Contribution of fibres to the visual perception of fabric roughness

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Roughness is a measure of the surface texture of fabrics, which is never ideally smooth. In general, it depends upon fibre properties, yarn count, yarn twist, and fabric structure (weft and warp density, as well as fabric design). Texture as a complex of sight and touch can be investigated by either mechanical methods, through friction or optical methods. The aim of this research is to determine the degree to which fibre count influences the visual perception, firstly by subjective evaluation and then by image analysis. The research showed that optical methods are sensitive enough to distinguish the increase of fabric roughness coming from increased fibre count, while human eyes are unable to make a distinction.
Key words: *visual perception, fabric roughness, fabric texture, fibre count*

1. Introduction

Fabrics are never ideally smooth. Their texture varies between fine and coarse, quantified through the surface's vertical deviation. Fabric roughness, or its opposite smoothness, is employed as measure of the surface texture of fabrics. In general, texture depends upon fibre properties, yarn count, yarn twist, and fabric structure (weft and warp density, as well as fabric design).

Together with style and colour, texture is often a characteristic examined when purchasing clothes. Visual perception is sufficient for examining style and colour, whereas texture requires an additional tactile examination. Colour is precisely defined by colour systems enabling accurate simulation in diverse media (e.g. fabric, prints, on-screen). Texture on the other hand is a complex of two senses, thus it can be examined mechanically, through friction forces, or through optical methods. Examples of both methods of fabric texture examination can be seen in literature.

Ajayi [1] examined fabric roughness through characterising the resistance against motion on the fabric surface, with smoother fabrics showing a lower coefficient of friction. Fabric roughness is an important contributor to fabric handle, included as smoothness (Numeri) in Kawabata's total hand value (THV). The KES-F system also uses a mechanical method for roughness determination, by determining the coefficient of friction and the geometrical surface roughness.

The perception of fabric texture depends as well on its optical characteristics. Optical properties of fabrics have been examined since 1917 [2]. Optical methods were traditionally used to characterize colour. Kobsa, Rubin et al. created a model for predicting the fabrics' optical properties by treating each filament separately [3], followed by similar investigation for multifilament [4]. Their results indicate that the quantity of dyestuff to obtain a certain tone depth depends inversely from the square root of the filament count. Bae [5] studied the change and evenness of colour in relation to the fabric surface when printing. More recently, optical methods were dedicated to 3D modelling and visualisation of textiles [6, 7].

Investigations into the combination of tactile and visual roughness assessment gave interesting results. Two separate researches (Guest and Spence [8], Tomovska and Zafirova [9]) confirmed that the visual and tactile cues act as independent sources of information. Rather than improving the assessment of roughness, the combination of touch and sight divides the attention of evaluators. Accordingly, sight and touch bring the same information in the perception complex. These results can be explained through the development of tactile memory. With the development of experience the sense of touch and sight grow closer together, making the need to touch a familiar object to know its tactile properties superfluous.

Image analysis is an objective method used to define the surface properties of fabrics. The key application of image analysis is in quality control, for identifying fabric failures [10]. Additionally, it can be used to identify woven structure, along with finding application in different research, e.g. unevenness [11]. Similarly, image analysis is appropriate for researching roughness as a fabric surface parameter.

Few authors have investigated the relationship between fabric roughness and fibre count. Recently, Akdun et al. [12] briefly addressed the subject, through reflectance method, concluding that fabrics with the finest fibre count are smoothest. For that reason, the aim of this research is to determine if fibre count influences the visual perception, by subjective evaluation and than by image analysis.

2. Experimental

2.1. Fabric samples

The research used nine fabric samples woven for the purpose. The weaving process was conducted with a carefully controlled loom setting, using the same loom in order to avoid parameter variation due to loom setting as much as possible. Apart from fibre count, all input parameters in the fabrics' design were kept constant. The raw materials were 100 % acrylic staple fibres, with a count of 2.2 dtex, 3.3 dtex and 5.0 dtex. They were spun in a yarn with a nominal count of T_t=25x2 tex, and yarn twist of T_m=530 m^{-1}, used both as warp and weft during sample production. Samples were woven in 3-harness twill. In addition, samples were designed in three different weft densities.

2.2. Results for fibre, yarn and fabric tests

Fibre fineness was measured on a sample of 25 fibres by a vibration method, using a Lenzing vibroscope, (DIN 53812/2). The results and standard deviations of the fibre tests are given in Tab.1. Yarn count was measured by a skeins method, (MKS F.S2.050) and number of twist on simple twist tester (MKS F.S2.021). Yarn test results, as well as deviation are presented in Tab.2.

From the obtained yarns with different fibre count three sets of fabrics were woven, with designed weft count (c_w) 17, 15 and 13 cm^{-1}. The designed warp count was 23 cm^{-1}. The obtained fabrics' structural parameters by warp (c_{wa}) and weft (c_w), weft crimp (U_w), fabric mass (M) and thickness (D) are shown in Tab.3.

2.3. Subjective and objective measurement of fabric texture

Firstly, a subjective evaluation of fabric texture by five expert evaluators was conducted. Each sample, from a set of 3 samples with the same weft set, was graded by comparison with the other two, as follows: (0) – if the sample was smoother compared to a sample from the set; (1) – if the sample was rougher compared to a sample from the set; or (1/2) – if the sample had the same or similar roughness compared to a sample from the set. Further on, the same method was used to compare each sample with the total set of 9 samples.

Image analysis was used to objectively measure fabric texture. In order to conduct the analysis an instrument for obtaining an image with standard lighting and a PC with software for processing and analysing the image are required. The examined samples were digitized by scanning them with an Epson Stylus SX115, with a resolution of 1200x1200 dpi. The samples are shown on Fig.1. Image analysis was conducted using Adobe Photoshop software. To avoid the influence of colour the pictures were converted to achromatic (grayscale). One of the parameters generated by Photoshop is the percentage of black (K%), a numerical value representing the grayscale sample images in general. This parameter allows the comparison of the percentage of black in sample images, i.e. defining lighter and darker samples. As K values in Photoshop were measured in pixels, to obtain uniformity the pixels number of each image was kept constant. To determine the grayscale on the whole sample surface, i.e. the average K value for all pixels, the filter Blur average is used. Using this option shades in the image are mixed till one shade is obtained, obtaining the image average colour.

In addition, grayscale histograms were drafted (Fig.2), showing the distribution of pixels in an image through

Tab.1 Fibre count

Declared fibre count (dtex)	2.2	3.3	5.0
Count (dtex)	2.25	3.39	5.00
Standard deviation (dtex)	±0.18	±0.43	±0.28

Tab.2 Structural parameters of designed yarn, T_t=25x2tex

Declared fibre count (dtex)	2.2	3.3	5.0
Yarn count (tex)	24.78x2	25.54	25.82
Standard deviation (dtex)	±0.45	±0.48	±0.28
Yarn twist (m^{-1})	542.00	539.00	539.00
Standard deviation (m^{-1})	±36.00	±35.00	±45.00

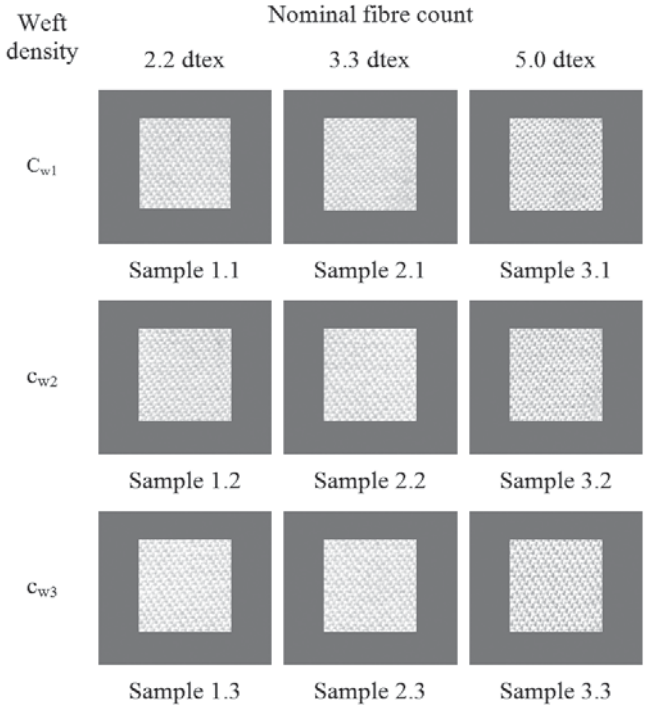

Fig.1 Scanned samples images

research, human vision can not adequately distinguish differences in fabric roughness.

When evaluating fabric roughness in relation to the fibre used in yarn formation, roughness will depend on the hairiness of yarns and their unevenness. With ring spun yarns hairiness depends upon the number of fibres in a defined yarn length, as it changes the number of protruding fibre ends. With more fibres in the yarn cross section (finer fibres), there are more fibres in the yarn length, consequently more protruding fibre ends.

This relationship can be seen on the histograms obtained by the image analysis of samples given in Fig.2. The different curve shape results from the different intensity of light on the fabric surface. As all other parameters were kept the same this difference is a result from the different fi-

grouping together pixels of each intensity of grey. Greyscale histograms give information on the different shades of grey in the image, as well as pixel distribution in light and dark grey shades.

The grayscale is placed on the histogram's abscissa, starting from black (0) to white (255). The ordinate shows the number of pixels in each shade of grey. Data on the mean, standard deviation, median, total number of pixels, and specific data for each point (colour intensity, number of pixels, and cumulative number of pixels) can also be read from the histograms.

3. Discussion

Sampling design ensured that the input parameters were with minimal variation. From Tab.1 it is visible that fibres of 3.3 dtex showed the largest deviation from the declared fibre count, whilst those of 5 dtex the least; whereas deviations from the nominative yarn count and twist were minimal, Tab.2.

The initial subjective visual grading of roughness on fabric samples showed that the evaluators were un-

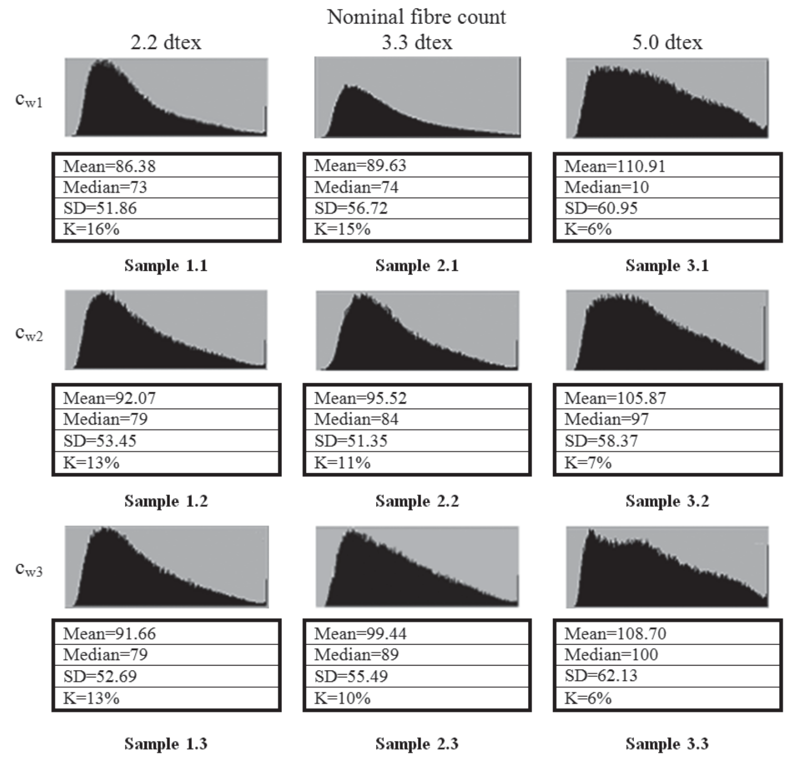

Fig.2 Analysed histograms of scanned samples images

able to perceive a difference. The grade was mostly 1/2 for all the samples. Also, the evaluators were unable to perceive any difference of the scanned fabrics. It should be stressed that all evaluators were textile experts. Although three subjective evaluations were conducted the results did not enable grading the samples, leading to the conclusion that, in this

Tab.3 Fabric parameters

Fibre count	2.2 dtex			3.3 dtex			5.0 dtex		
Sample Param.	1.1	1.2	1.3	2.1	2.2	2.3	3.1	3.2	3.3
c_{wa} (cm^{-1})	23.0	23.0	23.0	23.5	23.0	23.0	22.5	23.0	22.5
c_w (cm^{-1})	17.5	16.0	14.0	18.0	16.5	14.5	17.0	16.0	14.5
u_w (%)	6.0	5.3	4.0	6.6	4.6	4.0	6.0	4.0	3.3
M (g/m^2)	207	196	187	227	210	203	218	207	197
D (mm)	0.65	0.64	0.63	0.74	0.67	0.71	0.77	0.76	0.76

bre count. For samples made from finer fibres (1.1, 1.2, 1.3, 2.1, 2.2 and 2.3) the histogram curves are similar, showing a distinct peak. On the other hand, for samples 3.1, 3.2 and 3.3, the histogram curves have a flatter, less distinctive peak. All fabric samples have a rough surface, consequently the light that falls on the surface is reflected diffusely. A distinct curve peak is an indicator of a smooth fabric, showing the contrast between lit and shady areas. On the opposite, a flatter peak points out that the fabric surface is rougher. The value of black (K) in the fabric image declines from K=16 for sample 1.1, the smoothest fabric, to K=6 for sample 3.1, the roughest examined fabric, in relation to fibre count.

The increase in fibre count (samples 1.1, 2.1 and 3.1) leads to an increased average light intensity, for sample 1.1 it increases from mean value of 86.38 for fibres with a count of 2.2 dtex to a mean value of 110 for fibres with a count of 5 dtex. The same trend can be noticed with the other two series of samples with the same weft density.

The distribution of grey on the histogram is also influenced by weft density. By decreasing the weft count (samples 1.1, 1.2 and 1.3), the average intensity of light increases from a mean value of 86.38 for fabrics with weft density of 17.5 cm^{-1} to a mean value of 91.66 for fabrics with a weft density of 4 cm^{-1}.

4. Conclusion

The research shows that fibre count does not influence the subjective visual perception of fabric roughness, indicating that consumers would not be able to distinguish differences in fabric made of different fibre count, with the same input parameters, in either in-store or electronic shopping.

On the other hand, using an optical method, such as image analysis, demonstrates that an increase in fibre count leads to an increase in fabric roughness. In addition, fabric roughness is reversely proportional to the fabric set. From a manufacturer's point of view, it is important to know this relationship, as it will influence reflection of light from the fabric, therefore the visual perception of colour and finishing of fabrics.

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