KAUNAS UNIVERSITY OF TECHNOLOGY

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DEVELOPMENT OF SPATIAL DOUBLE-LAYER WOVEN FABRICS USING LITHUANIAN FOLK TEXTILE MOTIFS AND INVESTIGATION OF THEIR PROPERTIES

Summary of Doctoral Dissertation
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LIUCINA KOT

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INTRODUCTION

Justification of the investigation problem and the relevance of the thesis. Recently, in the light of the rapid development of the global industry and technology including the textile field, a need has arisen for the creation of fabrics characterized by a new structure, relief and original appearance as well as the possibility of weaving by using modern textile equipment. Such modern weaving looms are distinguished by their specific construction that enables to weave by using two warp beams with different warp tensions.

Taking advantage of the construction of this type of weaving loom, as well as new chemical and mechanical finishing possibilities, double-layered spatial fabrics distinguished by expressive relief and wavy surface reflecting the recent trends in the textile introduced in the world textile exhibitions can be designed and manufactured. The fabrics of expressive relief are denoted by natural fibres because they are environmentally friendly and friendly to the nature and the human body, which is particularly appreciated in modern industry and prevails in fashion trends. Authentic patterns and ornamentation of fabrics reflecting traditional textile is associated with modern, expressive and new textile structures. The manufacture of the modern textile thus inherently requires equipment of special construction.

The spread of the ideas of cosmopolitanism in the modern world show us that it is important to look back at the origins of the nation in the general European context which are also relevant in the textile industry of today, as well as at everything that is natural and authentic. Therefore, textile designers by creating spatial fabrics of the innovative double-layer structure aim to unite folk motifs of fabrics with the new spatial fabric structure which can be fulfilled with modern weaving looms. The employed fabrics can be grey and finished; during the finishing, they are being softened with chemical and mechanical implements. Therefore, the finishing significantly changes the appearance and properties of fabrics: after the finishing, the fabrics become softer, fluffier and assume wrinkling. Due to its smooth and rigid surface, grey fabric can be used for home and decorative textile, whereas the finished fabric can be used in the production of clothing due to its softness and fluffiness.

Therefore, such fabrics combine the patterns of the traditional classic textile and the peculiarities of ornamentation recommended in the fashion trends of the recent years with their new double-layer spatial structure of fabric proposed in the work. Fashionable and marketable newly created fabrics introduced in the range of fabrics are manufactured by *Klasikinė Tekstilė* Company and are used for home decoration, decorative textile as well as clothing. The company has introduced these fabrics in major international textile exhibitions where the newly created fabrics have been generating great interest among the manufacturers of textile and clothing.

Objective of the thesis. To create fabrics of the new double-layered structure based on the ethnographic fabric patterns and to evaluate the effect of the finishing on the properties of these fabrics.

Goals of the thesis:

1. To identify, study and compare the weaves, patterns and symmetry groups of folk skirts and home textile.
2. To create the methodology for the weave of double-layered spatial fabrics thus selecting the most appropriate way for the implementation of the objective.
3. To create spatial fabrics characterized by a new double-layered structure based on folk textile patterns.
4. To investigate the end-use and mechanical properties of the produced fabrics by considering the effect on finishing on them.
5. To create a prediction method for spatial double-layer fabric area density calculation based on the designed fabric settings parameters.

Scientific novelty and practical value of the thesis. The problems related to the design of fabrics characterized by the double-layered structure are particularly acute for the contemporary designers of fabrics – both for the employees and the designers of textile companies. In order to apply the new design fabric for everyday use, the new designs of new structure linen fabrics developed during the thesis are fitted to the industrial production of fabrics by providing guidelines for the fulfilment of the requirements by using the modern weaving equipment.

The thesis proposed and designed the fabrics featuring a double-layered spatial structure which has never previously been used in industrial textile. Several variants for the implementation of the new structure woven by different Lithuanian textile companies are suggested in the thesis. Fabrics of original structure can be woven by using weaving looms of special construction which are able to supply the warp of the two warp beams with different tensions. This may result in the formation of two fabric layers of different lengths. In addition, the novelty is that the fabrics were created on the grounds of folk fabric patterns, because of the recent trends being related to naturalness and authenticity which is frequently reflected in the modern textile. When creating fabrics of a new structure, it is appropriate to carry out analysis of traditional textile fabrics, to examine the patterns, motifs and ornamentation of folk fabrics with the view to implement them in modern, contemporary fabrics and to introduce them in the assortment of modern enterprises.

The developed fabrics are relevant both in the world of applied arts as the objects of an innovative textile design and the field of industrial textile expanding the possibilities of textile companies in their assortment. The preparation of data setting and plans of weave and their presentation to the manufacturers in an acceptable form can be used through the presentation of recommendations for the process of manufacturing of modern industrial textile fabrics. During previous studies, considerable attention was paid to the mechanical and end-use properties of fabrics. However, the above mentioned studies mainly dealt with single-layer classic fabrics, while the properties of the presented double-layer fabrics can vary significantly.

Therefore, the study of new double-layered fabrics is also an important innovative part of the study. It is essential not only to study experimentally the properties of double-layer fabrics but also to offer their theoretical evaluation methods. One of the fabric parameters characterizing the compliance of the fabric with its objective is the area density of fabrics. The manufacturers would like to predict it before the start of the manufacturing process. For this purpose, theoretical and reasonably accurate assessment of the relevant property of the fabric in order to determine the area density of double-layered spatial fabrics based on the primary settings of the fabric in the weaving loom is relevant. The thesis presents the new formula for the calculation of area density of double-layered spatial fabrics allowing sufficiently accurate prognostication of the said parameter of the fabric.

Since the fabrics are characterized in terms of a new and previously unused structure, consequently, it is difficult to predict their properties as well as the effect of finishing on these properties. It is therefore important to study the changes in fabric properties after finishing. For their rigidity and plain surface, grey fabrics are more suitable for the home and decorative textile use, and the finished ones would be more appropriate for clothing fabrics for their softness and pleasant hand.

Thesis statements to be defended:

1. Spatial double-layers of fabric can be woven by using loop, a plane fabrics weaving loom and a weaving loom with 2 warp beams with different levels of warp tension.
2. Double-layered fabrics of the new expressive relief structure based on folk motifs can be manufactured by using the proposed methodology for the weaving of double-layered spatial fabrics.
3. According to the changes of area density, breaking force and elongation at break of the new double-layered spatial fabrics after the finishing it can be stated if grey fabric is used for home textile or fabric after finishing – for clothes manufacturing.

4. According to the proposed double-layered fabric area density calculation methodology, the fabrics area density can be predicted for up to 10 % accuracy.
5. Finishing effect of the new double-layered fabric woven by using a weaving loom with 2 warp beams with different warp tensions influences their abrasion resistance which depends on the double-layered fabric being woven with part *A* or without it.

Thesis approbation. The topic of the following thesis was presented in 13 scientific publications including three articles published in *Thomson Reuters Web of Knowledge*-listed journals with a citation index (IF/AIF > 0.2), three articles featured in the database of the publications of the Institute for Scientific Information *Thomson Reuters Web of Knowledge* with a citation index (IF ≤ 0.2AIF). The research results were presented at five scientific conferences – three international and two national conferences. Seven reports were presented at conferences in total.

Thesis structure and scope. The thesis consists of the following parts: an introduction, 3 chapters, conclusions, a list of references (170 sources) and the list of the scientific works of the author of the thesis. The subject matter of the thesis is presented in 102 pages containing 14 tables, 44 figures and 6 formulas.

THESIS CONTENT

The **Introduction** presents the justification and the relevance of the study problem, the objective and the goals of thesis, its scientific novelty and practical value as well as the thesis statements to be defended.

Chapter One **Literature Review** presents the ethno-cultural analysis of Lithuanian ethnographic fabrics; it discusses the features of clothing and home textile fabrics in the five ethnographic regions of Lithuania (Aukštaitija, Žemaitija (Samogitia), Dzūkija, Suvalkija and Lithuania Minor). Studies of folk ornaments conducted all over the world as well as in Lithuania tend to analyze the technological aspects through the adaptation of the system for the classification and marking of ornaments. The review of theoretical evaluation methods of ornamentation suggests that some of the works by Lithuanian scientists provide recommendations for the creation of new ornaments by using the traditional system for the classification and marking of ornaments. The studies based on Woods-Hann Crystallography Theory and the fundamental rules on the theory of mathematical groups provided the basis for the comparison of the ornamentation of different nations and different types.

Many scholars discussed in the theoretical part of the thesis study the textile objects in detail; they perform the analysis of symmetry; however, the fabrics of new double-layered spatial structure are not analyzed at all.

Therefore, this thesis analyzes the symmetry groups of weaves and color repeats of the Lithuanian folk fabrics and examines the consumption characteristics of the double-layered fabrics.

Considering the recommendations provided in the scholarly literature by various authors for the creation and manufacturing of modern contemporarily-styled fabrics, the works of modern authors lack new designs based on the patterns of authentic fabrics which actually are particularly marketable and relevant in the textile of today. Especially, the fabrics of expressive structure, embossed and multidimensional fabrics are highly valued. Samples of fabrics of this type are developed and analyzed in the thesis.

For the evaluation of fabrics, the indicators of their properties (area density, breaking force, elongation at break, abrasion resistance) and predictions based on the parameters of the fabric structure are of fundamental importance. A number of properties of fabrics were also studied by Lithuanian and foreign scientists, but most of the reviewed literature sources explore the fabric properties of single-layer classic structure specimens and their modelling as well as the effect of various finishings on the properties of fabrics. As the structure of the fabrics developed in this thesis is completely innovative, the properties of such fabrics have not been examined yet. Therefore, the trends of the change in the characteristics of fabric properties and the way the fabrics are affected after their finishing are fundamental in the light of the research. If the parameters of the fabric structure are known, the theoretical evaluation of the fabric properties is also essential. The thesis analyzes the theoretical evaluation of the area density of double-layered spatial fabrics, which is a fundamental step in assessing the compliance of the fabric with the purpose a fabric is bound to serve.

The thesis presents samples of developed new double-layered fabrics based on folk motifs, and experimentally as well as theoretically evaluates the properties which are important for home textile and clothing fabrics.

Chapter Two **Study Object and Research Methods** describes the study object, i.e. home folk textile fabrics and folk skirts stored in six Lithuanian museums – *LLBM*, *NCDM*, *LNM*, *LAM*, *MLIM* and *SM*. 849 exhibits of home textile and 258 exhibits of folk skirts were analyzed. The investigated museum exhibits were collected from all the five ethnographical regions of Lithuania (Aukštaitija, Žemaitija (Samogitia), Suvalkija, Dzūkija and Lithuania Minor). The second object of the research was the spatial structure double-layered fabrics No. 1, No. 2 and No. 3, which is created by using three different methods and the modern weaving looms of various construction types as well as 8 newly created double-layered fabrics Magija 1, 2, 3, 4, 5, 6, 7, 8 woven on the grounds of the structure of fabric No. 3 while using the motifs of folk fabrics.

The methodology of the study of folk fabrics. The colour repeat, patterns and weaves of folk skirts and home textile and their symmetry groups were identified. All of these parameters were established in two stages. Initially, the researched fabrics were photographed, and their parameters from the photos were set by calculating multi-coloured yarns and analyzing their interlacing from the image on the computer monitor. At the second stage, a more detailed review was carried out by employing an experimental-analytical method involving the use of a needle, a counting glass and a metric ruler; analysis of particular exhibits took place *in situ* in the museums. The colour repeats of folk skirts and home textile were determined organoleptically. Since the fabrics are several centuries old and decolored, the standard color palette was not applied.

Method for analysis of textile ornamentation. Textile ornaments can be classified according to the principles of classical ornamentation, depending on the symmetry groups of fabric patterns. Woven ornaments can be described by four symmetry operations: displacement, rotation, reflection and glide-reflection.

Method for determination of double-layered fabric properties. The methodology for the weave of double-layered spatial fabrics of a new structure, which is one of the main products of the thesis, was developed. The following characteristics of the properties of the created fabrics were determined: area density, breaking force, elongation at break, and abrasion resistance. Double-layered fabrics were tested by using standard laboratory equipment and standard testing methods.

Area density of fabrics *(Q)* was determined by using international standard *ISO 12127*. The samples were weighed with electronic scales *KERN EW 150-3M (Kern & Sohn Gm Bh*, D-72336; max – 150 g; min – 0.02 g).

Fabric tensile tests were carried out according to international standard *ISO13934-1* under standard environmental conditions (temperature 20 ± 2°C; relative humidity 65 ± 2%). For these tests, standard tensile machine *Zwick/Z005* (Switzerland) was used.

Abrasion resistance was determined with *Martindale* abrasion and pilling machine *MESDAN-LAB, Code 2561 (SDL ATLAS*, England) in accordance with *ISO 12947-2* Standard.

The fabrics were conditioned under standard climatic conditions at the air temperature of 20 ± 2°C and relative humidity of 65 ± 2%. These climatic conditions correspond to standard *LST EN ISO 139:2005/A1:2011*.

The finishing operations for the fabrics were washing, rinsing, and softening. The spatial double-layered fabric finishing machine used in the research was *BRONGO 100* (Italy), which performed all the above mentioned finishing operations. The fabrics were washed at 65°C. The dual hot and cold

5 minute rinsing was applied for the fabrics. Moreover, additional operations, such as chemical and mechanical double-layered spatial fabric softening, which took place in an acid medium over 10–15 min. at 40°C (softeners: *LEVAFIX* (*DISTAR*, Germany) and *EVERSOL* (Japan)) were performed.

The reliability of the determination of the fabric properties was assessed by calculating the arithmetic average of the obtained results, the coefficient of variation and the absolute error. These statistical characteristics were calculated on the grounds of the known standard formulas.

Chapter Three presents ***the results of the study: the importance of the ornamentation of folk fabrics for the creation of contemporary textile and symmetry analysis of fabrics for folk skirts.*** The chapter discusses the distribution of patterns, weaves and the ornaments of folk skirts symmetry groups. The summary of the patterns of skirts revealed that the most prevalent are checked fabric patterns. In the second place in terms of popularity were vertically striped patterns, the third most popular type were plane fabrics, and the fourth most common type was found to be fancy fabrics. Fewer fabrics of other patterns (motley, horizontally striped, overlaid, printed) were found – a few units per type.

The plain weave fabrics prevail in the distribution of the weave (143 units). Combined weaves take the second place as they feature in 26 units of skirts. The number of reinforced twill weave fabrics is very similar (24 units). Even fewer diamond twill and broken twill weave fabrics can be found (12 and 11 units, respectively). Thus, it can be stated that fabrics for skirts are mostly woven by using plain and simple weaves.

After analyzing the ornamentation of color repeats of the fabrics, five different symmetry groups were found. Mostly, the symmetry groups of *pmm2* fabrics (32 units) were found, slightly fewer (22–24 units) fabrics of *p111*, *p1m1* and *p2mm* groups of fabrics were found. The least common case was the *pm11* group of skirts (5 units) (Fig. 1).

Distribution of the symmetry groups of the fabrics in terms of the weaves may be quite different. Regarding this distribution, the fabrics of *p111* symmetry group predominate clearly (183 units). These fabrics include plain, elementary, reinforced, fancy, broken twill and satin weaves which are often used in the fabrics for skirts. About 9 times less common are the *pm11*, *p1m1*, *pmm2* and *p2mm* groups of fabrics (17 to 22 units). The least common type (5 units) was detected to be the *p112* symmetry group of fabrics for skirts. Therefore, in summary, the fabrics of folk skirts were mostly woven by using simple weaves, but the variety of their patterns is mostly influenced by the distribution of colors (Fig. 2).

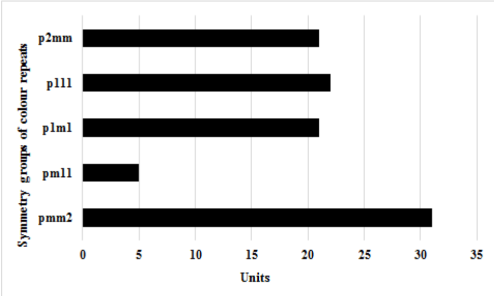


Figure 1. Distribution of color repeats of symmetry groups in skirt fabrics

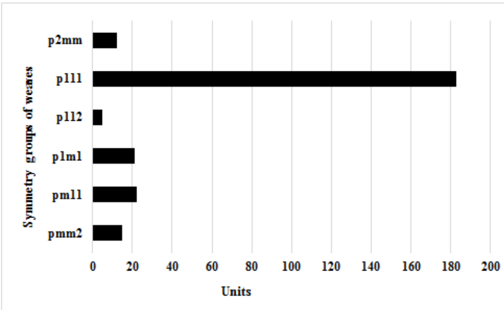


Figure 2. Distribution of weave symmetry groups in skirt fabrics

Analysis of the symmetry of folk home textile. Our summary of the analyzed home-made folk textile serving different purposes of use produced the statement that six types of patterns may be distinguished: plane, fancy, motley, checked, striped and crocheted. Of these, the most common ones are fancy, motley, checked and plane patterns. By using fancy pattern, overshot, checked twill (satin), mock leno, and combined weaves are woven. Motley pattern fabrics are combined with overshot, checked twill (satin) and combined weave. Checked pattern fabrics are usually woven by using the plain weave. Plane fabrics are combined with plain, elementary or reinforced twill weaves. As many as 22 different types of weaves are distinguished in the investigated home textile, where the most prevalent is the checked twill (satin), plain and overshot of four harness weaves. Other weaves in home textile occurred significantly less frequently.

Analysis of the groups of color repeats and weave symmetry according to the classical principles of ornamentation based on the principles of crystallography showed that, in both cases, six groups of the same symmetry type were identified. As for the symmetry groups of color repeats, symmetry group *p111* prevailed quite distinctly (as many as 460 units). The fabrics of other symmetry groups occurred significantly less frequently. The least common symmetry groups were *pm11*, *p2mm* and *pmm2*. Only a few cases of symmetry groups *p1m1* and *p112* were found.

What concerns the symmetry groups of weaves, they also contain more fabrics which were woven by using weave group *p111*, but the dominance of this group is not as prominent as in the case of the symmetry of color repeats. In the field of weave research, four symmetry groups are distributed similarly, i.e. *p111*, *p2mm*, *pmm2* and *p112*. The two remaining symmetry groups (*p1m1* and *pm11*) occurred significantly less frequently.

Creation of new fabrics of the double-layered structure based on traditional textile patterns. Development of the methodology for the weave of double-layer spatial fabrics.

The double-layered spatial fabric structure was obtained in three different ways by using modern industrial weaving looms of different constructions: rapier terry weaving loom *Smit GS940F*, rapier Jacquard loom *Dornier PTS 6/JC* for flat fabrics and rapier weaving loom *Itema R9500* for flat fabrics. Comparison of the three variants of the manufacturing of fabrics leads to the statement that the ways of formation and the possibilities of differences in the weaving looms are essential.

By using the first way, the new double-layered spatial fabrics of the new structure were woven with rapier terry weaving loom *Smit GS940F* (Fig. 3). In part *A*, the back and the face part of the wave are woven. Two separate layers of the fabric are woven. In this part, the setting of wefts is 200 dm^{-1} for both layers. In part *B*, the finishing of the face wave is woven by the interlacing point, i.e. only the face layer of the fabric is formed. In this part, the setting of wefts is 100 dm^{-1} (only for the face layer). In part *C*, the connection of the two layers is carried out. Only one fabric layer is woven, where the terry weaving loom completely beats up the wave formed in the face fabric layer. In this layer, all the fabric warps and all the wefts form one layer with the weft setting of 200 dm^{-1}. Such fabric structure can be formed only with the terry weaving loom, which is equipped with incomplete weft beating-up possibility.

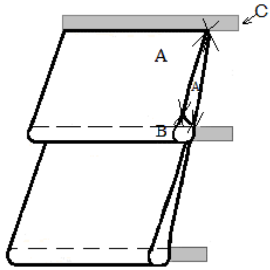


Figure 3. Scheme of the structure of double-layered fabric woven with the terry weaving loom

The right and left sides of fabric No. 1 are woven with the terry rapier weaving loom. They are shown in Figure 4. It is evident that the spatially expressed relief structure of the fabric, which can only be achieved when the face layer of fabric is longer than the back part. It is due to this reason that the relief of the fabric right side is obtained more expressed than the left side. Meanwhile, only the back fabric layer woven in plain weave and the intersection places of the two layers show up on the left side of the fabric.

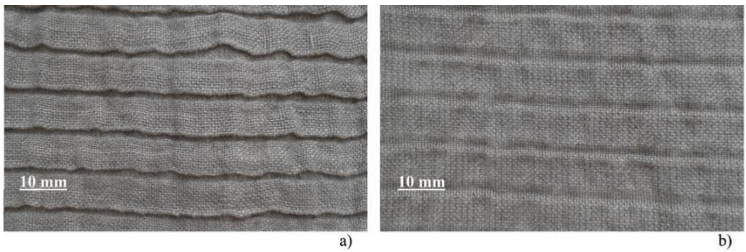


Figure 4. Image of a fabric woven with the terry rapier weaving loom: a – right side; b – left side

The second sample of a double-layered spatial fabric was woven with computerized flat modern rapier Jacquard weaving loom *Dornier PTS 6/JC*. The fabric woven with this loom has a double-layered spatial structure which is obtained when the face layer is longer than the back. In part *A*, these layers are woven at the same time but separately. The weft setting of the face layer is 220 dm^{-1}, the weft setting of the back layer is 110 dm^{-1}, i.e. the weft setting of the face layer is twice as high as that of the back layer which was set by selecting the corresponding ratio of weft yarns in both layers in part *A* of the fabric. The fabric 'waves' formed in both layers are connected by plain weave in part *C*. In this part of the fabric, the setting of wefts was 330 dm^{-1}. The ratio of warp layers was 1 top and 1 bottom. (Fig. 5).

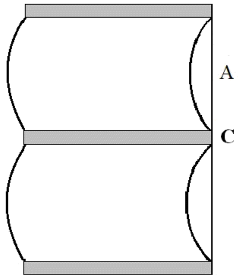


Figure 5. Structure scheme of the spatial double-layered structure fabric woven by a smooth rapier weaving loom

Pictures of the right side and the left side of the fabric woven by using the flat weaving loom are shown in Figure 6. As it is evident from the figure, the fabric may also be characterized by the double-layered spatial structure, but the relief of the right side is not as expressive as that of fabric No. 1, for which, the fabric is formed with the terry weaving loom. The left sides of fabric No. 1 and fabric No. 2 are almost identical.

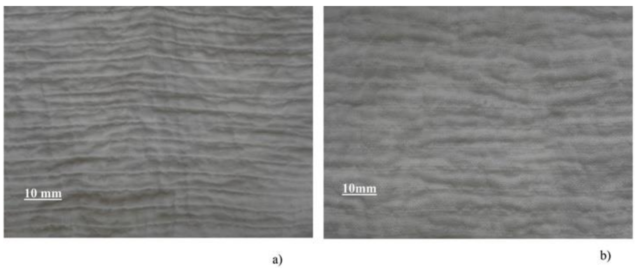


Figure 6. Fabric woven with smooth fabric rapier Jacquard weaving loom: a – right side; b – left side

In the third case, double-layered spatial fabrics were woven with special rapier loom *Itema R9500*. Weaving this way, the setting of wefts was different in different parts of the fabric. The setting of warps was 200 dm^{-1}. In part *A*, two separate layers of equal setting and the number of threads are woven. The weft ratio in part *A* is 1 face and 1 back thread. In part *B*, only the face twice-denser layer in the direction of wefts is woven thus leaving non-woven back warps in the bottom layer. In part *C*, both layers of fabric are woven – the face and back warps are arranged in a single layer. When weaving, either all the three parts of fabric (*A*, *B* and *C*) or only parts *B* and *C* may be formed. In the second case, more prominent but narrower fabric waves are obtained (Fig. 7).

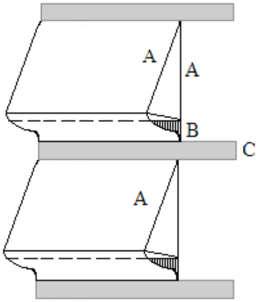


Figure 7. Double-layered spatial fabric structure scheme

The photos of the right and the left sides of fabrics are shown in Figure 8. It is evident that sufficiently expressive relief of fabric is obtained.

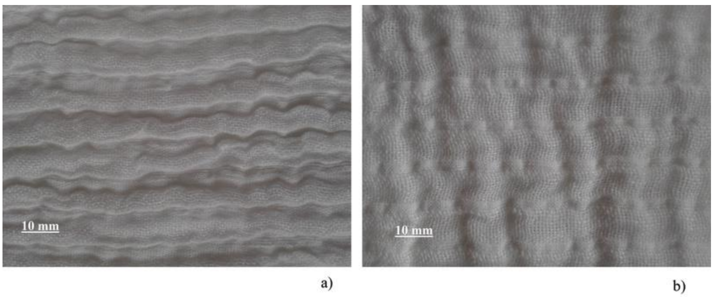


Figure 8. Image of fabric woven by smooth gripper weaving loom *Itema R9500*: a – right side; b – left side.

In order to choose the most appropriate variant of the three newly proposed structures, some characteristics of the properties of fabrics were set: area density, breaking force, elongation at break, and abrasion resistance.

The values of these characteristics related to all the three discussed structures of fabric are outlined in the radial graph shown in Table 1. The best fabric is considered to be the one whose area density is the lowest because the lighter fabrics are preferred and the breaking force, the elongation at break and the abrasion resistance are the greatest. Thus, the analysis of the fabrics of the three different structures leads to the observation that fabric No. 1 is the heaviest (the area density is 515.7 g/m^2), and the area density of fabric No. 3 is the lowest (280 g/m^2). The breaking force of fabric No. 2 is significantly higher than the other two fabrics (it reaches 631.2 N). Meanwhile, the lowest breaking force is shown by fabric No. 1 (246.8 N). The analysis of the trends of the elongation at break showed that fabric No. 3 (14 %) is denoted by the highest elongation, and fabric No 2 has the lowest value (7.24 %). In all the three fabrics, initially, the back layer of the fabric was torn apart, and only then, the face layer started to rip. This happened because the face layer of the fabric in all the fabrics was longer than the back part. As a result, the back layer was tenser. Abrasion resistance of all the three fabrics was the same – all the researched fabrics withstood 7,500 cycles of abrasion. In short, fabric No. 3 showed the highest values of almost all the properties, with the exception of the breaking force of the fabric. Therefore, it was decided to weave double-layered spatial fabrics by using method No. 3.

Table 1. Reliability of fabrics *No. 1, No. 2, No. 3*

Fabrics	Statistical indicators	Property factors			
		Q, g/m^2	*F*, N	*ε*, %	*AD*, cycles
No. 1	*X*	515.71	246.82	10.40	7,500
	V	0.01	2.43	1.13	0
	Δ	0.10	9.64	0.11	0
No. 2	*X*	401.42	631.23	7.24	7,500
	V	0.01	3.20	4.90	0
	Δ	0.10	8.10	0.33	0
No. 3	*X*	280.02	332.11	14.00	7,500
	V	0.01	1.30	2.61	0
	Δ	0.01	5.40	0.25	0

The fabric area density variation coefficient is equal to 0.01, and the absolute prediction error changes from 0 to 0.01 g/m^2, the breaking force variation coefficient ranges from 1.3% to 3.2%, the elongation at break ranges from 1.13% to 4.90%, and all the fabrics withstand the same number of abrasion cycles. Hence their variation coefficients are equal to 0.

Creation of double-layered fabrics of a new structure based on the motifs of Lithuanian folk patterns. During the ethnographic analysis of fabrics, prototypes were selected, according to which, new double-layered fabrics were developed. The selection of the fabrics produced in various Lithuanian regions (manufactured in the 19th century or at the beginning of the 20th century) according to the color repeats and weave symmetry groups was performed. The prototypes were selected according to the four most common color repeat symmetry groups (*p1m1, pmm2, p2mm* and *pm11*), and four weave symmetry groups (*pm11*, *p2mm*, *pmm2* and *p111*) among skirts and home textile fabric samples from different ethnographic regions of Lithuania (Table 2).

In all the types of home (in terms of their purpose) textile fabrics, mostly the white color was chosen as the main color for the development of a new fabric. Other color combinations were chosen according to the color fashion trends offered in *Heimtextile16* exhibition. Based on this analysis and by using the double-layered fabric structure, the work presented a collection of 8 double-layered spatial fabrics which was devised by using ethnographic motifs of Lithuanian fabrics.

Table 2. The prototypes distribution according region and symmetry groups

Fabric	Original fabric	Region	Symmetry groups of color repeats	Symmetry groups of weaves
Magija-1	Bedspread *LM440* (ŠM)	Lithuania Minor	*p1m1**	*p111*
Magija-2	Skirt *E1307* (NČDM)	Suvalkija	*pmm2**	*pm11*
Magija-3	Skirt *E3384* (NČDM)	Aukštaitija	*p2mm**	*p111*
Magija-4	Skirt *E41484* (NČDM)	Suvalkija	*pmm2*	*pm11**
Magija-5	Pillowcase *LBM36364* (LLBM)	Žemaitija (Samogitia)	*p111*	*p111**
Magija-6	Bedspread *EMO2740* (LLBM)	Dzūkija	*pmm2*	*p2mm**
Magija-7	Tablecloth *LBM36333* (LLBM)	Aukštaitija	*p111*	*pmm2**
Magija-8	Tablecloth *LDM6712* (LDM)	Lithuania Minor	*pm11**	*p1m1*

The thesis describes and analyses the collection of 8 double-layered spatial fabrics which was created by using a double-layered fabric structure based on folk fabrics. One of the created and woven double-layered fabrics is shown in Figure 9. The fabric texture in fabric *Magija-1* (Fig. 9) is formed only from parts *B* and *C* of the fabric. Part *C*, which combines both fabric layers, is woven with blue wefts, and in part *B*, where only the top fabric layer is woven thus creating expressive waves on the surface of the fabric, is woven with white linen wefts. Part *C* is woven in 1/3 twill weave, and in part *B*, both layers are woven in plain weave. This fabric is created by bedspread *LM440 (SM)*, which was woven in Lithuania Minor by using the color repeats of symmetry group *p1m1*, which is one of the most popular symmetry groups.

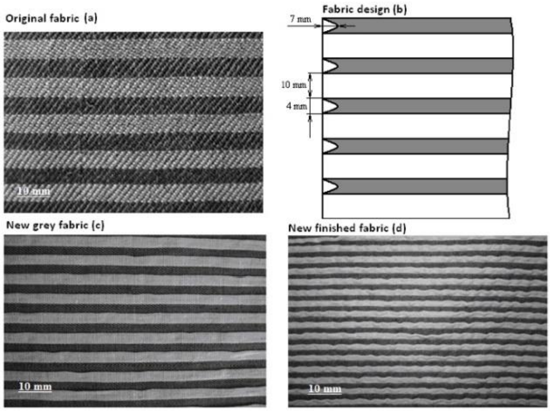


Figure 9. Fabric *Magija-1*: a) original fabric, bedspread *LM440* (SM) woven in Lithuania Minor by using color repeat symmetry group *p1m1*; b) fabric design; c) grey fabric; d) finished fabric

Figure 10 presents double-layered fabric *Magija-4* created on the basis of skirt *E41484 (NCDM)* woven in Suvalkija by using weave symmetry group *pm11*.

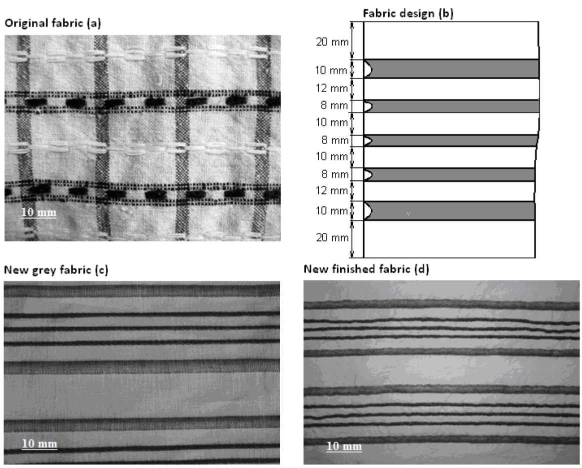


Figure 10. Fabric *Magija-4*: a) original fabric, skirt *E41484* (NCDM) woven in Suvalkija by using weave symmetry group *pm11*; b) fabric design; c) grey fabric; d) finished fabric

Experimental and theoretical assessment of the properties of new double-layered fabrics. In order to investigate and compare the main properties of newly manufactured double-layered fabrics (in terms of mass, strength, extensibility, and abrasion resistance) and their changes after finishing, the following characteristics of the fabrics were identified and studied: area density, breaking force and elongation at break as well as fabric abrasion resistance.

In the general case, the area density of the double-layered fabric can be calculated by using the following formulas (1) – (4):

$$Q_e = \sum_{n}^{i=1}\left(\frac{T_{mv}S_{mv}}{1-\frac{\alpha_{mv}}{100}} + \frac{T_{ma}S_{ma}}{1-\frac{\alpha_{ma}}{100}} + \frac{T_{av}S_{av}}{1-\frac{\alpha_{av}}{100}} + \frac{T_{aa}S_{aa}}{1-\frac{\alpha_{aa}}{100}}\right)k_2 + \quad (1)$$

$$+\sum_{m}^{j=1}\left(\frac{T_{mb}S_{mb}}{1-\frac{\alpha_{ab}}{100}} + \frac{T_{ab}S_{ab}}{1-\frac{\alpha_{ab}}{100}}\right) k_1 ;$$

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

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

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

where T_{mv} is face warp linear density; S_{mv} stands for face warp setting of double-layered place; α_{mv} represents the warp crimp of the face layer of a double-layered place; T_{ma} refers to back warp linear density; S_{ma} denotes back warp setting of double-layered place; α_{mv} is the value of the warp crimp of the back layer of a double-layered place; T_{av} shows face weft linear density; S_{av} is face weft setting of a double-layered place; α_{av} represents the weft crimp of the face layer of a double-layered place; T_{aa} gives the value of back weft linear density; S_{aa} refers to back weft setting of a double-layered place; α_{aa} shows the weft crimp of the back layer of a double-layered place; T_{mb} denotes warp linear density in a single-layer place; S_{mb} represents warp setting in a single-layer place; α_{mb} is warp crimp in a single-layer place; T_{ab} is the value of weft linear density in a single-layer place; S_{ab} shows weft setting in a single-layer place; α_{mb} refers to weft crimp in a single-layer place; S_{av1} represents face weft setting in part *A* (see Figure 7); S_{av2} denotes face weft setting in part B (see Figure 7); S_{aa1} shows weft setting in part A (see Figure 7); k_1 refers to the single-layer part of the fabric repeat; k_2 represents the double-layered part of the fabric repeat; k' is part *A* of the double-layered part of the fabric; k'' denotes part *B* of the double-layered part of the fabric.

In the course of the calculation, it was estimated that the fabric consists of single-layer and double-layered parts of the fabric, and the double-layered part also consists of two parts (*A* and *B*) where the weft settings are different. The experimental settings of all the parts of the fabric are shown in Table 3.

Table 3. Experimental density rates of different parts of the fabric

Fabric	S_{mv}, dm^{-1}	S_{ma}, dm^{-1}	S_{av},dm^{-1}	S_{aa},dm^{-1}	S_{mb},dm^{-1}	S_{ab},dm^{-1}
Magija-1 (areas *B*, *C*)	100	100	300	0	200	340
Magija-2 (areas *B*, *C*)	100	100	260	0	200	230
Magija-3 (areas *B*, *C*)	100	100	400	0	200	190
Magija-4 (areas *B*, *C*) (areas *A*, *B*, *C*)	100	100	400 125	0 75	200	230
Magija-5 (areas *A*, *B*, *C*)	100	100	120	80	200	200
Magija-6 (areas *A*, *B*, *C*)	100	100	118	82	200	200
Magija-7 (areas *A*, *B*, *C*)	100	100	125	88	200	240
Magija-8 (areas *A*, *B*, *C*)	100	100	144	88	200	200

All the fabric parameters, except for the crimp of threads, are found out or set by patching the fabric in the weaving loom. In order to predict the crimp of the thread in a new double-layered fabric structure, it is necessary to choose the average of the crimp of the thread in each part of the fabric from the experimental values. The most difficult task is to determine the warp of the crimp of fabrics, which is different in different areas of the same warp because the same warp is woven in both double-layered and single-layer places. In order to determine the warp crimp correctly in different areas of the fabric, the double-layered area of the fabric was colored with a colored marker. As a result, the single-layered area was left uncolored. Thus, removing the warp from the fabric, it was clear in which part of the fabric, the thread section was woven. The colored areas of the fabrics showed the warp crimp in the double-layered part of the fabric, and the white areas represented the crimp in the single-layer part of fabric. The experimentally determined crimps in different areas of the fabrics are presented in Table 4.

Table 4. Experimental crimps in different areas of the fabric

Fabric	α_{mv}	α_{ma}	α_{av}	α_{aa}	α_{mb}	α_{ab}
Magija-1 (areas *B*, *C*)	63.6	0	1.9	0	10.0	1.9
Magija-2 (areas *B*, *C*)	42.8	0	1.2	0	10.0	7.7
Magija-3 (areas *B*, *C*)	63.6	0	2.0	0	10.0	10.0
Magija-4 (areas *B*, *C*)	33.0	0	2.9	0	3.4	1.0
(areas *A*, *B*, *C*)	20.0	20.0	2.9	1.9		
Magija-5 (areas *A*, *B*, *C*)	20.0	16.7	2.0	2.0	10.0	1.0
Magija-6 (areas *A*, *B*, *C*)	20.0	8.3	1.0	1.0	10.0	1.0
Magija-7 (areas *A*, *B*, *C*)	18.2	10.0	1.6	1.6	10.0	1.6
Magija-8 (areas *A*, *B*, *C*)	20.0	10.0	2.0	2.0	10.0	1.0

Data in Tables 3 and 4 shows that the crimps of the fabrics of a similar structure (with and without part *A*) was determined experimentally, and the settings of individual parts are shown to have similar values. Therefore, while calculating the theoretical area density of the fabrics of different structures, the commonly used appropriate parameter values, which are presented in Table 5, can be roughly accepted.

Table 5. Accepted crimp and setting values

Fabric structure	α_{mv}	α_{ma}	α_{av}	α_{aa}	α_{mb}	α_{ab}
areas *B*, *C*	60.0	0	2.0	0	10.0	2.0
areas *A*, *B*, *C*	20.0	15.0	2.0	1.5	10.0	2.0
Settings	S_{mv}, dm^{-1}	S_{ma}, dm^{-1}	S_{av}, dm^{-1}	S_{aa}, dm^{-1}	S_{mb}, dm^{-1}	S_{ab}, dm^{-1}
Equation	$S_{mb}/2$	$S_{mb}/2$	$S_{ab}/2+20$	$S_{ab}/2-20$	S_{mb}	S_{ab}
areas *B*, *C*	100	100	400	0	200	200
areas *A*, *B*, *C*	100	100	120	80	200	200

By using the data from Table 5, the following formulas (5) for the calculation of the theoretical area density were established. The first bracket given in the formula matches the mass of the parts woven only with areas *B* and *C*, the second bracket represents the parts with all the three areas (*A*, *B* and *C*), and the third bracket serves for obtaining the mass of area *C* only (where both layers of the fabric are combined).

$$Q_t = \sum_{n}^{i=1}\left(\frac{T_{mv}S_{mb}}{0,8} + \frac{T_{ma}S_{mb}}{2} + \frac{T_{av}S_{ab}}{0,49}\right)k_2 +$$
$$+\sum_{m}^{j=1}\left(\frac{T_{\mathrm{mv}}S_{\mathrm{mb}}}{1,6} + \frac{T_{\mathrm{ma}}S_{\mathrm{mb}}}{1,7} + \frac{T_{\mathrm{av}}(S_{\mathrm{ab}}/2+20)}{0,98} + \frac{T_{\mathrm{aa}}(S_{\mathrm{ab}}/2-20)}{0,985}\right)k_3 + \quad (5)$$
$$+\sum_{m}^{k=1}\left(\frac{T_{mb}S_{mb}}{1-\frac{\alpha_{mb}}{100}} + \frac{T_{ab}S_{ab}}{1-\frac{\alpha_{ab}}{100}}\right)k_1\ ;$$

Theoretical Q_t and experimental Q_e area density of all the fabrics was established, and the error of the theoretical area density by using Formula (6) was calculated during the study. The obtained data is presented in Table 6.

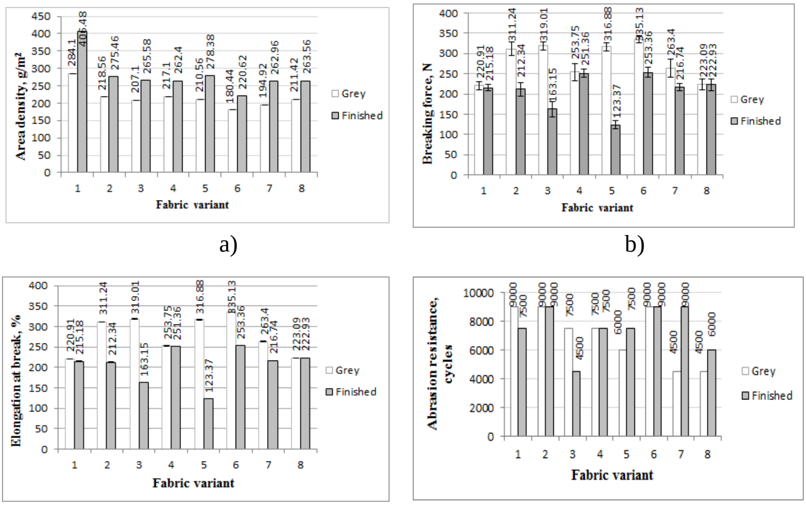
$$\Delta = \frac{Q_e - Q_t}{Q_e}\ 100\%\ ; \quad (6)$$

Table 6. Data of theoretical and experimental area density

Fabric variant	Experimental area density, g/m^2	Theoretical area density, g/m^2	Error, %	Variation coefficient, %
Magija-1 (areas *B*, *C*)	258.20	236.01	8.63	0.02
Magija-2 (areas *B*, *C*)	218.60	235.70	7.81	0.02
Magija-3 (areas *B*, *C*)	188.61	179.41	4.30	0.05
Magija-4 (areas *B*, *C*) (areas *A*, *B*, *C*)	205.12	183.52	9.54	0.02
Magija-5 (areas *A*, *B*, *C*)	189.70	193.31	1.92	0.01
Magija-6 (areas *A*, *B*, *C*)	180.42	181.80	0.81	0.02
Magija-7 (areas *A*, *B*, *C*)	194.90	177.51	8.93	0.01
Magija-8 (areas *A*, *B*, *C*)	211.41	193.33	8.64	0.01

The error of area density calculation ranged from 0.8 to 9.5%, i.e. it did not exceed 10 %. The variation coefficients of the calculated values are very low (they range from 0.008 to 0.046 %). Therefore, we can claim that the proposed methodology for the calculation of the area density of the double-layered spatial fabric and Formula (5) are suitable for the calculation of the area density of such fabrics with sufficient accuracy.

Bar diagrams of the above mentioned properties (area density, breaking force, elongation at break, and abrasion resistance) are shown in Figure 11.

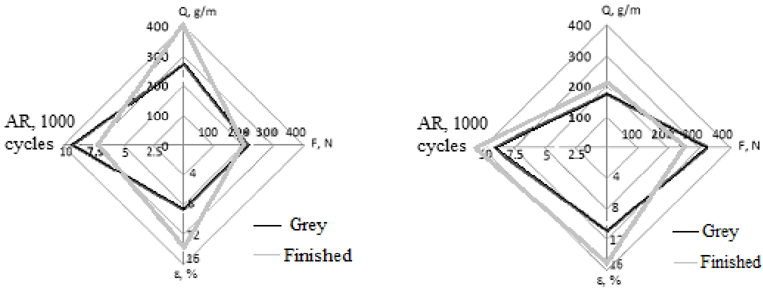


c) d)

Figure 11. Characteristics of the double-layered fabric properties: a – area density, g/m^2; b – breaking force, N; c – elongation at break, %; d – abrasion resistance, cycles

Figure 11, *a* shows that, considering all the fabrics, the area density of a finished fabric is higher than that of a grey fabric. This is natural because the stress of yarns is released in the finishing process, so the threads come closer, their setting increases in both directions, and the fabric becomes heavier. The breaking force of the grey fabric (Fig. 11, *b*) is greater than that of the finished one. During the finishing process, the fabrics undergo both chemical and mechanical influences, which may adversely affect the strength of the fabric. For this reason, the breaking force of finished fabrics may be reduced. However, the elongation at break of the finished fabrics (Fig. 11, *c*) is greater than that of the grey fabrics. After the finishing, the fabrics become softer, their yarns crimp, and the fabrics acquire additional elasticity. Therefore, the fabrics are more elastic, the shrinkage of fabrics after the finishing and thus the elongation at break of the fabric become higher. What concerns the abrasion resistance of the double-layered fabrics (Fig. 11, *d*), the resistance of grey and finished fabrics to abrasion is distributed differently. This characteristic for some fabrics is greater for their grey variations, while for others, it is superior after the finishing. It is notable that for weaving with part *A*, the abrasion resistance of the fabrics after the finishing increases, and for weaving without part *A*, the abrasion resistance after the finishing either remains the same or decreases. This may be affected by the structure of the fabric because when weaving with part *A*, the settings of warps and wefts in this area of the fabric are twice lower than in the single-layer part. Therefore, when abrading the fabric, the threads in this area become closer to each other after the finishing, and the abrasion resistance of the finished fabric increases.

After the comparison of the results of *Magija-1* and *Magija-6* fabrics before and after the finishing, the radial graphs, which are presented in Figure 12, were drawn.



a) b)

Fig. 12. Charts of the properties of *Magija-1* (a) and *Magija-6* (b) fabrics

These fabrics differ in their structure, i.e. *Magija-1* fabric contains parts *A*, *B* and *C*, and *Magija-6* contains only parts *B* and *C*. The charts show that the area density of both fabrics increased after the finishing. This is not a beneficial phenomenon because these fabrics are characterized by high area density, and, therefore, the lighter fabrics would be preferable. The breaking force after the finishing decreased. This phenomenon is also not desirable because it indicates that the fabric weakened after the finishing. The elongation at break in the case of both fabrics increased after the finishing. This is an advantage because the fabrics became more tensile and elastic. The abrasion resistance of *Magija-1* fabric decreased after the finishing, and for *Magija-6* fabric it increased. Such trends could be determined by the fabric structure. The face layer of the wave in the fabrics having no part *A* is twice denser than in the single-layer fabric part. Therefore, after the finishing, the double-layered part becomes even denser, and for this reason, the abrasion process of the fabric is slower. Thus, after the finishing, most of the properties of the double-layered fabrics worsen or remain the same, and only the extensibility of the fabric improves. Therefore, when choosing whether to use grey or finished fabrics, the manufacturer needs to decide whether the expression and relief (in the finished fabric) is more desirable or better values of its properties (in the grey fabric) are required.

CONCLUSIONS

1. The analysis of patterns and weaves of folk skirts and home textile showed different trends. 8 groups of different patterns were distinguished in skirts, and for home textile, 6 types of patterns were singled out. The distribution of the patterns is also determined by the weaves and the weaving techniques used for the fabrics. 16 different weave types were identified in skirts, of which, the most common is plain weave (143 units), and the variety of weaves in home textile is much wider – 22 different weaves were established, where checked twill (satin) (268 units), plain (197 units) and overshot of four harnesses (165 units) weaves are clearly distinguishable.
2. The comparative analysis of color repeats and the symmetry groups of weaves in folk skirts and in home textile showed that the consistent patterns of color repeats and weave ornamentation are different – the fabrics of symmetry group *p111* (460 units) prominently prevail in domestic fabrics, while the four symmetry groups in the weaves are distributed more or less evenly – *p111* (238 units), *p2mm* (222 units), *pmm2* (141 units) and *p112* (128 units). As for the symmetry groups of color repeats in skirts, the fabrics of symmetry group *pmm2* (32 units) were mostly found, to a lesser extent (22–24 units), the fabrics of symmetry groups *p111*, *p1m1* and *p2mm* were observed. In terms of the distribution of the symmetry groups of weave, the fabrics of symmetry group *p111* (183 units) are clearly predominant; 9 times less common are the fabrics of the other groups.
3. What concerns the comparison of the characteristics of the fabric properties manufactured by using three methods of weaving, the proposed double-layered spatial fabrics (area density, breaking force, elongation at break, and abrasion resistance), the most appropriate methodology for weaving such fabrics was selected. All the properties of the fabric woven by using this methodology, except for the fabric breaking force, are optimal: the area density is 1.8 times lower in comparison with the highest indicator, the breaking force is 2.6 times lower (this is a disadvantage), the

elongation at break is 1.9 times higher, and the abrasion resistance of the three proposed methods was the same.

4. It was found that the proposed methodology and the formula for the determination of the theoretical area density of the double-layered spatial fabrics, when evaluating the linear densities, yarn settings and crimps of all parts of the fabric, is suitable for the calculation of the fabric area density at sufficient accuracy because the errors of the experimental and theoretical area density range from 0.8 to 9.5 %. Thus the fabric surface density predictive analysis showed that the linen double-layered fabric-calculated surface density values are close to the experimental values, and the error never exceeds 10 %.
5. The finishing of new double-layer fabrics changes their area density, breaking force, and elongation at break. The examination of the characteristics of the double-layered fabric's properties showed that the area density after the finishing increases by 1.4 times when weaving without part *A* and rises by 1.2 times when weaving with part *A*, because the fabric shrinks, and the threads come closer to each other therein. The breaking force of fabrics reduced by 0.9 times when weaving without part *A*, and by 0.8 times when weaving with part *A* since the fabric undergoes various chemical and mechanical influences which weaken the fabric during the finishing. The elongation at break after finishing increases by 1.7 times when weaving without part *A*, and by 1.4 times weaving with part A because the fabric's yarn crimps more during the finishing, and the fabrics become more tensile.
6. The abrasion of the double-layered fabric results in the increase of the mass loss (weaving without part *A* of the fabric structure reduces the mass by 3.2 % in the grey fabric and 5.27 % in the finished fabric, and weaving with part *A* yields 9.12 % and 9.28 %, respectively) because the fabric yarns break down, yarn piles separate, and a hole appears in the fabric. The abrasion results are dependent not only on the finishing but also on the structure of the fabrics. When weaving without part *A*, the grey (without finishing) fabrics can withstand up to 2 times more abrasion cycles than the fabric after the finishing. Meanwhile, what concerns the fabrics woven with part *A*, the finished fabrics are also up to 2 times more resistant to abrasion.
7. The mass loss dispersion homogeneity and informativeness analysis showed that there is no link between the mass loss and the number of abrasion cycles. Although all the dispersions are homogeneous (their table *Cochrene* criteria is higher than calculated), all the experiments except for one are non-informative because their table *Fisher* criteria are higher than

calculated. So, the dependences of mass loss during the research of abrasion on the number of abrasion cycles cannot be established.

8. The analysis of traditional textile fabrics enables expedient selection of authentic patterns and motifs for the weaving of the new double-layered structure fabrics which are intended for industrial production. New fabrics are distinguished by expressed relief evaluating the trends of the recent home textile fashion as well as the needs of consumers and manufacturers. The collection of 8 fabrics is introduced in the assortment of the company *Klasikinė Tekstilė* and presented at the conference *Pramonės inžinerija 2016*, and can be designed for both home and clothing textile.

LIST OF PUBLICATIONS OF THE THEME OF DISSERTATION

Articles in the journals from *Thomson Reuters Web of Knowledge* list

1. Kumpikaitė, E.; Kot, L.; Vizbaras, M. (2015). Development of a Weaving Method for Spatial Two-layer Innovative Structure Linen Fabric // In: *Fibres and Textiles in Eastern Europe*. Lodz: Institute of Biopolymers and Chemical Fibres. ISSN 1230-3666. 2015, vol. 23, no. 6, pp. 68–71. [Science Citation Index Expanded (Web of Science); Current Contents (Engineering, Computing & Technology); Textile and Technology Complete (Ebsco)]. [IF: 0.566, AIF: 1.665 (E, 2015)].
2. Kumpikaitė, E.; Kot, L.; Tautkutė-Stankuvienė, I. (2015). Ornamentation of Lithuanian Ethnographic Home Textile // In: *Fibres & Textiles in Eastern Europe*. Lodz: Institute of Biopolymers and Chemical Fibres, ISSN 1230-3666. 2016, vol. 24, no. 5, pp. 100–109. [Science Citation Index Expanded (Web of Science); Current Contents (Engineering, Computing & Technology). [IF: 0.566, AIF: 1.665 (E, 2015)].
3. Kumpikaitė E., Kot L., Tautkutė-Stankuvienė I. (2016). Double-layer Fabrics with Folk Motives. Experimental and Theoretical Study for Their Characteristics // In: *Fibres and Textiles in Eastern Europe*. *Lodz*: Institute of Biopolymers and Chemical Fibres. ISSN 1230-3666. 2016, vol. 24, no. 6, pp. 100–108. [Science Citation Index Expanded (Web of Science); Current Contents (Engineering, Computing & Technology). [IF: 0.566, AIF: 1.665 (E, 2015)].

Articles in the journals from *Thomson Reuters Web of Knowledge* list (IF≤0.2AIF)

1. Kot, L.; Kumpikaitė, E.; Ragaišienė, A.; Rukuižienė, Ž. (2015). Evaluation of Lightness in Linen and Semi-linen Fabrics // In: *Materials Science = Medžiagotyra* / Kaunas University of Technology, Academy of

Sciences of Lithuania. Kaunas: KTU. ISSN 1392-1320. 2015, vol. 21, no. 1, pp. 87–91. [Science Citation Index Expanded (Web of Science); INSPEC; Scopus]. [IF: 0.428, AIF: 3.983 (E, 2015)].

2. Kumpikaitė, E.; Kot, L. (2014). Patterned Woven Fabrics in Lithuanian Folk Skirts // In: *Materials Science = Medžiagotyra* / Kaunas University of Technology, Academy of Sciences of Lithuania. Kaunas: KTU. ISSN 1392-1320. 2014, Vol. 20, no. 2, pp. 205–209. [Science Citation Index Expanded (Web of Science); INSPEC; Scopus]. [IF: 0.510, AIF: 3.673 (E, 2014)].
3. Kumpikaitė, E.; Kot, L. (2013). Weaves and Colours of Lithuanian Folk Skirts Fabrics // In: *Materials Science = Medžiagotyra* / Kaunas University of Technology, Academy of Sciences of Lithuania. Kaunas: KTU. ISSN 1392-1320. 2013, Vol. 19, no. 3, pp. 314–318. [Science Citation Index Expanded (Web of Science); INSPEC]. [IF: 0.455, AIF: 3.535 (E, 2013)].

Participation in conferences
International conferences

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2015: Kaunas University of Technology conducted an interdisciplinary project *Use of Innovative Textile Technologies in Contemporary Design* (proj. No. MTEPI-P-15007). It was organized in innovative textile exhibitions **Linomagija I**, **Linomagija II** in Vilnius and Kaunas.

2012-2014: Science project "Preservation of Traditional Textile and National Identity in Contemporary Ecological Way of Life" (proj. No. VAT45/2012).

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REZIUMĖ

Tiriamos problemos pagrindimas ir darbo aktualumas. Pastaruoju metu sparčiai vystantis pasaulinei pramonei ir technologijoms, taip pat ir tekstilės srityje, iškyla nauja struktūra, reljefu ir originalia išvaizda pasižyminčių audinių kūrimo ir jų išaudimo moderniais tekstilės įrenginiais galimybės poreikis. Tokios modernios audimo staklės pasižymi specifine konstrukcija, kuri įgalina austi iš dviejų metmenų velenų su skirtingais metmenų įtempiais.

Pasinaudojant šia audimo staklių konstrukcija, taip pat naujomis cheminės bei mechaninės apdailos galimybėmis, galima sukurti ir pagaminti išraiškingu reljefu ir banguotu paviršiumi pasižyminčius dvisluoksnius erdvinius audinius, atspindinčius pastarojo meto tekstilės mados tendencijas, pristatytas pasaulinėse tekstilės parodose. Šiose mados tendencijose vyrauja išraiškingų reljefinių formų audiniai, pasižymintys natūraliais pluoštais ir tradicinėmis spalvomis, nes jie yra ekologiški ir draugiški gamtai bei žmogaus organizmui, kas šiuolaikinėje pramonėje yra ypač vertinama. Taip pat šiai mados tendencijų krypčiai aktualūs ir autentiški, tradicinę tekstilę atspindintys audinių raštai bei ornamentika, susieti su šiuolaikinėmis išraiškingomis, naujomis tekstilės struktūromis, kurioms gaminti reikia modernių, specialia konstrukcija pasižyminčių tekstilės pramonės įrenginių.

Pasaulyje plintant kosmopolitiškumo idėjoms, bendrame Europos kontekste labai svarbu yra atsigręžti į savo tautos ištakas, kurios taip pat yra aktualios nūdienos tekstilėje, kaip ir viskas, kas natūralu ir autentiška. Todėl tekstilės dizaineriai, kurdami erdvinius naujos dvisluoksnės struktūros audinius, siekia sujungti tautinių audinių motyvus su nauja erdvine audinių struktūra, kurią galima pasiekti tik moderniomis šiuolaikinėmis audimo staklėmis. Audiniai gali būti naudojami žali ir po apdailos, apdailos metu juos minkštinant cheminėmis ir mechaninėmis priemonėmis. Todėl apdaila smarkiai pakeičia audinių išvaizdą ir savybes – po apdailos audiniai tampa minkštesni, puresni, labiau susitraukia. Žali audiniai dėl savo lygaus ir standaus paviršiaus gali būti naudojami buitinei, dekoratyvinei tekstilei, o audiniai po apdailos dėl savo minkštumo ir purumo gali būti naudojami drabužių siuvimo pramonėje.

Taigi tokie audiniai klasikinės tradicinės tekstilės raštus ir ornamentikos ypatumus, rekomenduojamus pastarųjų metų mados tendencijose, sujungia su nauja, darbo metu pasiūlyta erdvine dvisluoksne audinių struktūra. Madingi ir paklausūs naujai sukurti audiniai įdiegti į įmonės „Klasikinė tekstilė“ gaminamų audinių asortimentą, kur naudojami tiek gaminant buitinę, dekoratyvinę tekstilę, tiek ir siuvant drabužius. Įmonė šiuos audinius pristatė pagrindinėse tarptautinėse tekstilės parodose, ir šie naujai sukurti audiniai sukėlė didelį tekstilės ir aprangos gamintojų susidomėjimą.

Darbo tikslas. Sukurti naujos dvisluoksnės struktūros audinius etnografinių audinių raštų motyvais, įvertinant apdailos įtaką šių audinių savybėms.

Darbo uždaviniai:

1. Identifikuoti, ištirti ir palyginti etnografinių sijonų ir buitinių audinių pynimus, raštus, simetrijos grupes.
2. Pasiūlyti ir išanalizuoti dvisluoksnių erdvinių audinių išaudimo galimybes, parenkant tinkamiausią tokios struktūros formavimo būdą.
3. Suprojektuoti nauja struktūra pasižyminčius natūralaus pluošto erdvinius dvisluoksnius audinius etnografinės tekstilės raštų motyvais.
4. Ištirti pagamintų audinių vartojamąsias ir mechanines savybes, įvertinant apdailos įtaką joms.
5. Sukurti prognozavimo metodą dvisluoksnių erdvinių audinių paviršiniam tankiui apskaičiuoti pagal projektuojamo audinio užtaisymo parametrus.

Darbo mokslinis naujumas ir praktinis vertingumas. Dvisluoksne struktūra pasižyminčių audinių projektavimo problemos yra ypač aktualios šiuolaikinių audinių projektuotojams – tiek tekstilės įmonių darbuotojams, tiek dizaineriams. Siekiant platesnio naujų audinių dizainų pritaikymo, disertacijos metu sukurti naujos struktūros lininiai audiniai pritaikyti pramoninei gamybai, pateikiant jų audimo moderniomis staklėmis gaires.

Darbe pasiūlyta ir sukurta erdvinė dvisluoksnė audinio struktūra, kuri anksčiau nebuvo naudota pramoninėje tekstilėje. Pasiūlyti keli naujos struktūros įgyvendinimo variantai, audiniai išausti skirtingose Lietuvos tekstilės įmonėse. Originalios struktūros audinius galima išausti tik specialios konstrukcijos audimo staklėmis, kai yra galimybė tiekti metmenis iš dviejų metmenų velenų su skirtingais įtempiais. Taip gali būti suformuoti du skirtingų ilgių audinių sluoksniai. Taip pat nauja yra tai, kad audiniai buvo sukurti etnografinių audinių raštų motyvais, nes pastarojo meto šiuolaikinės tekstilės tendencijos susijusios su natūralumu ir autentiškumu. Norint naujos struktūros audinius pritaikyti moderniems, šiuolaikiniams interjerams ir drabužiams bei įdiegti juos į šiuolaikinių įmonių kasdieninį asortimentą, tikslinga atlikti tradicinės tekstilės audinių analizę, išnagrinėti etnografinių audinių raštus, motyvus, ornamentiką.

Sukurti audiniai yra aktualūs tiek taikomojo meno pasaulyje kaip inovatyvūs tekstilės dizaino objektai, tiek pramoninės tekstilės srityje, praplečiant tekstilės įmonių asortimento galimybes. Užtaisymo duomenų ir brėžinių parengimas bei pateikimas gamintojams priimtina forma galės būti naudojamas siūlant šiuolaikinės tekstilės pramoninių audinių gamybos rekomendacijas. Ankstesnių tyrimų metu nemažas dėmesys buvo skiriamas mechaninėms ir vartojamosioms audinių savybėms. Atliktuose tyrimuose daugiausia nagrinėti vienasluoksniai klasikiniai audiniai, o darbe pristatomų dvisluoksnių audinių savybės gali smarkiai skirtis. Todėl naujųjų dvisluoksnių audinių savybių tyrimas taip pat yra nauja ir svarbi tyrimo dalis.

Dvisluoksnių audinių savybes svarbu ne tik ištirti eksperimentiškai, bet ir pasiūlyti teorinius jų įvertinimo metodus. Vienas iš audinių parametrų, nusakančių audinio atitikimą paskirčiai, yra audinių paviršinis tankis. Gamintojai norėtų jį prognozuoti dar prieš pradėdami gaminti audinį. Tam tikslui aktualus teorinis ir pakankamai tikslus šios audinio savybės įvertinimas, siekiant nustatyti dvisluoksnio erdvinio audinio paviršinį tankį iš pradinių audinio užtaisymo parametrų. Disertacijoje pateikta nauja dvisluoksnio erdvinio audinio paviršinio tankio skaičiavimo formulė, leidžianti pakankamai tiksliai prognozuoti šį audinio parametrą.

Kadangi audiniai pasižymi nauja, anksčiau nenaudota struktūra, tai ir jų savybes bei apdailos įtaką šioms savybėms yra sunku prognozuoti. Todėl svarbu ištirti, kaip pakinta audinių savybės po apdailos. Žali audiniai dėl savo standumo ir lygaus paviršiaus labiau tinkami naudoti buitinei, dekoratyvinei tekstilei, o audiniai, patyrę apdailą, dėl savo minkštumo ir malonaus grifo labiau tiktų aprangai gaminti.

IŠVADOS

1. Išanalizavus etnografinius sijonų ir buitinių audinių raštus bei pynimus, pastebėtos skirtingos tendencijos. Sijonuose išskirtos 8 grupės skirtingų raštų, o buitiniuose audiniuose – 6 tipų raštai. Raštų pasiskirstymą lemia ir audiniams naudoti pynimai bei audimo technika. Sijonuose nustatyti 16 skirtingų pynimų tipų, iš kurių labiausiai paplitęs drobinis pynimas (143 vnt.), o buitinių audinių pynimų įvairovė kur kas didesnė – 22 skirtingi pynimai, kur aiškiai išsiskiria languotasis ruoželinis (atlasinis) (268 vnt.), drobinis (197 vnt.) ir pusantro sluoksnio, austas dimine technika, keturnytis (165 vnt.) pynimai.
2. Atlikus etnografinių sijonų ir buitinių audinių spalvų raportų ir pynimų simetrijos grupių lyginamąją analizę, nustatyta, kad spalvų raportų ir pynimų ornamentikos dėsningumai yra skirtingi – buitiniuose audiniuose spalvų raportuose ryškiai vyrauja (460 vnt.) simetrijos grupės *p111* audiniai, o pynimuose keturios simetrijos grupės pasiskirsčiusios apylygiai – *p111* (238 vnt.), *p2mm* (222 vnt.), *pmm2* (141 vnt.) – ir *p112* (128 vnt.). Kalbant apie spalvų raportų simetrijos grupes sijonuose, daugiausia aptikta simetrijos grupės *pmm2* audinių (32 vnt.), kiek mažiau (22-24 vnt.) – *p111*, *p1m1* ir *p2mm* simetrijos grupių audinių. Pynimų simetrijos grupių

pasiskirstyme ryškiai vyrauja *p111* simetrijos grupės audiniai (183 vnt.), kitų grupių audinių rasta 9 kartus mažiau.

3. Palyginus trimis pasiūlytomis dvisluoksnių erdvinių audinių išaudimo metodikomis pagamintų audinių savybių rodiklius (paviršinį tankį, trūkimo jėgą, trūkimo ištįsą, atsparumą dilinimui), parinkta tinkamiausia tokių audinių išaudimo metodika, nes atrinkta metodika išausto audinio visi savybių rodikliai (išskyrus audinio trūkimo jėgą) yra geriausi: paviršinis tankis yra 1,8 karto mažesnis, palyginti su didžiausiu rodikliu, trūkimo jėga – 2,6 karto mažesnė (tai trūkumas), trūkimo ištįsa – 1,9 karto didesnė, o atsparumas dilinimui visų trijų pasiūlytų metodikų buvo vienodas.
4. Nustatyta, kad pasiūlyta metodika ir formulė dvisluoksnių erdvinių audinių teoriniam paviršiniam tankiui nustatyti, įvertinanti visų audinio dalių ilginius tankius, siūlų tankumo koeficientus ir sąaudas, yra tinkama šių audinių paviršiniam tankiui apskaičiuoti pakankamu tikslumu, nes eksperimentinio ir teorinio paviršinio tankio paklaidos kinta nuo 0,8 iki 9,5 proc. Taigi audinio paviršinio tankio prognozavimo analizė parodė, kad lininių dvisluoksnių audinių apskaičiuotosios paviršinio tankio vertės yra artimos eksperimentinėms ir neviršija 10 proc.
5. Naujų dvisluoksnių audinių apdaila keičia jų paviršinį tankį, trūkimo jėgą, trūkimo ištįsą. Ištyrus dvisluoksnių audinių savybių rodiklius, nustatyta, kad audinio paviršinis tankis po apdailos padidėja 1,4 karto, audžiant be *A* dalies, ir 1,2 karto, audžiant su *A* dalimi, nes audinys susitraukia, siūlai jame suartėja. Audinių trūkimo jėga sumažėja 0,9 karto, audžiant be *A* dalies, ir 0,8 karto, audžiant su *A* dalimi, kadangi audinys apdailos metu patiria įvairius cheminius ir mechaninius poveikius, kurie susilpnina audinį. Trūkimo ištįsa po apdailos padidėja 1,7 karto, audžiant be *A* dalies, ir 1,4 karto, audžiant su *A* dalimi, nes audinio siūlai apdailos metu labiau išsirango, todėl audiniai tampa tąsesni.
6. Dilinant dvisluoksnius audinius, jų masės nuostoliai didėja (audžiant be *A* audinio struktūros dalies – 3,2 proc. žaliame audinyje ir 5,27 proc. audinyje po apdailos, o audžiant su *A* dalimi, – atitinkamai 9,12 ir 9,28 proc.), nes audinio siūlai nutrūksta, atsiskiria verpalų plaukeliai, audinyje atsiranda skylės. Dilinimo rezultatai priklauso ne tik nuo apdailos, bet ir nuo audinių struktūros. Audžiant be *A* dalies, žali (be apdailos) audiniai atlaiko iki 2 kartų daugiau dilinimo ciklų negu audiniai po apdailos. O audiniai, patyrę apdailą, austi su *A* dalimi, taip pat iki 2 kartų atsparesni dilinimui.
7. Atlikus masės nuostolių dispersijų vienarūšiškumo ir informatyvumo analizę, nustatyta, kad nėra ryšio tarp audinių masės nuostolių ir dilinimo ciklų skaičiaus, nors atliktų eksperimentų dispersijos yra vienarūšės, tačiau eksperimentai yra neinformatyvūs, nes beveik visų, išskyrus vieną, eksperimentų Fišerio kriterijaus vertės lentelėje yra mažesnės už

apskaičiuotąsias. Dėl šios priežasties galima teigti, kad masės nuostolių priklausomybės nuo dilinimo ciklų skaičiaus neegzistuoja.

8. Atlikta tradicinės tekstilės audinių analizė leidžia kurti šiuolaikinius naujos struktūros erdvinius dvisluoksnius audinius, išaustus naudojant etnografinių audinių motyvus, ir tikslingai parinkti autentiškus motyvus naujos dvisluoksnės struktūros audiniams, skirtiems masinei pramoninei gamybai, austi. Žali audiniai yra standesni, jų paviršiuje gerai išryškėja raštas, todėl jie rekomenduojami naudoti namų tekstilėje. Audiniai po apdailos yra minkšti, purūs, malonūs liečiant, tad juos siūloma naudoti aprangos gamybai. Suprojektuotų audinių kolekcija, atsižvelgus bei įvertinus vartotojų ir gamintojų poreikius, yra teigiamai įvertinta TŪB „Klasikinė tekstilė“ (Kaunas) ir pristatyta konferencijoje „Pramonės inžinerija 2016“ Kaune (2016 m. balandžio 28 d.).

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