It is probable that the highest pick and the deepest valley determining the Rz parameter for the whole area of the sample are located in a different place than the created profiles (Figure 8).

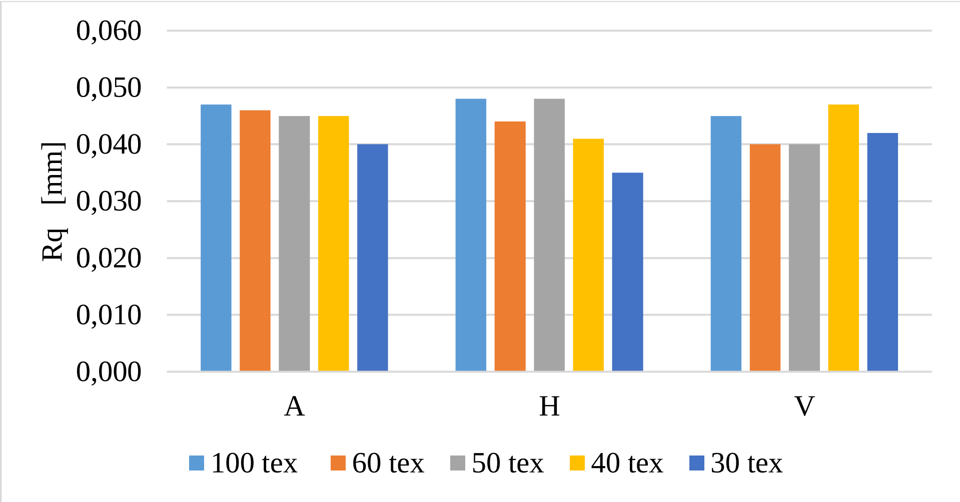


Fig. 7. The comparison of the Rq parameter determined for the investigated fabrics for whole area of the sample (A symbol) as well as for the created profiles: horizontal (H symbol) and vertical (V symbol); Source: [own source].

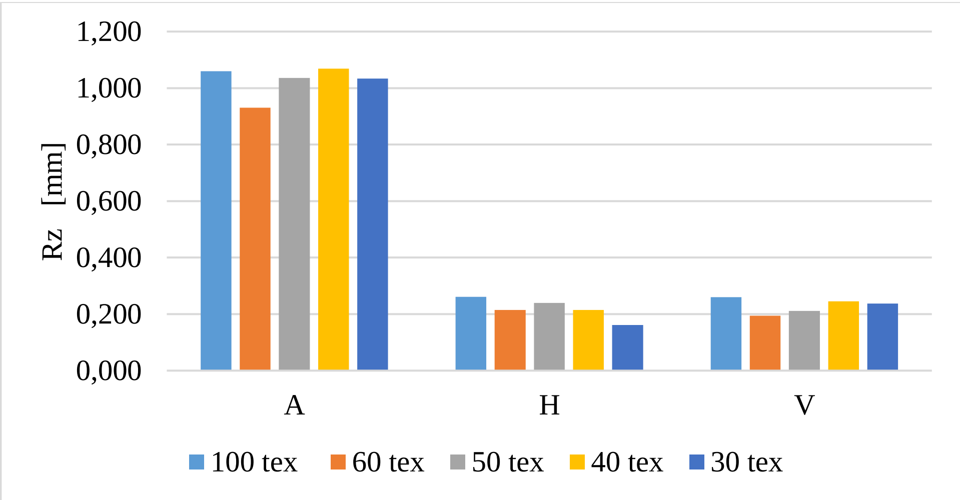


Fig.8. The comparison of the Rz parameter determined for the investigated fabrics for whole area of the sample (A symbol) as well as for the created profiles: horizontal (H symbol) and vertical (V symbol); Source: [own source].

It is clearly seen that the linear density of the weft yarn influences the value of the Ra parameter. In the case of the whole sample area the lower the linear density of the weft yarn is the lower value of the Ra parameter. Similar situation is observed for the profiles. However, in both cases the horizontal and vertical directions the trend is disrupted. In the weft direction(horizontal) the fabric variant with the 50 tex weft yarn is characterized by the highest value of the Ra parameter whereas, in the warp direction (vertical) the highest value of the Ra parameter occurs fir the fabric with the 40 tex weft yarn. Using the MicroSpy® Profile Profilometer supported by the Mar II software it is possible to determine a range of parameters and functions. All of them can be applied to complex characterization of the surface topography of textile materials. For instance it is possible to create the histograms of height presenting the distribution of height of all points on measured surface. Figure 9 presents exemplary histogram for the fabric with the 100 tex weft yarn.

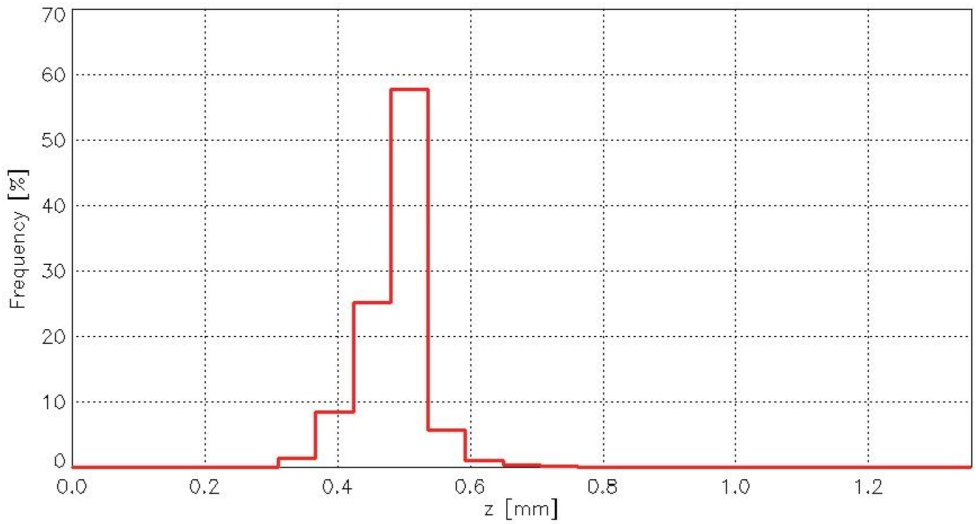


Fig. 9. An example of histogram illustration the height (z value) distribution on the surface of fabric with the100 tex weft yarn. Source: [own source].

There are two parameters characterizing the shape of histogram: the most frequent height and histogram maximum. The values of the parameters are presented in the Table 5. The table presents also the fractal dimension determined at the initial cell height 2.5 mm. A fractal dimension is a ratio expressing a complexity of a surface.

Tab. 5. Results from the MicroSpy® Profile profilometer for the whole area.

Sample	**Weft linear density [tex]**	**The most frequent height [mm]**	**Histogram maximum [%]**	**Fractal dimension**
1	100	0.508	57.716	2.399
2	60	0.514	49.035	2.399
3	50	0.574	58.445	2.399
4	40	0.493	47.449	2.411
5	30	0.410	44.650	2.482

The linear density of the weft yarn influence both the histogram parameters and fractal dimension. However, it is difficult to stat and clear trend. It needs further investigations. So far, no similar studies have been conducted that could be the subject of reference to the results obtained. Surface measurement of textile materials using non-contact methods is very rare. The works published so far concern other textile materials. For example, Matusiak [10] conducted research on seersucker woven fabrics. The topography of seersucker woven fabrics has a completely different character than that of standard fabrics. Therefore, at present it is not possible to compare the obtained results with literature reports.

4. Conclusions

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

- the MicroSpy® Proflie profilometer by FRT and the Mark III software enable comprehensive studies of the geometrical structure of the textile surface,

- investigated cotton fabrics of twill weave with different weft yarns differ between each other in the range of all presented surface topography parameters,
- a change in the linear density of the weft yarn while maintaining the same other parameters of the fabric structure affects the surface topography; the values of the Ra, Rq and Rk parameters decrease with the decrease of the linear density of the weft yarn while other structural parameters are unchanged.
- The influence of the structural parameters of the fabrics on their surface topography needs further investigations.

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