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RESEARCH ON SURFACE GEOMETRY OF WOVEN FABRICS OF DIFFERENT STRUCTURE

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ABSTRACT

The geometric structure of surface of textile materials is of significant functional, operational and aesthetic importance. Generally, the geometric structure of the surface of materials consists of three main elements: shape, waviness and roughness [1,2]. Parameters characterizing a quality of fabrics surface, i.e. surface topography are strongly related to the fabrics' structure, raw material composition and a way of finishing. The aim of presented work was to analyse the parameters characterizing the geometric structure of the surface of cotton woven fabrics with different weaves. Totally, 12 fabric variants were the objects of the investigations. They were woven fabrics of 6 weaves and 2 kinds of weft yarn. Surface topography measurements were made by means of the MicroSpy® Profile profilometer by FRT the art of metrology™ [3]. Using the Mark III software cooperating with the profilometer, the basic parameters characterizing the geometric structure of the fabrics' surface were determined according to standard [4]. Results showed that the fabrics differ between each other in the aspect of the majority of parameters characterizing the surface geometry. Statistical analysis confirmed that weave and linear density of weft yarn significantly influence the surface properties of the investigated fabrics.

KEYWORDS

Roughness, profilometer, weave, fabric.

MATERIALS AND METHODS

In order to analyse the influence of weave on the surface properties of woven fabrics, 12 variants of cotton woven fabrics were 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 od warp and weft [5]. Weaves applied in the woven fabric variants are presented in Figure 1.

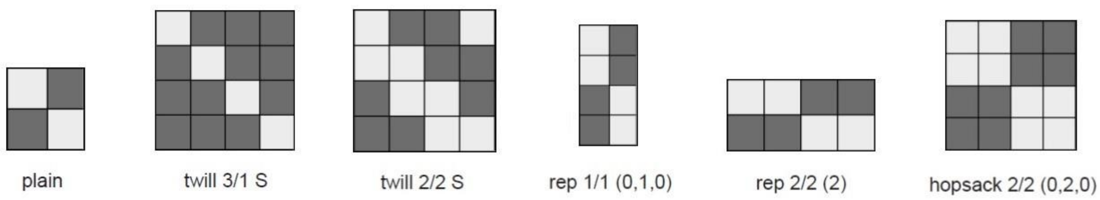

Figure 1. Weaves applied in the fabric variants manufactured.

The fabric surface topography tests were performed using the MicroSpy® Profile profilometer by FRT the art of metrology™. For each fabric variant, a sample scanning was performed on the right side of the fabrics. The scanning area was 49 mm × 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 analysed. The parameters characterizing the geometric structure of the fabric surface were determined according to the PN EN ISO 4287: 1993 standard [4].

Results have been analysed statistically using the multi-factor ANOVA.

RESULTS AND DISCUSSION

Figure 2 shows the 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 were 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*-values is significantly smaller than that recorded for the images of fabrics before the filter was applied (Figure 2).

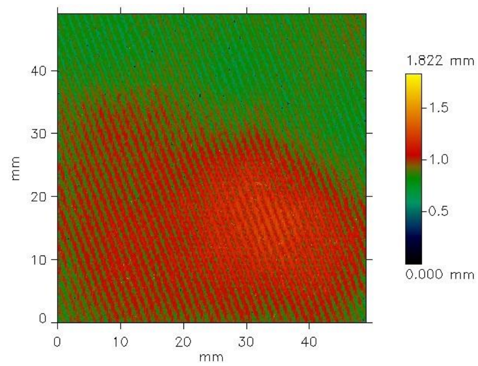

Figure 2. Image of the fabric before applying the filter.

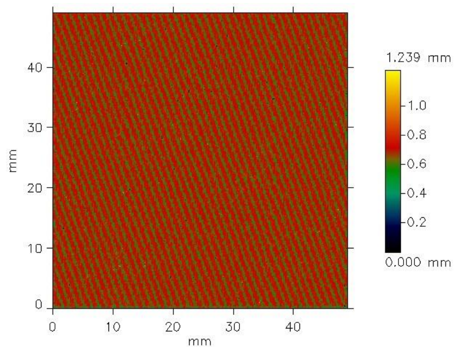

Figure 3. Image of the surface of the tested fabrics after eliminating waviness.

Using the Mark III software, it is possible to determine the values of a number of parameters characterizing the surface topography of fabrics. In the Table 1 there are presents only the selected parameters described below. According to the standard [4], 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 analysed *s* - surface.

sR_a – arithmetic mean height indicates the average of the absolute value along the sampling length.

When dealing with the roughness profile, R_a is referred to as the arithmetic mean roughness, while W_a is referred to as the arithmetic mean waviness for the waviness profile.

$$sR_a = \frac{1}{A}\int_0^A Z \quad x \quad dx \qquad [1]$$

where: *A* - surface area; *z*, *x* - cartesian coordinates.

$$sR_q = \sqrt{\frac{1}{A}\int_0^A Z^2 \quad x \quad dx} \qquad [2]$$

where: *A* - surface area; *z*, *x* - cartesian coordinates.

sR_z – mean roughness depth; it is the mean of 5 maximum peak-to-valley roughness depths in 5 successive sampling lengths;
sR_t – represents the sum of the maximum peak height and the maximum valley depth of a profile within the evaluation length, not sampling length;
sR_{sk} – skewness – the parameters represent the degree of bias of the roughness shape (asperity); parameter R_{sk} is used to evaluate deviations in the height distribution. An interpretation is following:

$sR_{sk} = 0$: the height distribution symmetric against the mean line,
$sR_{sk} > 0$: deviation beneath the mean line,
$sR_{sk} < 0$: deviation above the mean line.

R_{ku} – 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	SR_Q	SR_Z	SR_T	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 S/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] – fabrics with 100 tex weft yarn, [B] – fabrics with 60 tex weft yarn

On the basis of the results it is clearly seen that the fabrics differ between 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 4 presents the sR_a parameter in a function of weave. The highest sR_a value 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 of the weft yarn 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 – skewness. For all analysed surface parameters it was observed the statistically significant interaction between the main factors: weave and linear density of weft yarn.

In a majority of cases (all twill fabrics, rep 1/1 [B], rep2/2 [B] and hopsack fabrics) the negative values of the sR_{sk} parameters were stated. It means that the height distribution shows a deviation above 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.

The Mark III software makes it possible to analyse 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.

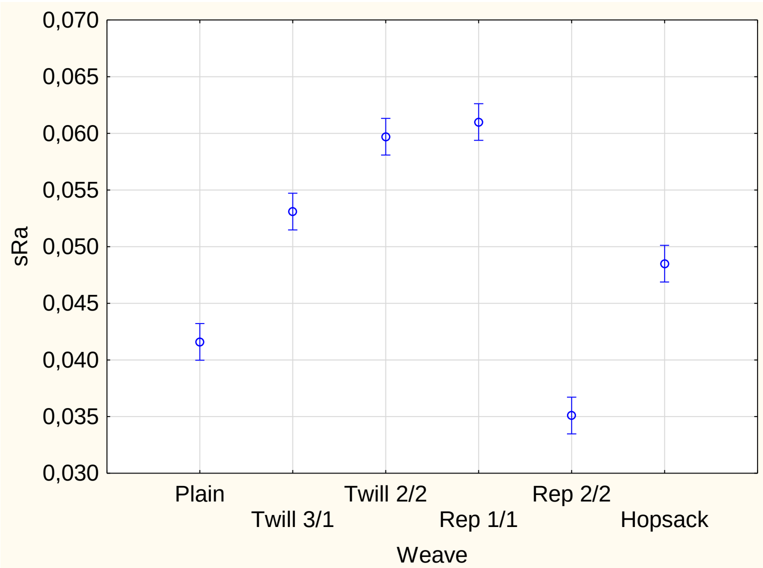

Figure 4. sR_a parameter in function of fabrics' weave.

Due to limited length of the article it is impossible to show all obtained results. They will be presented in next publications. Generally, it can be stated that using the applied method it is possible to characterise the geometric structure of fabrics' surface deeply and in a complex way.

CONCLUSION

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

- the MicroSpy® Proflie profilometer by FRT with the Mark III software enables comprehensive studies of the geometrical structure of the fabric surface,
- investigated cotton fabrics of different weave differ between each other in the range of all presented surface topography parameters; statistical analysis confirmed that influence of weave on the 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 weight 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. It means that influence of one factor on the surface parameters is modified by influence of the second factor.

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