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Effect of Weaving Pattern and Yarn Density on the Surface Roughness of Woven Fabrics

Dokuma Kumaşların Yüzey Pürüzlülüğüne Dokuma Deseni ve İplik Sıklığının Etkisi

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Araştırma Makalesi / Research Article

EFFECT OF WEAVING PATTERN AND YARN DENSITY ON THE SURFACE ROUGHNESS OF WOVEN FABRICS

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ABSTRACT: Surface roughness is an important characteristic of textile fabrics. It affects a variety of other properties such as the fabric hand, the surface friction properties and the efficiency of lamination and adhesion processes. Surface roughness in fabrics is typically measured using the KES-F system. This research paper proposes an innovative method for the measurement of fabric surface roughness based on image processing of photos of fabric cross-sections, obtained through the stereoscopic microscope.

Key Words: Surface roughness, woven fabrics, image processing, stereoscopic microscopy

DOKUMA KUMAŞLARIN YÜZEY PÜRÜZLÜLÜĞÜNE DOKUMA DESENİ VE İPLİK SIKLIĞININ ETKİSİ

ÖZET: Yüzey pürüzlülüğü, kumaşların önemli bir özelliğidir. Yüzey pürüzlülüğü, kumaş tutumu, yüzey sürtünme özellikleri, laminasyon ve adezyon işlemlerinin verimleri gibi diğer birçok özelliği etkiler. Kumaşlardaki yüzey pürüzlülüğü tipik olarak KES-F sistemi ile ölçülür. Bu araştırma, kumaş yüzey pürüzlülüğünün ölçümü için stereo mikroskop ile elde edilen kumaş enine kesit fotoğraflarının görüntü analizine dayanan yeni bir yöntem önermektedir.

Anahtar Kelimeler: Yüzey pürüzlülüğü, dokuma kumaşlar, görüntü işleme, stereo mikroskop

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1. INTRODUCTION

Surface roughness is a component of surface texture. Physically, any surface is generally composed of three components, form, waviness, and roughness, in accordance with wavelength or frequency of surface particles. These correspond to the low, medium local relative height differences respectively [1]. There are various methods that have been developed for characterisation of the surface roughness of fabrics. The methods can be roughly divided into methods that require contact between the fabric surface and the measuring equipment and methods that are contactless [2-5].

The most popular method is the Kawabata Evaluation System for fabrics (KES-F). The Kawabata system was designed in order to obtain objective measurements of fabric “hand”, i.e. the tactile sensations resulting from low level mechanical stress applied to the fabric and it comprises of a set of four apparatuses that each measures one component of fabric “hand”, namely shear/ tensile characteristics, pure bending, compression and surface characteristics. The KES-F surface roughness method provides measurements of the geometrical roughness and the coefficient of friction (μ) of the fabric (Figure 1) [2, 3].

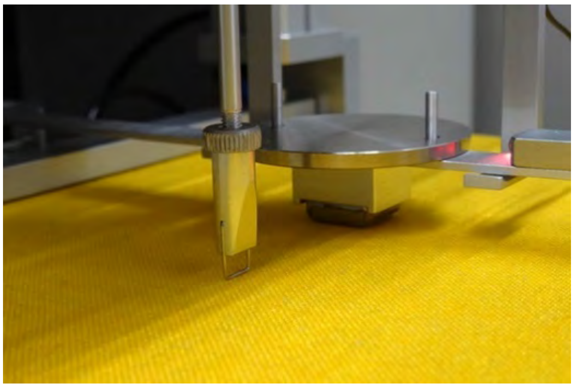

Figure 1. KES-F roughness probe

An example of a contactless method for the measurement of surface is described in a 1992 paper by Ramgulam et al. The method uses a laser sensor set-up. The laser sensor measures the distance between itself and the object, by using laser triangulation techniques [4, 5]. The paper by Ramgulam includes a quite thorough presentation of various methods suggested by the relevant literature up to the point of the papers publication.

For materials other than fabrics and especially metal there exist standardised methods that define terms connected to roughness and its measurement as well as various methods for said measurement. The instruments used for the measurement of the surface roughness are called profilometers and are divided into contact (typically using a diamond stylus) and contactless (mainly optical, e.g. a white light interferometer or laser scanning confocal microscope) [6].

A roughness value can either be calculated on a profile (line) or on a surface (area). The profile roughness parameter (Ra, Rq …) are more common. The area roughness parameters (Sa, Sq …) give more significant values but require specialized methods and equipment. Profile roughness parameters are described in BS EN ISO 4287 that provides terms, definitions and surface texture parameters for profile roughness parameters and the ISO 25178 which provides similar for the area roughness parameters [7, 8]. Figure 2 presents some of the parameters that can be used to quantify a surface profile regarding its roughness according to BS EN ISO 4287 [9]. In the figure, R_a corresponds to the arithmetic mean roughness, R_p is the maximum peak height, R_v is the maximum valley depth and R_z is the linear distance between top peak and base valley.

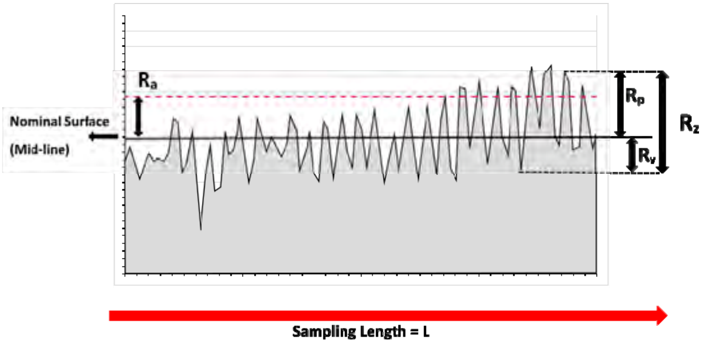

Figure 2. Quantifying scheme of surface profile roughness parameters.

A common characteristic of the contact methods involving a stylus e.g. the KES-F method is that they measure what could be described as the “mean” geometrical characteristics of the fabric and are not designed to represent the specific geometry of the fabric that is being examined. In the case of the KES-F system this is illustrated by the size of the surface sensor which compared to the actual “step” of the common number of threads per unit length used in fabrics results in measurement of groups of yarns as one. Furthermore, these methods require expensive, specialized equipment and complex methods.

Additionally, regarding measuring methods involving a laser, there are a number of challenges that are due to the nature of lasers as well as the nature of textile materials. These challenges include, the difficulty of measuring white or very light coloured materials, the need for precise and full alignment of fabric samples when measuring the profile of a specific surface features (e.g. valleys) – a condition that is difficult to achieve due to the flexible nature of fabrics and the errors that can appear due to lighting or speed of exposure.

In this paper, an objective method for visualizing the 3D profile of a fabric surface based on analysis of images of the fabric cross section obtained using stereoscopic microscopy. Advantages of this method are its simplicity, speed of execution, and low cost. Several fabrics were analysed, and their surface roughness was calculated as a percentage of the indentations between warp yarns that appear on the surface of the fabrics.

2. EXPERIMENTAL

2.1. Materials

This paper presents the study of the influence of weave patterns and yarn density on the surface roughness of woven fabrics using image processing of fabric cross-section photographs obtained through a stereoscopic microscope. The surface roughness of twelve fabrics, in total, was investigated (Figure 3).

Figure 3. Fabric samples

The yarns used in the warp direction for all fabrics were 100% Polyester with a linear density of 300 Denier and a density of 24 yarns/ cm. In the weft direction a conductive yarn (silver) was woven periodically in the fabric structure (every 14 non-conductive yarns). The conductive yarns used were of two different electrical resistance values and two different yarn counts, namely, 100 Ω/m (235x2 dTex) and 300 Ω/m (117x2 dTex). The non-conductive yarns in the weft direction were 100% Polyester, with a yarns linear density of 300 Denier and a yarn density of either 15 yarns/ cm or 20 yarns/ cm. Three different weave patterns were used, plain weave, twill and sateen. The variable structural parameters of the samples are presented in Table 1.

Table 1. Structural parameters of samples

Sample	Weaving pattern	Weft yarn density (yarns/cm)	Electrical resistance of conductive yarns (Ω/m)
N4/15_100	Plain	15	100
ST/15_100	Satin	15	100
S4/15_100	Twill	15	100
N4/15_300	Plain	15	300
ST/15_300	Satin	15	300
S4/15_300	Twill	15	300
N4/20_100	Plain	20	100
ST/20_100	Satin	20	100
S4/20_100	Twill	20	100
N4/20_300	Plain	20	300
ST/20_300	Satin	20	300
S4/20_300	Twill	20	300

2.2. Procedures

An example of the cross-section of the specimens can be seen in Figure 4. The specimen was cut along the conductive yarn. This option offered greater visibility of the specimen structure.

The fabrics surface roughness was determined as a percentage of the indentations created on the surface of the fabrics by the "voids" between the warp yarns. The indentations were determined by obtaining cross-sections of the fabric samples that were then photographed under a stereoscopic microscope. Five specimens (photographs) were obtained for each sample. The photographs were analysed using ImageJ, a Java-based image processing program developed in the public domain, and the area that corresponded to the voids was determined as a percentage of the total area of the photograph. A visual representation of the definition of the void areas and the calculation of the corresponding area values can be seen in Figure 5.

The photographs were cropped so that they only included the specimen and then the areas lacking material were outlined and the area was measured (i.e. the number of pixels in the areas was determined). The measurement of the numbers of pixels in any given outlined area is a feature of the ImageJ software and actual results of measurement can be seen in Figure 5 (column named Area). Comparing Figure 4 and Figure 5 the tight cropping of the photograph of the fabric cross-section is evident, as is the definition of the void areas, which are also numbered from 1 to 10 in Figure 5. Summarizing, the roughness of the specimen (expressed as a percentage) equals, the sum of the number of pixels that comprise the void areas, divided by the total number of pixels that comprise the whole of the fabric cross-section, multiplied by 100.

Figure 4. Fabric cross-section photograph

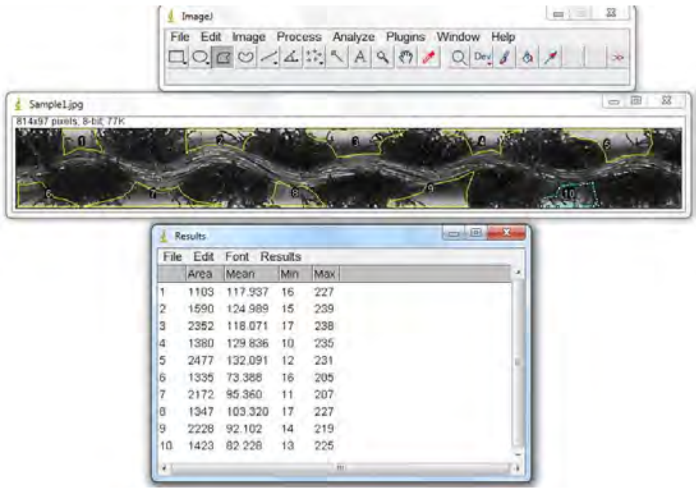

Figure 5. Measurement method

Surface roughness (%) = Sum of pixels in the void areas/ Total number of pixels in the cross-section photo x 100

3. RESULTS AND DISCUSSION

Before presenting the results of the roughness measurements for the samples, an ideal graphic representation of the cross section of the weaves used for the production of the fabric samples can be seen in Figure 6. Considering roughness as a relationship between area which can be defined as either a) area with material and b) a "void" area, where there is no material, we can classify the three patterns starting with plain weave as the one theoretically resulting in the roughest fabric and the satin weave as the one resulting in the least rough fabric.

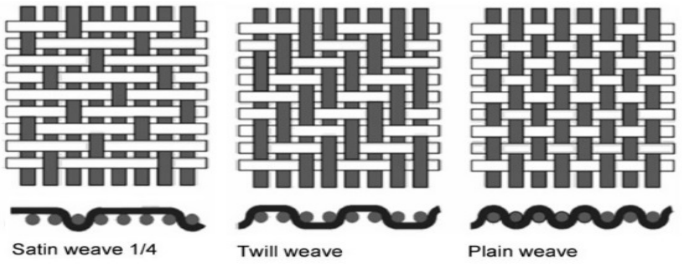

Figure 6. Cross section of weaving patterns [10]

The results for the determination of the surface roughness are presented in Figures 7 and 8. These figures illustrate the effect of the different number of yarns per unit length within the same weaving pattern. From these results it becomes evident that for all the weaving patterns an increase of 5 yarns per cm produces a less rough surface.

Furthermore, in these same Figures 7 & 8, the effect of the different weaving pattern onto a specific yarn density is presented. It can be seen that either yarn density the classification of the weaves regarding their roughness follows the assumption that was established in the beginning of this section. That is, the plain weave samples exhibit a higher roughness than either the twill or satin samples. It should be noted that even though the results for each category presented here are distinct, the overall the results do not present a significant spread of values over a wide range.

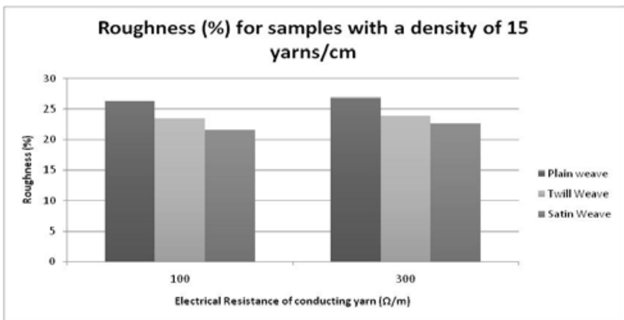

Figure 7. Roughness results for samples with a density of 15 yarns/ cm

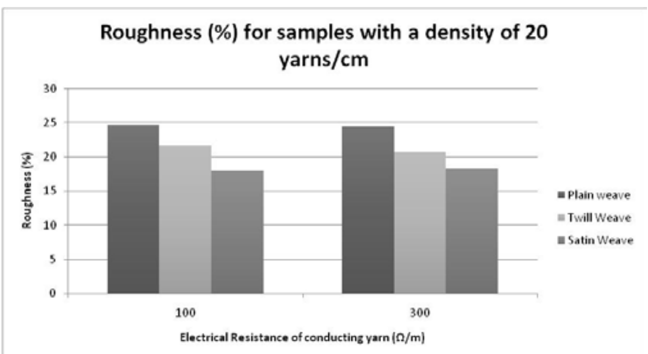

Figure 8. Roughness results for samples with a density of 20 yarns/ cm

4. CONCLUSIONS

An innovative method for the determination of the surface roughness of fabrics was proposed. The method was based on the examination of the cross-section of the fabrics and the expression of roughness as the ratio of areas that did not include material over the total area of the cross-section. The results obtained by using the method on a set of 12 fabrics to measure their roughness indicated a good agreement with what was described in theory of fabric structures. In summary, the surface roughness of the samples with a yarn density of 15 yarns/ cm was higher than the roughness of the samples with a density of 20 yarns/ cm. Additionally it was noticed that the highest roughness values were observed on the plain weave samples, while the lowest ones were observed on the sateen weave samples. In addition, using this method not only the fabric surface, but also the internal structure of the fabric is taken in to consideration, so the results can be associated with fabric handle. On the other hand during the research it was noted that due to the small dimensions of the specimens, the number of repetitions per specimen is a critical parameter of the method. Finally, further research is necessary in the applicability of the method on fabrics containing yarns with high hairiness or loose (low twist) structure as well as fabrics with different compositions (wool/ cotton) and different weave patterns.

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