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Double-layer Fabrics with Folk Motives. Experimental and Theoretical Study of their Characteristics

DOI: 10.5604/12303666.1221743

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Abstract
Nowadays authentic textile motifs are becoming very popular. The latest fashion trends show that the expressed relief and texture of fabrics are common. Combining these two tendencies, 8 fabrics of two-layer spatial structure were woven. It was established that the area density increases after finishing, the breaking force decreases, and the elongation at break increases. The abrasion resistance depends on the fabric structure. If fabric is woven with part A, the abrasion resistance increases after finishing, and if it is woven without part A, the abrasion resistance decreases. Theoretical calculation of area density of two-layer fabrics is presented. The formula suggested is accurate because the error is low.

Key words: *double-layer fabrics, Lithuanian folk motives, fabric structure design.*

Introduction

Folk textile investigations and reconstructions have been described by scientists in different countries. For instance, Kumpikaitė, Nėnienė and Kot [1 - 4] investigated weaves and patterns of Lithuanian folk skirts as well as their territorial and chronological distributions, and created a database of the skirts for the National M. K. Čiurlionis Museum of Art. Nėnienė analysed home and clothing textile of the 19th – 21st centuries in the Zanavykai region of Lithuania, and published a scientific monograph [5] containing over 300 drawings of fabric ornaments, made by Kumpikaitė. Also Kumpikaitė, Ragaišienė & Nėnienė [6] investigated an album of fabric pieces from the National M. K. Čiurlionis Museum of Art, composed by Gukovska in the 19th century, and analysed their classical and specific yarns, patterns, technical documentation, plan of weave making etc.

Kumpikaitė, Ragaišienė, Rukuižienė, Kot & Nenartavičiūtė [7 - 10] analysed home textile of the Lithuania Minor region. Authors analysed the yarns and fabrics of home textile of this region of Lithuania and used them in a contemporary ecological way of life. They prepared plans of the weave and manufactured 31 reconstructions of bedspreads, towels, tablecloths etc., woven by hand and an industrial weaving loom. Kumpikaitė, Ragaišienė and Nėnienė [11] investigated the weaves and patterns of Lithuanian folk skirts and home textile fabrics, as well as their chronological and territorial distribution, the use of colour threads in fancy fabrics, the plans of weave and other peculiarities.

Cybulska [12] describes the main properties of textiles, showing how important the awareness of their role is to all who deal with textiles, starting with artists and designers, conservators and critics and finishing with visitors to galleries and museums. Historical textiles, contemporary textile art and industrial textile products just seem to be separated independent worlds, yet in fact they influence each other.

Priberga [13] presented a scientifically substantiated openwork textile handicraft classification system which integrates, analyses and describes the types of lace which belong to the ancient lace handicraft technology group. When structuring and classifying, the systematized information and database allow different level users, both in Latvia and abroad, to obtain necessary information on various research directions and incorporate it into a single European information space. Jansone, Zommere and Kukle [14] investigated the composition principles of Zemgale national costume bronze sheet metal crowns and the organization of symbols and motifs used in Latvian patterned belts. They also tried to evaluate clothing values through national culture studies and analysed the influence of cultural values on clothing consumption behaviour.

However, analyses of the weaves and ornaments of textile heritage require describing ornaments not only in semantic and historical aspects, but also using scientific principles of classification. Thus Woods [15] noticed that every ornament in all spheres of human life is composed according to a particular symmetry law. Comparison of ornaments from all over the world have become possible due to Woods' symmetry classification system.

Woods [15] stated that any (textile, ceramics, printed, sculpture, architecture etc.) ornament could be described by 4 symmetry operations: translation, rotation, reflection and glide-reflection. Woods and later Hann [16], analysing different ornaments, proved that there are 17 different symmetry groups formed from points in perpendicular lines, and that they can make 5 geometrical shapes: a parallelogram, rectangle, square, rhombus and hexagon. Woods [15] suggested a system of classification and notation of two-directional ornaments based on the rules of geometry and crystallography. Also he proposed a system of classification of one-directional ornaments, the structure of which is based on crystallography theory, subsequently improved by Hann [16]. Making two-directional ornaments by the Woods-Hann method, motifs are translated in two non-perpendicular directions. This classification system can be used by many researchers for ornament analysis, classification and designing.

The results of analysis conducted applying Woods-Hann methods proved the necessity to correct and adapt this system to the investigation of woven ornament. The ornament structure and stepped line of the contour checked create the peculiarities of woven ornaments and their design – the symmetry axes and centres of ornaments may be between threads and through them. Applying this system to textile ornaments, corrections have been made by Milašius, Taylor (Neverauskienė), Katunskis and Kazlauskienė [17 - 20]. The authors investigated the symmetry groups' distribution in Lithuanian pick-up sashes and overshot fabrics and established that one-directional symmetry groups absolutely dominate in Lithuanian pick-up sashes. Fabrics symmetrical in both the warp and weft directions are the most popular. On the other hand, this symmetry was not obtained at all in overshot fabrics. In these fabrics two-directional symmetry groups with 4 symmetry axes were dominant.

However, paying attention to the fashion trends presented at the home textile exhibition "Heimtextil", we can see that the fabrics in which the unity of science and beauty are connected are topical. The hand, spatial texture and sense of textile are also very important. Thus it is relevant to look for new woven fabric structures which can give spatial effect and expressive the relief and texture of the fabric [21].

Thus a spatial two-layer structure of woven fabrics, as presented in reference [22] was used for the creation of fabrics with expressed relief in line with the motifs of folk fabrics. The use of folk motifs in everyday garments is an absolutely new development of home textile in contemporary human life. The relation of folk motifs to the new spatial double-layer woven structure and its use in modern home textiles also coincides with the newest fashion trends. Because of the absolutely new fabric structure, it is very important to check if the fabric corresponds to its purpose using experimental and theoretical investigation of its properties.

The goal of a study was to adapt previously created methodology for the weaving of new structure fabrics created using ethnic fabric motifs, and to evaluate their functionality theoretically and experimentally by testing their consuming features.

Methods

Double-layer spatial fabrics were woven with special rapier looms - Itema R9500 (Italy), by means of which fabrics could be woven from two warp beams with different tensions. The warp of the face layer was cotton yarn 20 tex × 2, and the back layer warp was plain linen yarn 38 tex. The weft was in two colours (white and blue). The setting of the warp was 200 dm^{-1}, and the setting of the weft was different in various parts of the fabric. The ratio of warp and weft layers of the two-layer fabrics was 1 face thread and 1 back thread. Fabrics woven with dual spatial structure methodology are shown in ***Figure 1***. In part A, two separate layers of the same setting and the number of threads are woven. In part B just the face layer is woven, which is twice denser in the weft direction, leaving the back warp not woven. In part C both layers of the fabric – the face and back warp are located in one layer. While all three parts (A, B and C) or just the B and C parts can be woven. The second case is more expressed, but narrower fabric weaves are accessed.

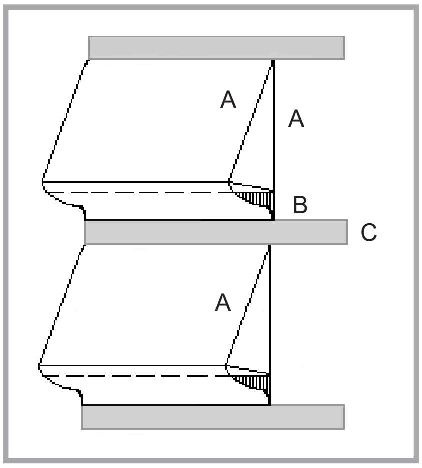


Figure 1. *Two-layer dimensional fabric structure scheme.*

Assessing functionality and compliance with their purpose, some characteristics of a fabric have been identified: area density, breaking force, elongation at break and abrasion resistance.

The area density of cut samples was established in accordance with the international standard ISO 12127. Fabric samples were weighted by an EW 150-3M electronic balance (Kern & Sohn GmbH, Germany).

Fabric tensile tests were carried out in accordance with the international standard ISO 13934-1 [15], at standard weather conditions (temperature of 20 ± 2 °C and relative humidity of 65 ± 2%), with the use of a Zwick/Z005 (Switzerland) standard tensile testing machine. The stretching speed was 100 mm/min, and the distance between clamps was 200 mm.

The yarns were tested on standard test equipment using standard test methods. The abrasion resistance of fabric with fancy yarn samples was assessed on a Martindale Abrasion and Pilling Tester MESDAN-LAB, Code 2561E (SDL ATLAS, England), in accordance with the standard ISO 12947-2.

The fabrics were conditioned at a temperature of 20 ± 2 °C and relative humidity of 65 ± 2%, as specified in the standard ISO 139:2005.

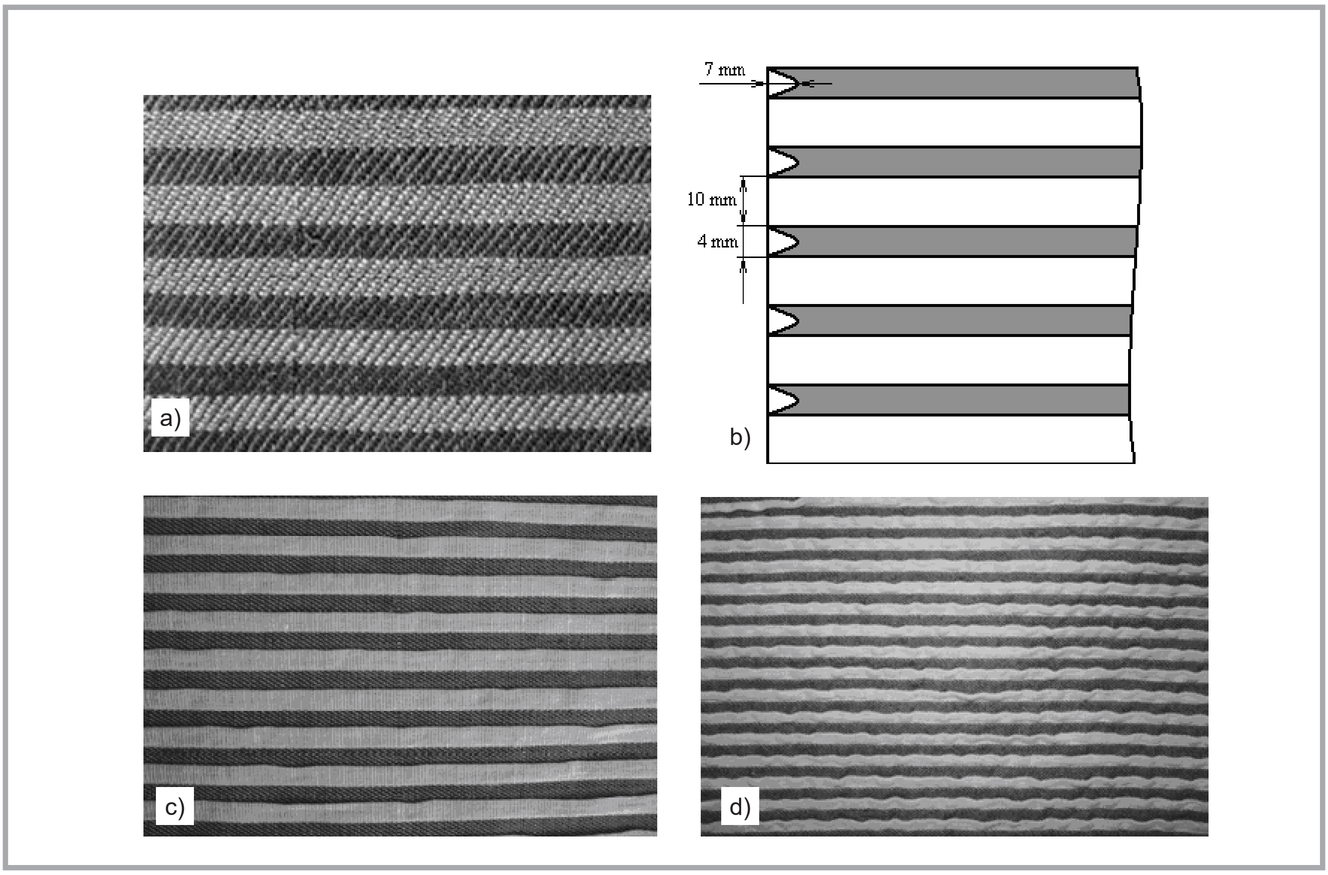


Figure 2. *Fabric Magic-1: a) original fabric, b) fabric design, c) grey fabric, d) finished fabric.*

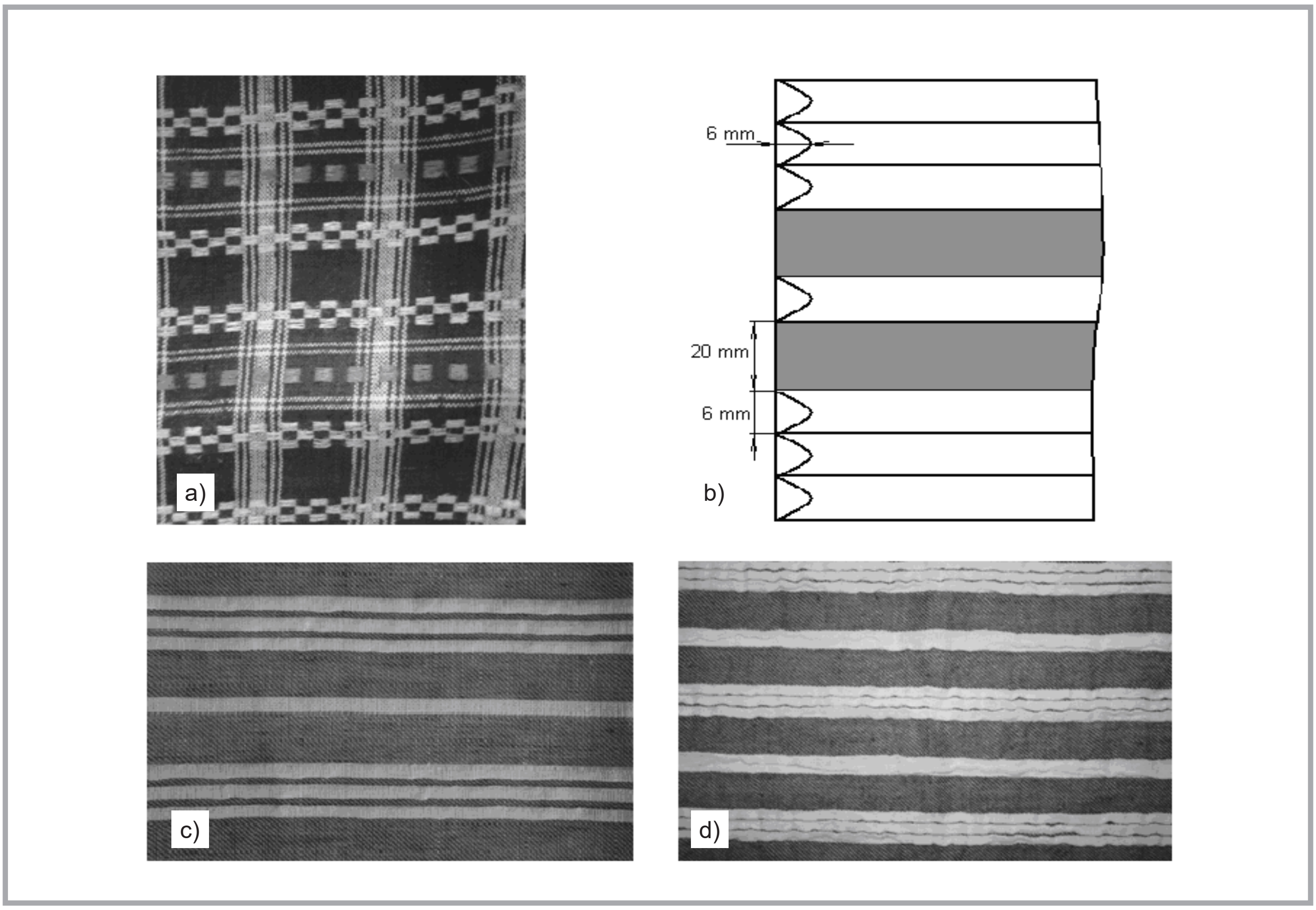


Figure 3. *Fabric Magic-2: a) original fabric, b) fabric design, c) grey fabric, d) finished fabric.*

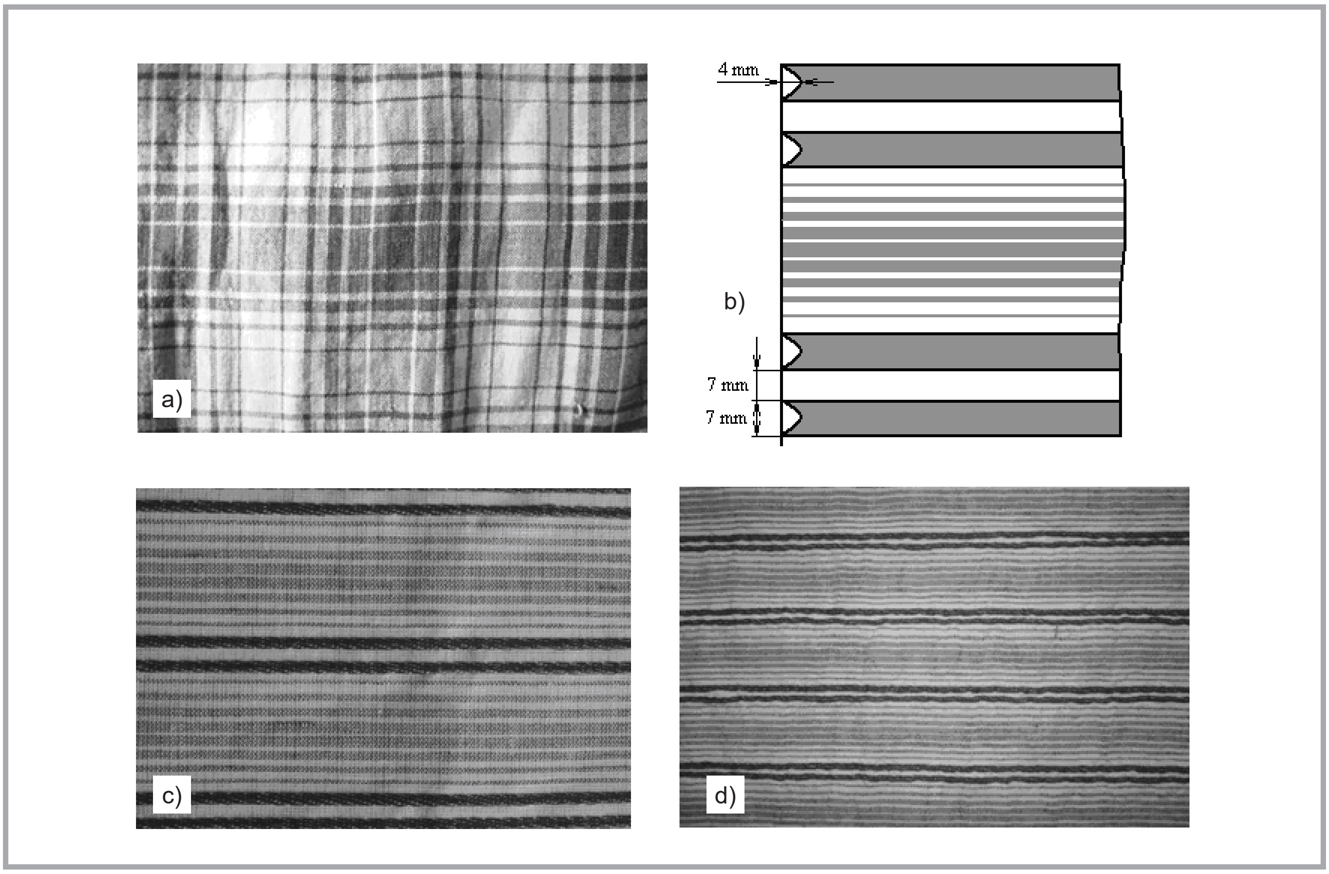


Figure 4. *Fabric Magic-3: a) original fabric, b) fabric design, c) grey fabric, d) finished fabric.*

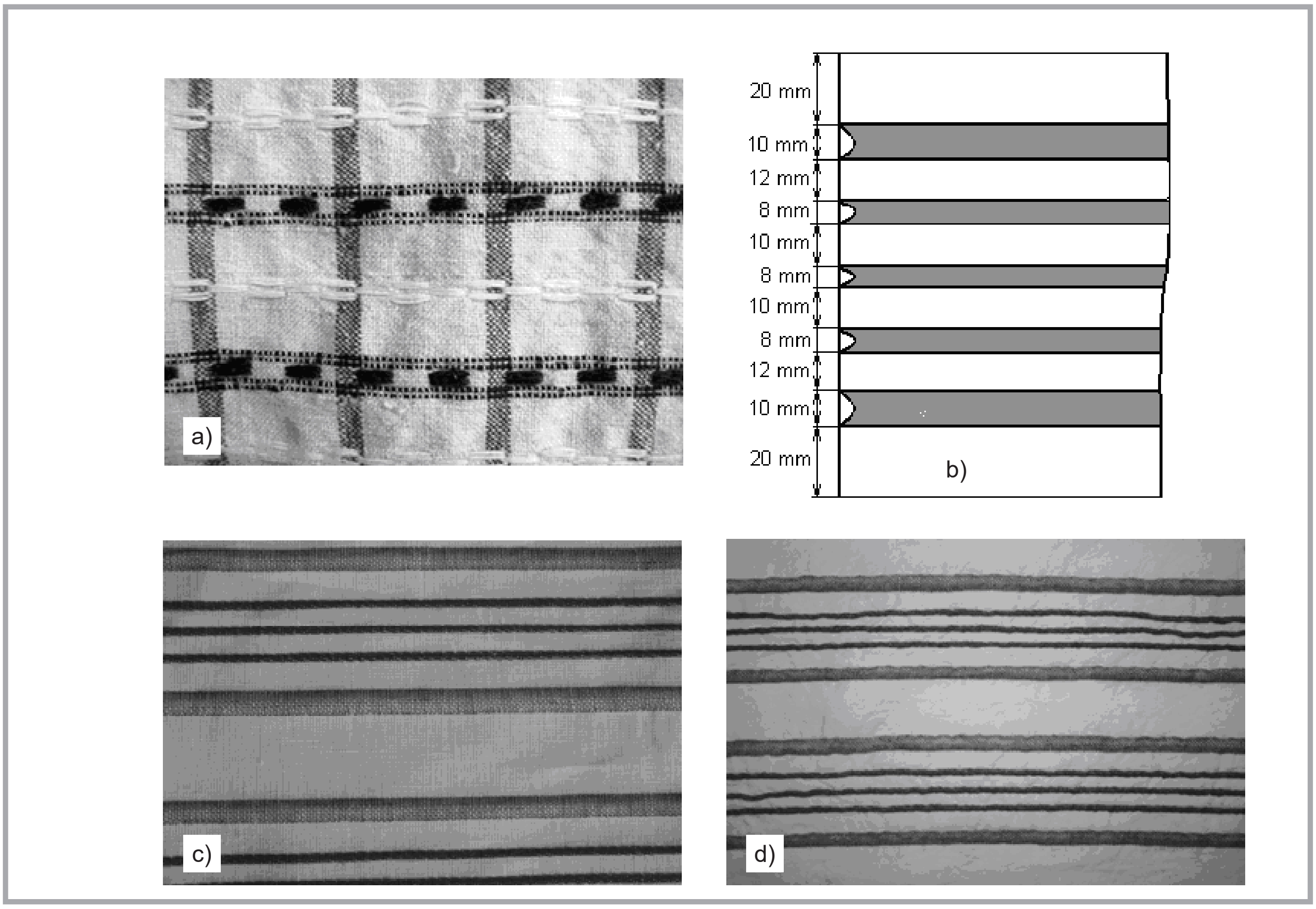


Figure 5. *Fabric Magic-4: a) original fabric, b) fabric design, c) grey fabric, d) finished fabric.*

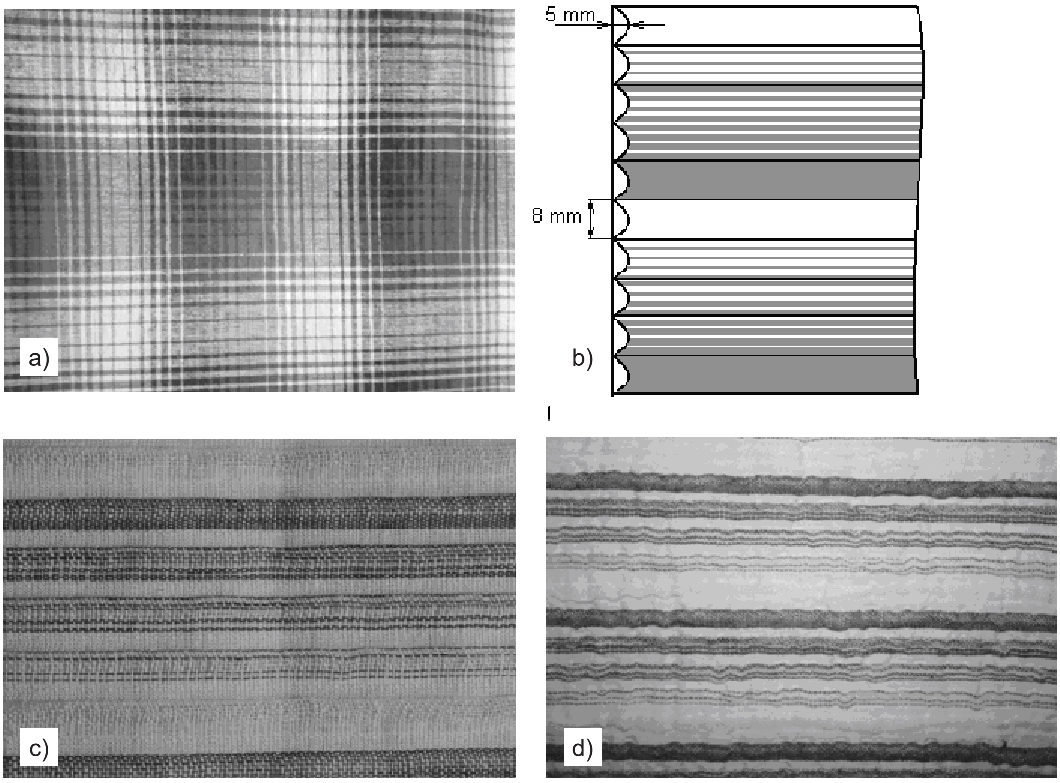


Figure 6. Fabric Magic-5: a) original fabric, b) fabric design, c) grey fabric, d) finished fabric.

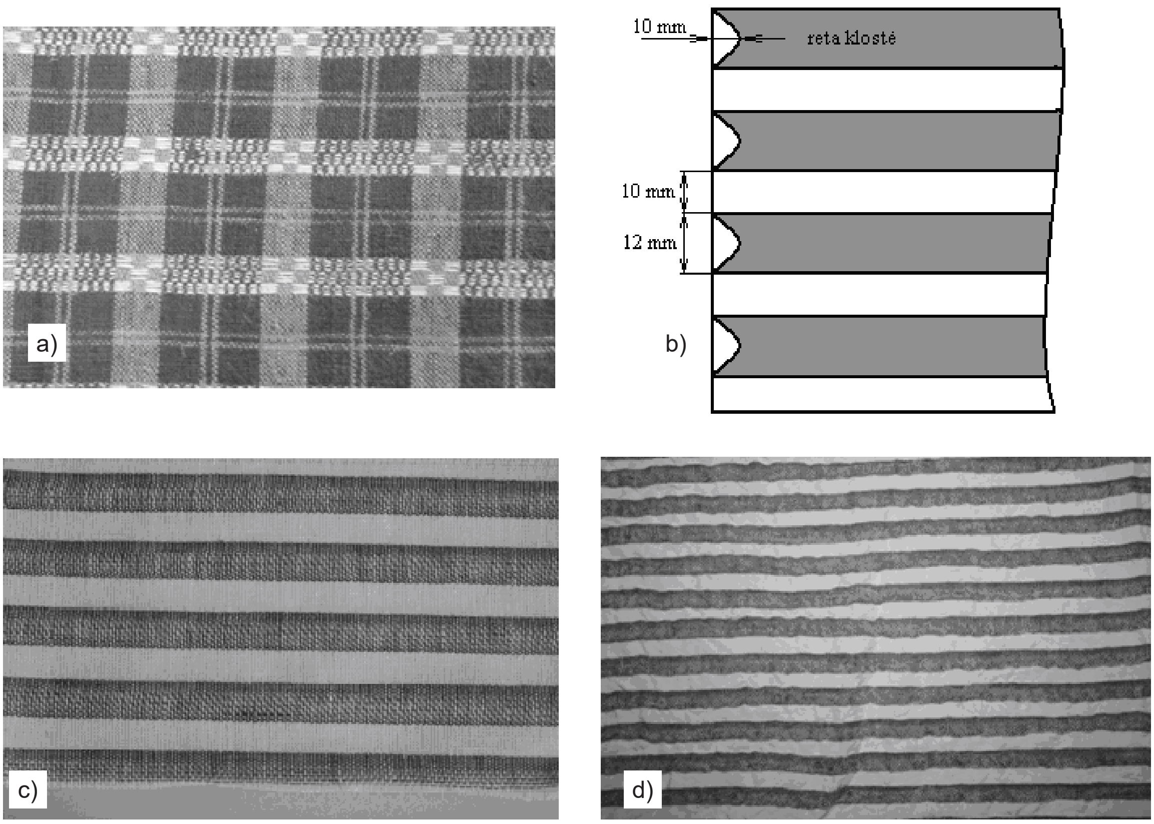


Figure 7. Fabric Magic-6: a) original fabric, b) fabric design, c) grey fabric, d) finished fabric.

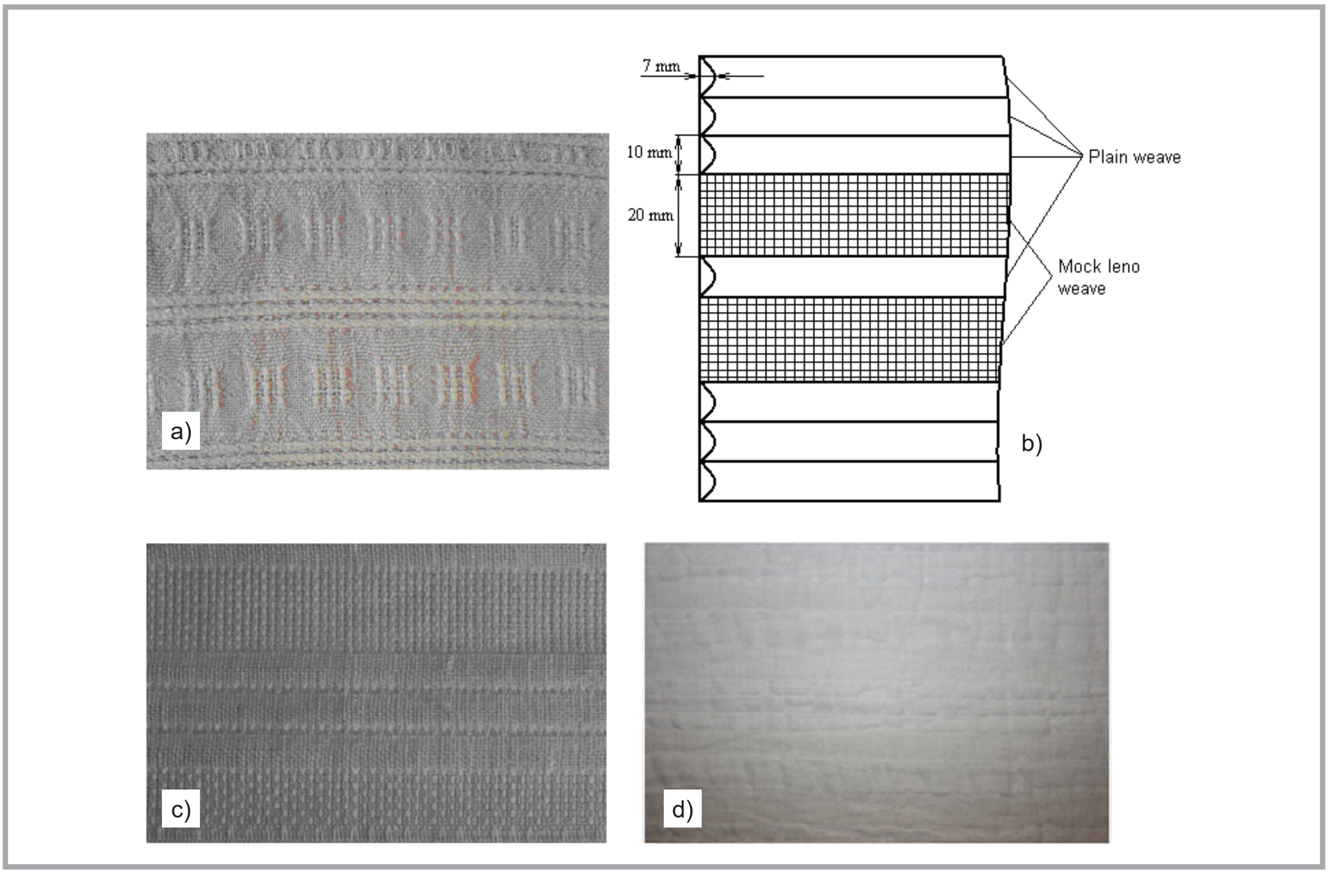


Figure 8. *Fabric Magic-7: a) original fabric, b) fabric design, c) grey fabric, d) finished fabric.*

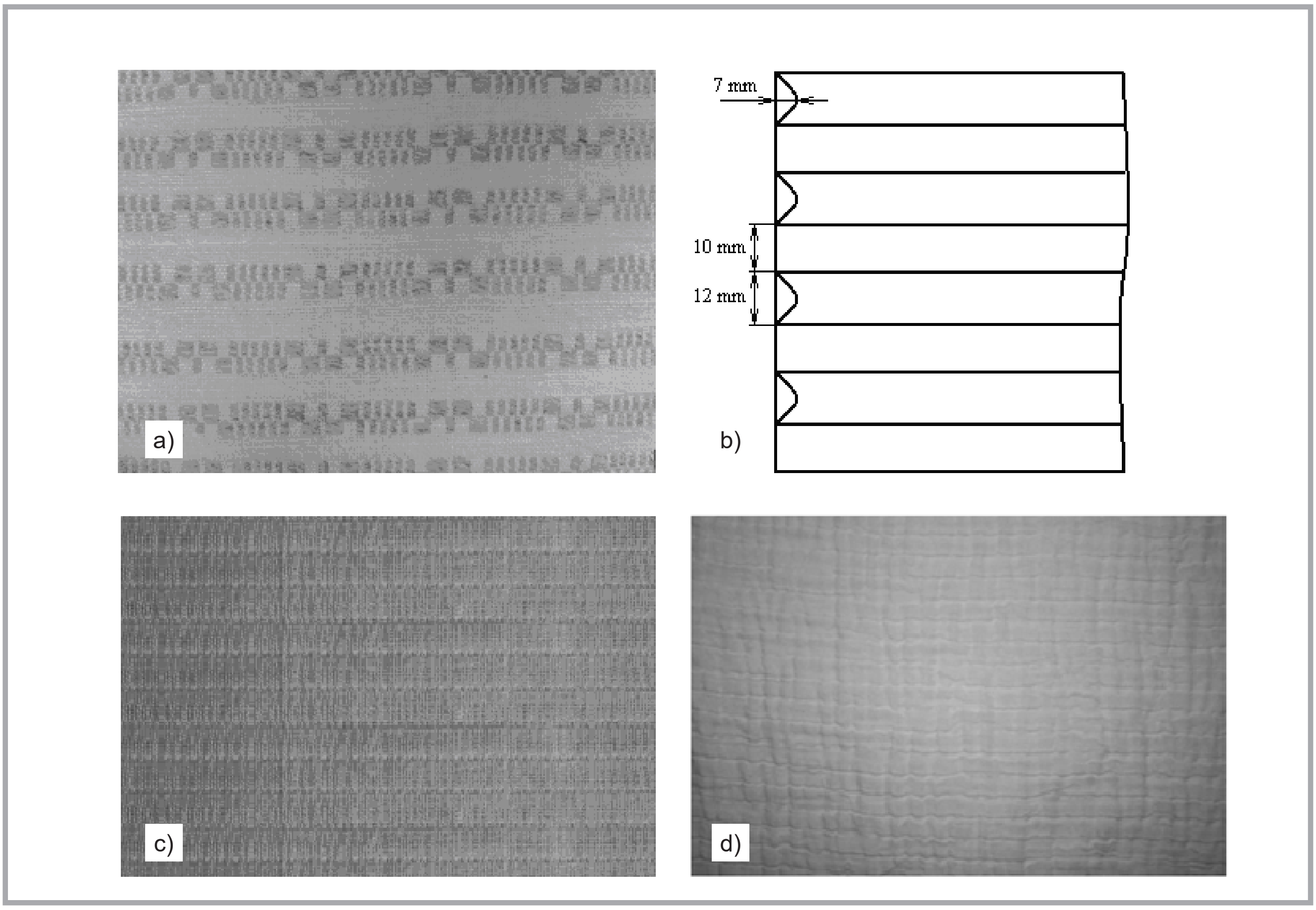


Figure 9. *Fabric Magic-8: a) original fabric, b) fabric design, c) grey fabric, d) finished fabric.*

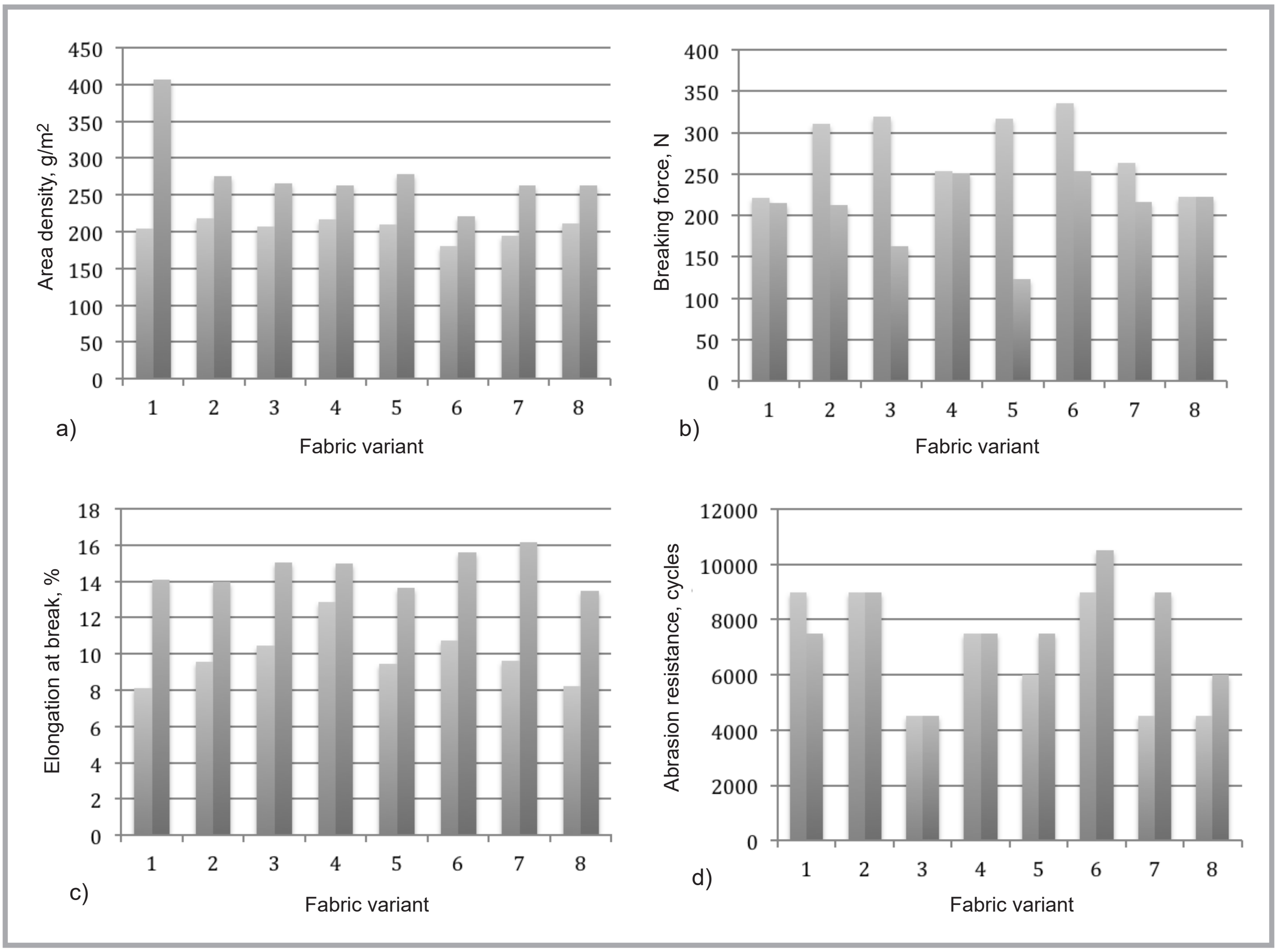


Figure 10. *Characteristics of two-layer fabrics: a - area density, g/m², b - breaking force, c - elongation at break, %, d - abrasion resistance, cycles.* ▒ *grey,* ▒ *finished.*

Results

Recently both in Europe and around the world, cosmopolitan ideas are spreading, but it is very important and relevant to return to our roots of authenticity and preservation of national identity. Therefore this article describes a collection of 8 two-layer spatial fabrics made using the above-mentioned fabric structure and ethnic grounds. Created and woven fabrics are shown in ***Figures 2 - 9***. As the fabrics needed to be woven on uniform fabric rapier looms, the weaving patterns were more or less modified compared with fabric prototypes shown in the Figures. For this reason, in most cases the new fabric patterns were formed in the horizontal direction. Thus in all figures shown the fabric prototype and its design are grey and finished fabric images.

In order to investigate the compliance of the fabrics produced, their purpose and suitability for purpose, properties such as area density, breaking force, elongation at break, and fabric abrasion resistance were examined, shown in the bar diagram in ***Figure 10***. From this it can be seen that in all finished fabrics the area density is higher than in the grey fabric, because finishing release yarns in the fabric, hence the threads become closer to each other, and their setting increases in both directions, whereby the fabric becomes heavier. The elongation at break of grey fabric (***Figure 10.b***) is higher than in the finished one. Fabrics at finishing experience both chemical and mechanical stresses which may adversely affect the fabric strength. For this reason the breaking force of finished fabric can be reduced. However, the elongation at break in the finished fabric is bigger than in the grey one (***Figure 10.c***). After finishing, fabrics become soft, their yarns wavy, and they have a rumble effect. Therefore fabrics become more elastic, and the fabric elongation at break after finishing becomes higher. As for the two-layer fabric abrasion resistance (***Figure 10.d***), in grey and finished fabric abrasion resistance is distributed differently. In one cases this fabric property is higher in grey fabrics, and in other cases - after finishing. As noted above, double-layer fabrics may be woven with part A or without it (see, ***Figure 1***). It was noticed that weaving with part A (5 - 8 fabrics), the abrasion resistance increases after finishing. Weaving without part A (1 - 4 fabrics) the abrasion resistance either remains the same or decreases after finishing. This can be a result of the fabric structure because weaving with part A in this field both the warp and weft setting is twice lower than in the one-layer place. Therefore in the abrasion process threads in this area after finishing are closer together and the abrasion resistance of the finished fabric increases.

Comparing the results of the 2nd and 7th fabrics before and after finishing, radial graphs were drawn, presented in ***Figure 11***. These fabrics are different in structure, i.e. in the second fabric there are A, B and C places (see. ***Figure 1***), but in the seventh one - only B and C places. The chart shows that the area density of

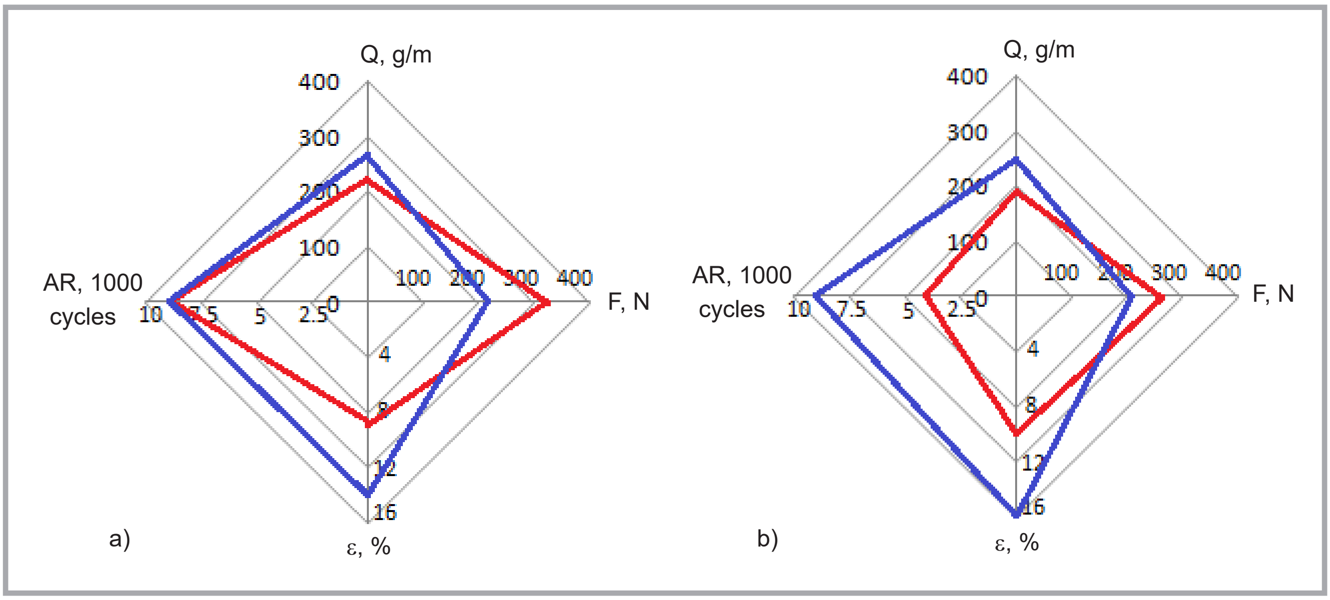


Figure 11. *Characteristic diagram of second (a) and seventh (b) fabrics.* —— *grey,* —— *finished.*

both fabrics after finishing increased, which is not a good phenomenon because these fabrics are generally heavy, and therefore low area density would be an advantage. The breaking force after finishing decreased in both fabrics, which is also a disadvantage because it shows that the fabric after finishing has weakened. The elongation at break of the two fabrics after finishing increased, which is an advantage because the fabrics become more elastic. Abrasion resistance in the second fabric did not change after finishing, and the seventh fabric after finishing became more resistant to abrasion. Thus it can be said that after finishing most of the two-layer fabric properties worsen or remain the same, with only the elasticity of the fabric improving. Therefore the choice of whether to use grey or finished fabric can only be affected by the properties of the finished product required.

During the research, a methodology and formula of two-layer spatial fabric was proposed which formula can help to determine its area density. Below is the calculation of the formula proposed (1) - (4): where T_{mv} - face warp linear density, S_{mv} - face warp setting of two-layer place, α_{mv} - warp crimp of the face layer of a two-layer place, T_{ma} - back warp linear density, S_{ma} - back warp setting of two-layer place, α_{mv} - warp crimp of the back layer of a two-layer place, T_{av} - face weft linear density, S_{av} - face weft setting of two-layer place, α_{av} - weft crimp of the upper layer of a two-layer place, T_{aa} - back weft linear density, S_{aa}

$$Q_t = \sum_{n}^{i=1}\left(\frac{T_{mv}S_{mv}}{\left(1-\frac{\alpha_{mv}}{100}\right)}+\frac{T_{ma}S_{ma}}{\left(1-\frac{\alpha_{ma}}{100}\right)}+\frac{T_{av}S_{av}}{\left(1-\frac{\alpha_{av}}{100}\right)}+\frac{T_{aa}S_{aa}}{1-\frac{\alpha_{aa}}{100}}\right)k_2+\sum_{m}^{j=1}\left(\frac{T_{mb}S_{mb}}{\left(1-\frac{\alpha_{mb}}{100}\right)}+\frac{T_{ab}S_{ab}}{\left(1-\frac{\alpha_{ab}}{100}\right)}\right)k_1 \quad (1)$$

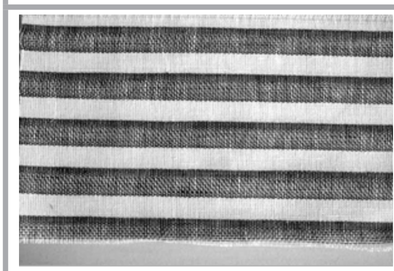
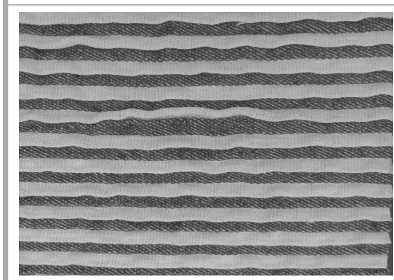
$$T_{mb} = \frac{T_{mv}+T_{ma}}{2} \quad (2)$$

$$S_{av} = \frac{k'S_{av1}+k''S_{av2}}{k'+k''} \quad (3)$$

$$S_{aa} = \frac{k'S_{aa1}}{k'+k''} \quad (4)$$

Equations 1, 2, 3 and 4.

Table 1. *Theoretical and experimental area density data.*

View of fabric	Theoretical area density, g/m2	Experimental area density, g/m2	Error, %
 Parts A, B and C	183.16	180.44	1.5
 Parts B and C	215.04	220.62	2.6

- back weft setting of two-layer place, α_{aa} - weft crimp of the back layer of a two-layer place, T_{mb} - warp linear density in one-layer place, S_{mb} - warp setting in one-layer place, α_{mb} - warp crimp in one-layer place, T_{ab} - weft linear density in one-layer place, S_{ab} - weft setting in one-layer place, α_{mb} - weft crimp in one-layer place, S_{av1} - face weft setting in part A (see, ***Figure 1***), S_{av2} - face weft setting in part B (see, ***Figure 1***), S_{aa1} - weft setting in part A (see, ***Figure 1***), k_1 - one-layer part of the fabric repeat, k_2 - two-layer part of the fabric repeat, *k'* - part A of a two-layer fabric part, *k"*- part B of a two-layer fabric part.

After calculations it was estimated that the fabric consists of one-layer and two-layer fabric parts, with the latter also made up of two areas (A and B), wherein the weft setting is different. The most difficult is to determine the fabric's weft crimp, because the same warp is woven both in the field of the two-layer and one-layer. In order to correctly determine the outline of places with different fabric fields, a double-layer fabric place was coloured with a colourful marker. Meanwhile a one-layer part was left uncoloured. Thus by removing the warp thread of the fabric, it was clear which part of the thread can be woven into one-layer or two-layer fabric parts. The colourful thread place was determined as that of two-layer fabric and the area of white space as that of one-layer fabric.

The investigation revealed the theoretical Q_t and experimental Q_p area density of the two fabrics. Using formula (5), the theoretical area density error was found. Data are presented in ***Table 1***.

Because the area density calculation error in both cases is low (up to 5%), it can be said that the method of calculation and formulas proposed (1) - (4) are applicable to calculation of the spatial fabric area density of a two-layer structure.

Conclusions

1. Selected folk fabric prototype motifs and two-layer spatial fabrics of unique structure and relief can be woven with new textile technology and equipment.

2. It was found that the area density of the fabric increases after finishing, the fabric strength decreases, and the elongation at break increases. These trends are a result of the finishing changing the fabric structure.

3. Finishing influences the abrasion resistance twofold depending on the fabric structure selected. The fabric woven with places A, B and C show increased abrasion resistance after finishing. Meanwhile the abrasion resistance of fabrics woven with only B and C places have less or equal abrasion-resistance to that of the finished fabric.

4. The two-layer fabric area density calculation procedure proposed is suitable for theoretical area density calculations, because the calculation error is low (not exceeding 5%).

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Received 13.04.2015 Reviewed 22.06.2015