Study of the properties of linen fabrics for the design of clothing decorated with embroidery

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Abstract

The article is devoted to the research of principles of designing sewing products with embroidery from linen fabrics based on the properties of fabrics. The physical and mechanical properties of linen fabrics are studied: thickness, mass, surface density, stiffness, drapery, tearing elongation and tearing load. The relationship between the physical and mechanical properties of linen fabrics with or without the use of interlinings is established. The classification of types of embroidery techniques is given and recommendations are developed for choosing fabrics and threads for the manufacture of products decorated with embroidery. The complex of scientific research conducted is the basis for the development of recommendations for the selection of linen fabrics for the development of modern collections of women's clothing models of various assortments with embellishments.

Key Words: Fashion Design, Physical and Mechanical Properties of Fabrics, Linen Fabrics, Trimming, Embroidery, Decoration, Clothing Shape, Fashion Designer

Introduction

The creation of new forms of clothing models becomes particularly important in the context of achieving a significant level of saturation of the modern market with clothing of various assortment types and purposes. This is related to the complexity of the structure of consumer needs, in which, along with quantitative indicators of the quality of products, qualitative indicators play an increasingly important role. One of the main conditions for obtaining high-quality products is the correct and reasonable choice of materials, taking into account the design features of the product, the manufacturing methods used and its operating conditions.

Over the past few seasons, world fashion houses have presented a large number of clothing collections that use eco-friendly materials. Fashion for ecologically clean and safe for health and the environment clothes is experiencing a new round of popularity. Today, organic fibers are used for the production of organic fabrics – cotton, flax, wool, nettle, bamboo, seaweed, hemp, eucalyptus, corn, etc. Clothing and shoes made from cotton, linen, bamboo and hemp grown without pesticides, as well as from processed organic materials are presented in the collections of Stella McCartney, Giorgio Armani, Donna Karan, Levi's and others. Among young modern fashion designers, the ideas of environmental friendliness and ethnicity are actively used by Maisop Martin Margiela, Yeohlee Teng, Timo Rissanen, Holly McQuillan.

One of the main conditions for obtaining high-quality products is the correct and reasonable choice of materials, taking into account the design features of the product, the manufacturing methods used and its operating conditions. Natural materials always remain in demand among clothing consumers and are considered an indicator of careful attitude to their health.

To meet the demands of a new industrial market, fibre flax must preserve its image as a high quality natural product, grown traditionally. Industrial flax, however, must meet the challenges of excessively rigorous agricultural constraints and risks related to its cultivation and retting [1].

Season after season, linen clothing is gaining popularity on world catwalks. Products made of linen fabrics are presented in the collections of world designers of clothing, shoes and accessories. The analysis of linen fabric products in designers' collections showed that a variety of decoration, especially hand embroidery, is often used in the production of linen fabric products, so the study of the design process of linen fabric clothing with decoration based on the study of fabric properties is an urgent task.

Analysis of previous studies

In the development of multifunctional linen fabrics using environmentally friendly chemicals, namely treatment using chitosan and green tea extract [2] as well as using reduced graphene oxide/silver nano composite [3] in order to give fabrics antibacterial properties and UV protection. The study [4] is aimed to investigate the thermophysiological comfort properties of shirt linen fabrics subjected to various finishing treatments such as enzymatic, softening and wrinkle-resistant treatments.

In the study [5] the authors determined that clothes made from mixtures of viscose fibers or linen can replace cotton fabrics for clothing designed for children with skin problems. In addition, some viscose materials (with chitosan) and linen are antibacterial, antistatic and thermoregulatory.

Research of tear characteristics of fabrics tear strength of a woven fabric is performed in article [6]. The authors conducted a strength study tear strength of four types of fabrics warp rib, weft rib, ripstop and plain weave were analysed, which were produced in different densities and with filament and texturised polyester yarns.

Authors [7-9] have conducted a study of the physical and mechanical properties of costume fabrics and determined that the main indicators affecting the design and shape of clothing are thickness, stiffness and surface density.

In paper [10] the experimental paradigm of cognitive behaviors is introduced to study cognitive activities in the contiguous sense cognition of the tested linen clothing. The expression of the experimental stimulus material is realized with the developed dressing contiguous sense measurement device. Changing the relative force for the contact between fabric and human skin, the dressing contiguous sense is tested.

The study [11] is aimed at identifying factors that have raised demand for fashionable linen clothing in Sri Lanka. Factors affecting the purchasing behavior of consumers of linen clothing were discussed.

In the article [3] the authors outline the prospects for the development of the production of linen fabrics and linen products in India. The authors emphasize that linen blends very well with fibers such as; wool, silk, cotton etc. and is used for manufacturing, suitings, shirtings, strong twines, canvas and various in dispensable products for defense purposes. Apart from its versatility, flax is also an ecofriendly fiber. It consumes much less amount of water for irrigation and doesn't require insecticides and pesticides as much as cotton.

Scientists pay considerable attention to the issues of expanding the range of linen fabrics and products by developing new methods of decoration, weaving, giving fabrics unique medical and biological properties, improving the process of processing fabrics and other aspects that contribute to improving product quality indicators.

In the study [12] an analysis of modern trends in clothing design is performed, features and methods of finishing, technological methods of artistic embroidery are considered, and an overview of modern and traditional embroidery techniques is given. The study by Leghari and Shar [13] examines the particular qualities of mirror embroidery of the Sindh region in Pakistan from the point of view of its use in modern textile design. The article by Melnyk *et al*. [14] discusses the use of the folk Ukrainian pattern in the knitted fabric embellishment.

In the article by Cheng *et al.* [15] the method of antimicrobial finishing of cotton fabric with TX-DF by the argon/oxygen-plasma techniques have been discovered.

The analysis showed that the interest of clothing consumers in environmentally friendly and health-safe clothing is growing. In the textile industry, a significant place among environmentally friendly and trendy goods is occupied by flax-containing textile materials containing natural-colored linen fiber, which has exceptional natural properties, high strength, hygiene, natural bactericidality, environmental friendliness and naturalness. Models of clothing of various ranges and purposes made of linen fabrics are often decorated with a variety of embellishments, especially embroidery, which is a historical type of decoration of national clothing [16].

The purpose of the work is to improve the design of products made of linen fabrics with embroidery decoration based on their properties.

Materials and Methods

For a scientifically based selection of materials for the manufacture of women's clothing from linen fabrics, which would satisfy the requirements of consumers, seven samples of linen fabrics of linen weave of different raw materials were studied in order to determine their characteristics (Figure 1). The raw material composition of the studied tissue samples is shown in Table 1.

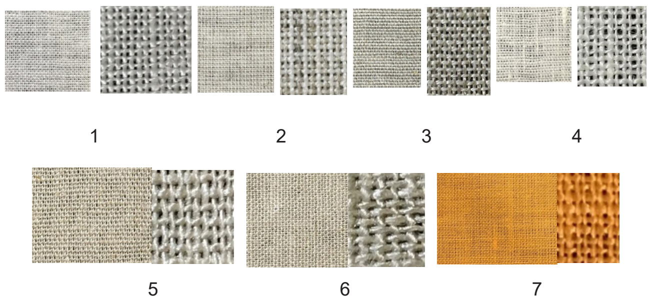


Figure 1. Samples of the studied linen fabrics

Table 1: Raw material composition of linen fabric samples (Fig. 1)

Fabric sample	F1	F2	F3	F3	F5	F6	F7
Raw material composition, %	30% linen / 70% viscose	15% linen/32% cotton / 53% polyester	30% linen/20% cotton / 50% polyester	100% linen	85% linen/15% elastane	55% linen / 42% viscose / 3% elastane	50% linen/ 50% cotton

The fabric obtained from linen is strong and coarse, has a large crease and shrinkage, so to improve the elastic properties of the fabric, other fibers are added to its composition, for example: cotton, elastane, viscose, nylon, etc. Therefore, modern linen-based materials can have a smooth surface, be thin, translucent, or be almost transparent.

According to DSTU 3047-95, pure linen fabrics include fabrics containing at least 100% of linen fiber; to linen – fabrics with at least 92%; semi-linen – fabrics containing at least 30%; to mixed linen – fabrics with at least 15% of linen fiber.

In the manufacture of linen products, various decorations are often used, especially embroidery, for which the fabric is strengthened with an adhesive lining material, which, thanks to its properties, changes the physical and mechanical characteristics of linen fabrics. To conduct the experiment, two samples of each fabric measuring 35050 mm in the longitudinal and transverse directions were prepared, which were doubled with two types of non-woven fabric: L1 – Gunold STIFFY 1620B dot adhesive non-woven fabric; L2 – Peri JUF4111H interlining dot adhesive non-woven fabric. The characteristics of non-woven fabrics are given in Table. 2.

Table 2: Characteristics of non-woven fabrics for embroidery

Code	Name	Raw material composition	Weight, g	Thickness, mm	Surface density, g / m2
L1	GUNOLD STIFFY 162B	75% cellulose / 25% polyester	0.43	0.10	42
L2	Peri JUF4111H	100% polyester	0.41	0.18	40

Taking into account the aim and the purposes of the researches, it was decided to analyze 7 samples of linen fabrics of different fibrous composition, which differ in their appearance (thickness, structure, type of weave, etc.). The main focus was on determining the properties of the fabrics, such as: thickness, surface density, flexural rigidity and drapeability. The test was carried out in accordance with the current normative documents, kept up the requirements to the objects of the experimental research; the processing of the results of the measurements was made using the mathematical apparatus of statistical analysis of the data. The test [17] was carried out in climatic conditions according to ISO standard 139:2005. Before the test, each sample had been kept in climatic conditions (relative air humidity 65 ± 4 % and temperature 20 ± 2 °C) for at least 24 hours.

Thickness [18] is measured under the pressure of 1kPa according to ISO standart 5084-1996.

The surface density [19] of the fabric (mass per unit area, Ms) in g/m2 was determined according to (ISO standard 3801:1977). Drapeability, in accordance with (ISO standard 9073-9:2008), is “the ability of a circular specimen of a fabric of known size to deform when suspended under specified conditions” [20].

The draperability of the materials is determined by the disk method using the device, the scheme of which is shown in Figure 2.

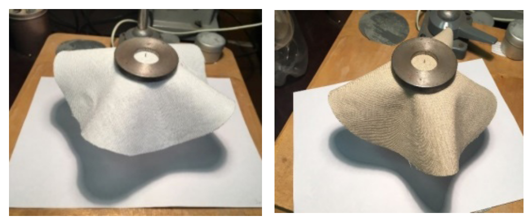


Figure 2: The device for determination the drapeability of the fabric by the disk method

In evaluating the drapery properties of the dress materials of the different fibrous composition, the recommended values of the drapeability coefficient of the dress fabrics, given in Table 3, were taken into account.

Table 3: Evaluation of the degree of drapeability of the dress fabrics according Suprun at al. [21]

Fibrous composition	Drapeability coefficient, %		
	well	satisfactory	bad
Cotton	>65	45…65	<45
Wool	>80	68…80	<68
Silk	>85	75…85	<75

The rigidity [22] is determined using the console non-contact method according to GOST (State Standard) 10550-93, using a device of type PT-2 (Figure 3). For the study, 5 elementary samples were cut in longitudinal and transverse directions with dimensions of 160 × 30 mm. The elementary samples are weighed on scales with an error of not more than 0,01 g and the total weight (m, g) of the samples of longitudinal and transverse directions is determined separately.

Figure 3: The device type PT-2 for determination of the fabric rigidity by the console method

In accordance with the recommendations ISO 9073-9:2008, the coefficient of rigidity of the linen fabrics shall not exceed 9000 μN·cm2. The tearing [23] under tension characteristics is determined by the scale of the tearing machine at the time of material rupture according to GOST (State Standard) 3813-72, using a device of type PT-250M (Figure 4).

Figure 4: The fabric tearing under tension determination device

Results and Discussions

Results of the experimental study

Seven samples of linen fabrics of plain weave of various raw materials were studied and their physical and mechanical characteristics of linen fabrics were determined (Table. 4).

The tearing under tension characteristics of linen fabrics reinforced with non-woven fabrics and their rigidity are presented in Table 5 and Table 6.

Table 4: Basic physical and mechanical characteristics of linen fabrics

Fabric sample	Raw material composition, %	Thickness, mm	Surface density, g / m2	Drapery coefficient, %	Warp stiffness, μN×cm²	Weft stiffness, μN×cm²
F1	30 % linen / 70 % viscose	0.40	200	21	6799	5923
F2	15 % linen / 32 % cotton / 53 % polyester	0.39	176	51	3470	884
F3	30 % linen / 20 % cotton / 50 % polyester	0.36	150	70	2120	773
F4	100% linen	0.44	194	30	3538	5923
F5	85 % linen / 15 % elastane	0.40	196	56	7302	1587
F6	55 % linen / 42 % viscose / 3 % elastane	0.41	194	52	6459	1049
F7	50 % linen / 50 % cotton	0.28	125	44	6174	2003

Table 5: Tearing under tension characteristics of linen fabrics before and after duplication

№ sample	Tearing Elongation, mm						Tearing Load, N					
	without non-woven fabric		L1		L2		without non-woven fabric		L1		L2	
	warp	weft	warp	weft	warp	weft	warp	weft	warp	weft	warp	weft
F1	20	22	24	26	23	26	601	542	653	550	620	580
F2	27	27	31	32	31	31	900	790	910	815	910	825
F3	30	24	33	31	33	21	1382	870	1365	867	1372	875
F4	22	21	29	17	31	26	400	310	660	584	658	487
F5	18	18	21	49	20	50	384	180	426	230	430	250
F6	23	27	21	58	22	57	377	240	390	280	430	310
F7	11	20	8	33	7	30	490	300	720	480	640	480

Table 6: Stiffness of linen fabrics after duplication

sample No.	Warp stiffness, μN×cm²			Weft stiffness, μN×cm²		
	without non-woven fabric	L1	L2	without non-woven fabric	L1	L2
F1	6799	75513	217179	5923	76216	69337
F2	3470	41140	81756	884	87232	132976
F3	2120	70076	41694	773	30537	45156
F4	30537	89542	208492	5923	66055	208492
F5	7302	119095	38133	1587	38735	151973
F6	6459	191118	164465	1049	30616	73040
F7	6174	69785	69785	2003	86085	114410

Discussion

The results of the correlation analysis of the physical and mechanical characteristics of linen fabrics are shown in the Table 7.

Table 7: Correlation coefficients between physical and mechanical characteristics of linen fabrics (number of samples N=7)

Physical and mechanical characteristic	Correlation coefficient r				
	Thickness, mm	Surface density, g / m^2	Drapery coefficient, %	Warp stiffness, μN×cm²	Weft stiffness, μN×cm²
Thickness, mm	-	0,92	-0,26	-0,06	0,39
Surface density, g / m2		-	-0,39	0,30	0,43
Drapery coefficient, %			-	-0,35	-0,91
Warp stiffness, μN×cm²				-	0,13
Weft stiffness, μN×cm²					-

Based on the results of the study, it was determined that in most samples, thickness and surface density correlate with each other (r=0.92). As can be seen from the Table 7, surface density of fabrics is directly proportional to their thickness, i.e. as the fabric thickness increases; its surface density indicator also increases. Samples F1, F4, F5, and F6 have the highest thickness, respectively, and their surface density is the highest.

When evaluating the properties of textile materials, their ability to form is determined by the drapeability ratio. Analysis of the table 3 shows that fabric samples F2, F3, F5, and F6 have the highest drapeability ratio. This is due to the fact that fabric samples F2 and F3 have a low content of linen fiber, while fabric samples F5 and F6 contain elastane. Fabric samples F1, F4 have poor drapery because they have the highest surface density. At the same time, a weak negative relationship was found between Surface density and Drapery coefficient (r=-0.39). The product is made of linen fabric with a high surface density of the fabric, will not have high creasing ability, will retain the shape of the product better and will have high performance characteristics, but will not be convenient in everyday use, as it may limit the consumer's freedom of movement. For such fabrics, it is not recommended to use three-dimensional decorations: assemblies, pleats, flounces, etc.

A comparison of drapery and stiffness of the studied samples of linen fabrics was made, which showed that drapery is inversely proportional to stiffness, the lower the stiffness value in the samples is, the greater the drapery coefficient of the fabric is. At the same time, a strong negative relationship was established between Drapery coefficient and Weft stiffness (r=0.91). In the process of manufacturing sewing products and their operation, textile materials undergo a variety of mechanical influences that cause tensile, bending, compression, torsion, and friction deformations. Indicators of mechanical properties are widely used in clothing production, they characterize the property of the material to acquire and maintain a given shape and size, and are of great importance for assessing the quality of textile materials.

Analysis of data from Table 5 and comparison of the values of tearing elongation and tearing load of linen fabrics on the basis showed that samples F1, F2 and F3 have the highest tearing load indicators, samples F4, F5, F6, F7 have approximately the same strength and withstand almost the same tearing load, while samples F4, F5 and F6 are characterized by the fact that at a low tearing load they have a high tearing elongation both on the basis and on the weft. This dependence is explained by the fact that samples F4, F5, F6 in terms of raw material composition have the highest percentage of linen fibers, and samples F2 and F3 have the lowest content of linen fibers (less than 30%) and a high content of impurities from synthetic fibers (more than 50%), so they are stronger.

Comparison of the value of tearing elongation and tearing load of linen fabrics by weft (Table 5) showed that samples F1, F2 and F3 are the strongest, can withstand the greatest tearing load, while the tearing elongation is significant, that is, these fabrics have a direct relationship with a high tearing load and have a high tearing elongation.

The properties of fabric samples after their duplication with two types of non-woven fabrics were studied, the characteristics of which are given in Table 5. A comparison of the stiffness of interlining-reinforced linen fabrics is given in the Table 6.

The analysis shows that samples duplicated with L2 non-woven fabric have higher stiffness values than samples duplicated with L1 non-woven fabric. Thus, the result of the study shows that samples F1, F4, F6 on the basis and samples F2, F4 and F5 on the weft with L2 non-woven fabric have the best performance and can be recommended for use in products with machine embroidery. Comparison of the tearing load of duplicated linen fabrics showed that samples F4, F6, and F7 became significantly stronger after duplication, and their tearing load has increased. Samples F1, F2, F5 have a slight increase in tearing load, sample F3 is the strongest, because it contains synthetic fibers, so duplication did not significantly affect its characteristics. Usually, fabrics in the weft direction are less resistant to tearing load, so non-woven fabrics have enhanced their breaking characteristics in this direction more. The use of non-woven fabrics L1 and L2 significantly affected the performance of fabric samples on the warp, but when using L2, more fabric strengthening occurred on the weft.

After analyzing the tearing elongation of the fabric samples (Table 5), it was found that the tearing elongation increased after duplication, only in samples F6 and F7 the tearing elongation decreased after duplication, these samples have been quickly teared. Thus, it can be noted that the use of non-woven fabrics contributes to an increase in the tearing elongation of fabric samples, but F5 and F6 samples were most enhanced as a result of duplication, which can be explained by the elastane content in the samples of these fabrics.

A comparison of the tearing elongation obtained by the tissues after duplication is made. A comparison of the properties of L1 and L2 non-woven fabrics showed that L2 non-woven fabric has better properties, since fabric samples duplicated with it have better tearing characteristics than samples duplicated with L1 non-woven fabric. After duplicating fabrics with L2 non-woven fabric, they have become more durable, so this non-woven fabric can be recommended for use in embroidery products. The main factor that must be taken into account when choosing non-woven fabric is recommended to consider the tearing load.

The conducted experiment shows that samples of fabrics F1 and F4 can be recommended for hand embroidery, samples F1, F4 and F5 with L2 non-woven reinforcement can be recommended for use in products with machine embroidery.

Justification of the choice of fabrics and threads for hand embroidery

Embroidery is often used in linen fabric products. Embroidery is a type of decorative design of textile products, in which the figure pattern is applied to the fabric using colored, gold and silver threads, beads, glass beads, beads, etc.

Embroidery decoration is used in the manufacture of the first line of clothing, so designers emphasize the uniqueness and exclusivity of products. Clothing with this type of decoration, according to the analysis of collections at fashion weeks in recent years, is relevant among many world designers. In their collections, embroidery is actively used and demonstrated by such fashion houses as Valentino, Givenchy, Tom Ford, DandG, Chloe, Paula, Cademartori, Balmain, Zuhair Murad, Christian Dior, Elie Saab and others.

Embroidery is divided into hand and machine embroidery. Hand embroidery is popular in the collections of modern designers, because it is unique, original, differs from machine embroidery in the quality of execution and the variety of materials used. Since the 19th century, the development of technologies and the use of special embroidery equipment had made it possible to reduce manual labor and use machine embroidery.

Embroidery is divided into perforating and surface embroidery. Techniques in which the fabric is embroidered on a solid surface without pulling out or cutting the thread are called surface-embroidered. Perforating – these are openwork embroidery on the fabric, placed not on the surface, but withing the fabric, thereby changing its structure.

According to the method of performing embroidery, they are divided into free and counting ones. Counting embroidery involves calculating the number of stitches. Free embroidery techniques are performed according to pre-planned contours of patterns, while the stitch length is not calculated. Free seams allow you to embroider patterns with curved contours on any fabric: silk, velvet, wool fabrics, etc. Most often, free embroidery techniques are used to reproduce plant ornaments.

Embroidery is also divided into one-sided and two-sided. One-sided embroidery form a pattern only on the front side of the product, and only individual stitches and thread transitions will be visible from the reverse side. The two sides form a pattern almost identical on both sides of the fabric.

There is a classification of types of embroidery: cross, smooth, openwork-slotted, knotted, vestibule stitches, etc. Based on the study of technological and artistic features of embroidery, the following varieties can be distinguished: based on the materials used – threads, sequins, beads, pearls, gold or silver thread, etc.; according to the types of seams and stitches: free, with arbitrary arrangement of stitches according to the drawing or counting - according to calculations; by the number of threads of fabric and stitches: openwork embroidery, colored satin stitch, free seam, cross, half-cross, satin stitch, vestibule, tapestry seam, etc.; by the nature of the pattern: ornamental, plot, etc.; by color: white, multicolor, etc.

Cross-stitch is the most common technique of embroidery and decorating clothes and the simplest type of counting embroidery, which uses threads of different colors. The basis of smooth embroidery techniques are stitches that form an even and smooth surface along a free contour. The possibilities of this seam are very diverse. According to the method of creation, the satin stitch is divided into counting (straight and oblique) and free satin stitch, which is performed according to the contour of the drawing. In turn, it can be one-sided or two-sided. The following types are distinguished: close stitch, flat stitch, layered stitch, split stitch, loop stitch, “forward needle” stitch and others.

“Grain output” is an embroidery technique that uses stitches that form diagonal lines made up of small contoured squares. The “grain output” seam is usually used in combination with other seams (“counting stitch”, “punching”) in geometric ornaments. Each stitch of the contour square of the grain output is made double, that is, by superimposing threads on top of each other, while pulling the threads of the fabric. When using embroidery, it is important to choose fabrics with certain properties that characterize its thickness, surface density and raw material composition. An experimental study of 7 samples of linen fabrics showed that all of them are suitable for embroidery decoration. Due to the fact that samples F4, F5 and F7 are similar in properties, four fabric samples were selected: sample F1 (30% linen, 70% viscose; 0.40 mm, 200 g / m2), sample F2 (15% linen, 32% cotton, 53% polyester; 0.39 mm, 176 g / m2), sample F3 (30% linen, 20% cotton, 50% polyester, 0.36 mm, 150 g / m2), sample F4 (100% linen, 0.44 mm, 194 g / m2). On the selected samples of fabrics, embroidery “satin stitch” and “grain output” is performed with three different types of threads in order to determine the best initial conditions for obtaining high-quality embroidery and provide recommendations on the use of a certain embroidery technique and a certain type of thread for its implementation.

24 embroidery samples were made on selected fabric samples, using two types of techniques: grain output and smooth surface. Each embroidery technique is made with three types of threads. Photos of samples of snippets with embroidery are given in Table 8, Table 9. The samples are marked as follows: the first mark is the fabric sample number; the second mark is the type of embroidery: 1 – grain output; 2 – satin stitch; the third mark is the type of thread: 1 – DMC cotton floss threads; 2 – YarnArt woolen threads; 3 – linen yarn.

Table 8: samples of linen fabrics with embroidery “grain output”

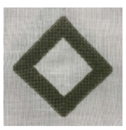
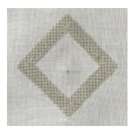
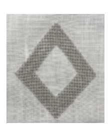
Fabric	Thread type		
	DMC cotton floss threads	Yarn Art woolen threads	Linen yarn
Sample 1 (30% linen, 70% viscose; 0.40 mm, 200 g / m^2)			
	F1.1.1	F1.1.2	F1.1.3
Sample 2 (15% linen, 32% cotton, 53% polyester; 0.39 mm, 176 g / m^2)			
	F2.1.1.	F2.1.2.	F2.1.3
Sample 3 (30% linen, 20% cotton, 50% polyester, 0.36 mm, 150 g / m^2)			
	F3.1.1	F3.1.2	F3.1.3
Sample 4 (100% linen, 0.44 mm, 195 g / m^2)			
	F4.1.1	F4.1.2	F4.1.3

Table 9: Samples of linen fabrics with embroidery satin stitch

Fabric	Thread type		
	DMC cotton floss threads	Yarn Art woolen threads	Linen yarn
Sample 1 (30 % linen, 70 % viscose; 0.40 mm, 200 g / m^2)			
	F1.2.1	F1.2.2	F1.2.3
Sample 2 (15% linen, 32% cotton, 53% polyester; 0.39 mm, 176 g / m^2)			
	F2.2.1	F2.2.2	F2.2.3
Sample 3 (30% linen, 20% cotton, 50% polyester, 0.36 mm, 150 g / m^2)			
	F3.2.1	F3.2.2	F3.2.3
Sample 4 (100% linen, 0.44 mm, 195 g / m^2)			
	F4.2.1	F4.2.2	F4.2.3

To determine the best embroidered sample, an expert assessment was carried out. Experts evaluated the following indicators: volume of embroidery, smoothness of the embroidery surface, texture of embroidery (fluffiness), deformation of the embroidered area (bulge, depression, undulation); deformation of the area adjacent to the embroidered one; correspondence of embroidery to the design (skew, curvature of the drawing).

The quality of embroidered materials was evaluated by a group of 10 experts. All experts have a higher education in fashion design and work experience in the field of fashion design or fashion education for 15-26 years, 4 of them have a scientific degree of candidate of technical sciences, 2 have a degree of Doctor of Technical Sciences, 4 have the title of Master of Artistic Creativity. For a comprehensive combined assessment of the quality of embroidered material, an embroidery quality assessment card was developed in accordance with the methodology described in the study Yezhova, Pashkevich at al. (2018), adapted to hand embroidery on linen fabric. Experts were asked to evaluate the quality of each piece of embroidery separately.

Expert quality assessment was carried out on a 4-point scale: 3 – defects are absent or almost invisible, 2 – defect is barely noticeable and somewhat affects the quality of the semi-finished product; 1 – defect is very noticeable and significantly spoils the quality of the semi-finished product; 0 – the semi-finished product is unsuitable.

The quality of embroidered semi-finished products was evaluated after 30 minutes of rest after removal from the embroidery frame. An example of a card for evaluating the quality of embroidered samples is given in Table 10.

Table 10: Embroidery quality assessment card

Embroidery sample No.	Embroidery defect	Defect around embroidery	Rating, points
F1.1.1	-	-	3
F1.1.2	slight deformation of the drawing	-	2
F1.1.3	-	-	3
F2.1.1.	skew, asymmetry of the drawing	bulge	0
F2.1.2.	drawing deformation	bulge	1
F2.1.3	skew, asymmetry of the drawing	bulge	0
F3.1.1	drawing deformation	bulge	1
F3.1.2	drawing deformation	bulge	1
F3.1.3	slight deformation of the drawing	bulge	2
F4.1.1	slight deformation of the drawing	bulge	2
F4.1.2	slight deformation of the drawing	-	2
F4.1.3	slight deformation of the drawing	-	2
F1.2.1	-	-	3
F1.2.2	-	-	3
F1.2.3	-	-	3
F2.2.1	-	undulation	2
F2.2.2	-	-	3
F2.2.3	-	undulation	2
F3.2.1	-	-	3
F3.2.2	-	-	3
F3.2.3	-	-	3
F4.2.1	-	bulge	2
F4.2.2	-	-	3
F4.2.3	-	bulge	2

Average ratings of embroidered samples are shown in Table 11.

Table 11: Average ratings of embroidered samples based on the results of the examination (number of experts N=10)

<table>
<tr><th rowspan="3">Embroidery technique</th><th rowspan="3">Material No.</th><th colspan="3">Average sample rating, points</th><th>Average rating of samples from the material, points</th></tr>
<tr><th colspan="3">Threads No.</th><th></th></tr>
<tr><th>1 – floss</th><th>2 – wool</th><th>3 – linen</th><th></th></tr>
<tr><td rowspan="5">“grain output”</td><td>F1</td><td>2.9</td><td>2.2</td><td>2.9</td><td>2.7</td></tr>
<tr><td>F2</td><td>0.4</td><td>1.2</td><td>0</td><td>0.5</td></tr>
<tr><td>F3</td><td>1.5</td><td>1.4</td><td>1.9</td><td>1.6</td></tr>
<tr><td>F4</td><td>2.0</td><td>2.2</td><td>1.8</td><td>2.0</td></tr>
<tr><td>Average rating value</td><td>1.7</td><td>1.8</td><td>1.7</td><td>1.7</td></tr>
<tr><td rowspan="5">satin stitch</td><td>F1</td><td>3.0</td><td>2.9</td><td>2.9</td><td>2.9</td></tr>
<tr><td>F2</td><td>2.3</td><td>2.8</td><td>2.2</td><td>2.4</td></tr>
<tr><td>F3</td><td>3.0</td><td>2.9</td><td>3.0</td><td>3.0</td></tr>
<tr><td>F4</td><td>2.3</td><td>2.6</td><td>2.1</td><td>2.3</td></tr>
<tr><td>Average rating value</td><td>2.7</td><td>2.8</td><td>2.6</td><td>2.7</td></tr>
</table>

Recommendations and implementation of research results

According to the results of the experts’ assessment of the “grain output” embroidery technique, the embroidered samples from F1 and F4 materials received the highest average score - 2.7 and 2.0, respectively. This means that when designing products from these samples, it is recommended to use the “grain output” embroidery technique. As can be seen from the Table 4, these are the samples with the highest surface density (200g / m2 and 194 g / m2 respectively), and with the lowest drapery (21% and 30%, respectively). These samples also exhibit high warp and weft stiffness, with the sample with the highest embroidery quality score of F1 having warp stiffness only 15% different from weft stiffness (6799 μN×cm² and 5923 μN×cm², respectively). Sample F4 received lower ratings, while its warp stiffness (3538 μN×cm²) is 1.7 times lower than the weft stiffness (5923 μN×cm²). For samples F2 and F3, for which the average score is 0.5 and 1.6 points, respectively, it is not recommended to use counting techniques of hand embroidery, in particular, “grain output”. These are samples with a lower surface density (176 g / m2 and 150 g / m2 and better drapery (51% and 70%, respectively). At the same time, the weft stiffness in these samples is significantly lower than the warp stiffness (F2: 3470 μN×cm² and 884 μN×cm², respectively, F3: 2120 μN×cm² and 773 μN×cm², respectively). So, for counting techniques of hand embroidery, in particular, “grain output”, we recommend choosing linen materials with a high surface density (more than 190 g / m2) and low drapery (30% or less). At the same time, the warp stiffness should not differ significantly from the weft stiffness, and should be at least 3000 μN×cm².

We note that the highest ratings (2.9 points each) were given to the F1.1.1 and F1.1.3 samples embroidered with floss threads and linen threads. At the same time, the average score (1.8 points) is the highest for samples embroidered with woolen threads, which is only 3% higher than the average score of all samples embroidered with the “grain output” technique (1.7 points). This indicates that, based on the results of the experiment, it is impossible to provide reasonable recommendations for choosing threads for hand embroidery.

According to the results of the expert evaluation of the satin stitch embroidery technique, all samples received ratings of 2.1 ... 3.0 points. This result indicates that you can embroider with the satin stitch technique on any linen fabric with a surface density of 150 ... 200 g / m2. At the same time, embroidered samples made of F1 and F3 materials received the highest average rating – 2.79 and 3.0, respectively, which demonstrates the independence of the quality of embroidery with the satin stitch technique from the surface density of the fabric sample.

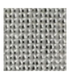
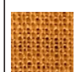
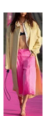
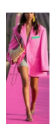
We note that the maximum scores (3.0 points each) were given to samples F1.2.1 and F3.2.1 embroidered with floss threads, as well as a sample F3.2.3 embroidered with linen threads. At the same time, the average score (2.8 points) is the highest for samples embroidered with woolen threads, which is only 5%

higher than the average score of all samples embroidered with the "satin stitch" technique (2.7 points). As in the previous case, this indicates that based on the results of the experiment, it is impossible to provide reasonable recommendations for choosing threads for hand embroidery. In each specific case, you should choose embroidery threads in accordance with the creative idea and design of the product, taking into account the color, shine, volume that are inherent in a particular type of thread.

The conducted complex of scientific research is the basis for developing recommendations on the choice of linen fabrics for the development of modern collections of women's clothing models of various ranges.

Based on the data table in Table 3, recommendations for the design of women's products are given for the studied samples of linen fabrics (Table 12).

Table 12: Recommended clothing models for linen fabric samples

Sample characteristics	Fabric sample						
	F1	F2	F3	F4	F5	F6	F7
							
Raw material composition, %	30% linen / 70% viscose	15% linen/32% cotton / 53% polyester	30% linen/20% cotton / 50% polyester	100% linen	85% linen/15% elastane	55% linen / 42% viscose / 3% elastane	50% linen/50% cotton
Surface density, g / m^2	200	176	150	194	196	194	125
Thickness, mm	0.40	0.39	0.36	0.44	0.40	0.41	0.28
Recommended models of clothing	dress, skirt, shorts, pea jacket,	dress, blouse, skirt	dress, skirt, shorts	dress, skirt, jumpsuit, jacket	dress, skirt, shorts, jacket	dress, skirt, jumpsuit, jacket	top, blouse
Example of recommended models of clothing	 Jacquemus SS20	 Prada SS20	 Rejina Pyo SS20	 Jacquemus SS20	 Oscar de la Renta SS20	 Gabriela Hearst SS20	 Rejina Pyo SS20

Sketches of the author's collection of women's clothing made of linen fabrics have been developed (Figure. 5), which consists of five clothing models and is based on the principles of consistency, connections and development of the original basic symbol-shape (rectangle). The collection includes models of women's youth clothing of the spring-summer season made of linen fabrics in warm shades of sand and brown. Products of a semi-fitting silhouette without sleeves or with sewn sleeves and contain relief lines. For decoration, embroidery is used, which is located on different parts of the products.

Figure 5: Sketches of clothing models of the women's clothing collection made of linen fabrics

Conclusion

The sequence of clothing design made of linen fabrics is considered and fashion trends regarding the use of embroidery in clothing collections are determined. Classification of varieties of modern embroidery is provided. Embroidery as a decoration in the work of foreign designers is analyzed and it is established that embroidery is most often used in couture collections by well-known fashion houses such as Dior, Chanel, Balmain. Most designers use embroidery to make the product exclusive, hand embroidery increases the value of the product. Mass market brands usually adapt embroidery and use it in the form of prints and applications.

Samples of linen fabrics were studied and their physical and mechanical parameters were determined: thickness, surface density, tearing load and tearing elongation. The relationship between the physical and mechanical properties of linen fabrics with or without the use of interlinings is established.

24 embroidery samples were made using two embroidery techniques: satin stitch and grain output. An expert assessment was carried out to determine the best embroidered samples in order to determine the best initial conditions for obtaining high-quality embroidery and provide recommendations on the use of a certain embroidery technique and the type of thread for its implementation. It is established that for counting techniques of hand embroidery, it is recommended to choose linen materials with a high surface density (more than 190 g/m2) and low drapery (30% or less). At the same time, the warp stiffness should not differ significantly from the weft stiffness, and should be at least 3000 μN×cm². It is proved that you can embroider with the satin stitch technique on any linen fabric with a surface density of 150 ... 200 g / m^2.

When choosing embroidery threads, it is recommended to take into account first of all the design of the product, considering the color, shine, volume that are inherent in a particular type of thread.

Sketches of models of the women's clothing collection with embroidery made of linen fabrics are offered. Prospects for further research include consideration of innovative technologies for decorating linen fabrics and products made from them, providing scientifically based recommendations for the selection of fabrics with certain properties in the manufacture of clothing of various assortments and purposes.

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