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Research of the Influence of the Loop Thread Length in the Back Layer of Two-Layer Knitted Fabric on Its Physical and Mechanical Properties

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ABSTRACT: In order to study the effect of the length of the thread in the loop of the back layer of two-layer knitted fabric on its physical and mechanical properties it was created new structures of two-layer jersey, knitted samples on a flat-knitting machine and investigated them properties. Two-layer knitted fabrics were developed on the basis of semi-cardigan stitch, where connection of the layers of knitted fabric was with tucks.

KEY WORDS: two-layer knitted fabric, physical and mechanical properties, cardigan stitch, flat-knitting machine.

I. INTRODUCTION

The assortment of knitted products has expanded significantly recently. It was enriched with new types of fabrics, in particular, knitted fabrics of lightweight structures, such as combined and two-layer, made mainly on double-line machines. To develop new structures on the basis of the above stitches in order to create lightweight fabrics, we analyzed the existing structures and methods of their production on various types of knitting machines.

The results of the analysis show that the expediency of studying the possibilities of producing combined and two-layer jersey, its structure, knitting processes, properties and areas of practical use is beyond doubt.

PhD E.P. Pospelov proposed a classification of two-layer jersey. According to this classification two-layer knitted fabrics can be divided into six main groups according to the combination of the connected stitches: jersey as a combination of two main (weft- or warp-knitted) stitches, derived stitches, patterned stitches, main and derived stitches, main and patterned stitches, derivatives and patterned stitches [1].

The proposed division of two-layer jersey according to layers connection methods, as well as the division according to the combination of stitches, is based on the theory of knitted stitches and takes into account the well-known classification of prof. A. S. Dalidovich.

To improve the heat-shielding properties of two-layer jersey, methods of producing two-layer jersey offleecy and plush stitch on a flat-fanged machine have been developed [2, 3, 4, 5].

In order to reduce the consumption of raw materials and increase the dimensional stability of two-layer jersey, structures and methods for the production of inlay two-layer jersey have been developed, where the fixing of the inlay thread in the ground of the knitted fabric is carried out due to the formation of closed loops and fleecytucks from the inlay thread.

As a result of the analysis of the technological parameters and physical-mechanical properties of jersey, it was found that the use of the proposed structures and methods for the production of inlay two-layer in the manufacture of knitted products, reducing the consumption of raw materials is achieved from 10 to 12% [6, 7, 8, 9].

In works [10, 11, 12, 13, 14], the influence of the type of used yarn on the parameters and properties of two-layer knitted fabrics is studied in detail. The dependences for cotton, woolen and synthetic yarns of various production methods were investigated.

Research combined with practice has established a list of indicators that characterize the quality of knitted fabrics: their structure, physical and mechanical properties and appearance.

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Among the indicators characterizing the physical and mechanical properties of knitted fabrics, the following are accepted: strength and elongation at break, tensile under loads less than breaking loads, resistance to single and multiple stretching, resistance to crushing and abrasion, shrinkage during wet-heat treatment, etc.

Of the indicators characterizing the physical properties of knitted fabrics, the most often used are: air permeability, water absorption, hygroscopicity, total thermal resistance and other indicators that determine the heat-shielding properties of fabrics, as well as electrification, etc.

II. INVESTIGATION OF PHYSICAL AND MECHANICALPROPERTIES OF DOUBLE LAYER KNITTED FABRIC

In order to study the effect of the length of the thread in the loop of the back layer of two-layer jersey on its physical and mechanical properties, seven variants of two-layer jerseywere developed on a Long Xing 252 SC flat-knitting machine. The variants of the two-layer jersey differed from each other in the length of the thread in the loop of the back layer of the knitted fabric. Two-layer jersey was developed on the basis of semi-tuckstitch, where connection the layers made by press method with main threads.

The structure of two-layer jersey is illustrated in Fig. 1, a. The jersey consists of elongated reverse loops 1, face loops 2, tucks 3 and broaches 4.

In the formation of one rapport of the proposed two-layer jersey on a flat-knitting machine, two knitting systems are involved.

The first system forms a tuck loops row, and the second system, on the needles of the back bed, forms plane stitch row (Fig. 1, b).

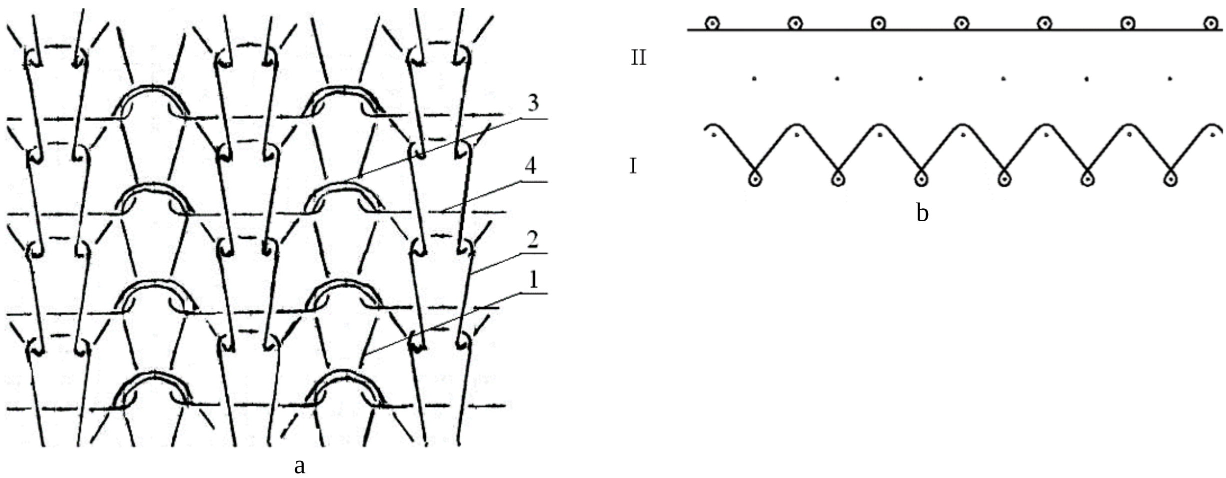

Fig. 1. Structure (a) and graphic record (b) of the production of two-layer jersey

As a raw material, cotton yarn with a linear density of 30 tex x 2 was used - for the back side of a two-layer knitted fabric and polyacrylnitrile yarn (PAN) with a linear density of 32 tex x 2 - for the front side of the knitted fabric.

III. EXPERIMMENTS AND DISCUSSION

The physical and mechanical properties of two-layer jersey were determined according to the standard method [15, 16] in the “CentexUz” laboratory at TITLI, the results are shown in Table 1.

Many properties of two-layer jersey depend directly on its thickness.

These include breathability, thermal resistance, wear resistance.

The research results show that the thickness of the two-layer jersey depends on the type and method of connection the layers. A smaller thickness can be obtained using various variants of the inlay connection with the main or additional threads, a larger one –connection with tucks, lining or cover.

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Table 1. Technological parameters and physical-mechanical properties of two-layer jersey

Indicators		Variants I	II	III	IV	V	VI	VII
Type and linear density of yarn	Face layer	PAN (polyacrylonitrile) 32 texx 2						
	Back layer	Cotton yarn 30 tex x 2						
The content of threads in the fabric, %	Face layer	68	66,5	64,4	63	62	61	60
	Back layer	32	33,5	35,6	37	38	39	40
Length of thread in the loop l , mm	Face layer	15,4	15,4	15,4	15,4	15,4	15,4	15,4
	Back layer	6,18	6,78	7,0	7,5	7,82	8,4	9,16
Surface density M_S , g/m^2		571,3	521	452,7	401,1	383,8	372,5	329,8
ThicknessT,mm		2,2	2,2	2,0	1,83	1,8	1,77	1,6
Bulk densityδ, mg/sm^3		259,7	236,8	226,3	219,2	213,2	210,5	206,1
Air permeabilityB, sm^3/cm^2·sek		36,51	45,34	64	74,8	90,7	104,7	126,7
Abrasion resistance И, thousand turns	Face layer	24	24	24	23	23	21	22
	Back layer	31	33	32	31	34	32	31
Breaking load P, H	By wale	304,5	309	285,5	275	271	270	216,5
	By course	267	249,5	227	176,5	175	168	161
Elongationat 6 N L, %	By wale	11,5	13	14,8	16,2	18,3	20,1	21,6
	By course	13	17,5	27,5	32,5	38	44,5	48
Irreversible deformationε_H, %	By wale	27	22	19	27	16	18	22
	By course	15	18	18	21	19	23	20
Reversible deformationε_O, %	By wale	73	78	81	83	84	82	78
	By course	85	82	82	79	81	77	80
Shrinkage У, %	By wale	2,4	5,2	5,6	6,3	7,1	8,0	8,3
	By course	1,6	2	0,8	2,4	3,6	4,4	3,2
Thermal resistanceR, %		55,8	55,6	49,3	48,8	38,6	31,7	29,5

The air permeability of textile fabrics, which is determined at a constant pressure drop, depends to a greater extent on the porosity, the number and size of open pores, as well as on the thickness of the knitted fabric [17].

The greater the porosity of the material, the lower its weight filling and the higher the air permeability.

The amount of air permeability is influenced not only by the total number of pores, but also by the size and shape of each pore. The smaller the pores, the greater the air friction in the knitted fabric and the less breathable the knitted fabric.

The air permeability of the experimental samples of two-layer jersey was determined on the AR-360 SM device in cm^3 / cm^{2}s at 1 atm.

The air permeability of two-layer knitted fabrics varies from 36.51 to 126.7 cm^3 / cm^2 · sec, depending on the length of the thread in the loop of the back layer of the two-layer knitted fabric.In order to reduce air permeability, its

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face layer should be as dense as possible, and in order to improve its heat-shielding properties, the distance between the layers should be large enough to provide the required thickness.

The change in air permeability depending on the length of the thread in the loop of the back layer of a two-layer jersey can be seen in Fig. 1.

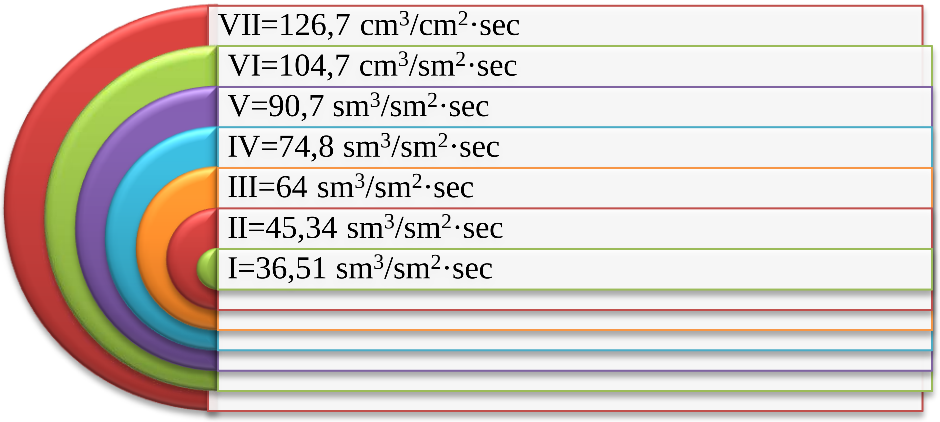

Fig. 1. Air permeability of two-layer jersey

The air permeability index of the experimental samples of two-layer jersey meets the requirements for outerwear.

During operation, the cloths in the products are abraded on the surrounding objects in contact with them and, as a result of wiping of individual parts, become unsuitable for wear.

The evaluation of the abrasion resistance of knitted fabrics is usually determined by the number of turns of the device before wiping the test sample.

The abrasion resistance values of knitted fabrics very widely depending on the type of yarn, stitch, density, etc.

The abrasion resistance of the tested samples corresponds to the standards of abrasion resistance of knitted fabrics for outerwear [18]. The most resistant to abrasion were the variants with the highest density.

Breaking characteristics are the main indicators adopted for the qualitative assessment of knitted fabrics. All standards for knitted fabrics include requirements parameters for elongation at break and breaking load.

The breaking load of the presented samples was determined by the standard method on the Dynamometer "AG-1".

With an increase in the length of the thread in the loop of the back layer of a two-layer knitted fabric, the density of the knitted fabric decreases both in length and width, therefore its strength decreases.

With the length of the thread in the loop of the back layer of the two-layer jersey 6.18 mm, the strength of the knitted fabric along the length is 304.5 N, and along the width 267 N, with the length of the thread in the loop 9.16 mm, the strength of the knitted fabric the length is 216.5 N, i.e. decreases in comparison with I variant of two-layer jersey by length 28.9%, and in width by 39.7% (Table 1, Fig. 2).

With an increase in the length of the thread in the loop of the back layer of two-layer jersey, the face layer of knitted fabric takes the main load.

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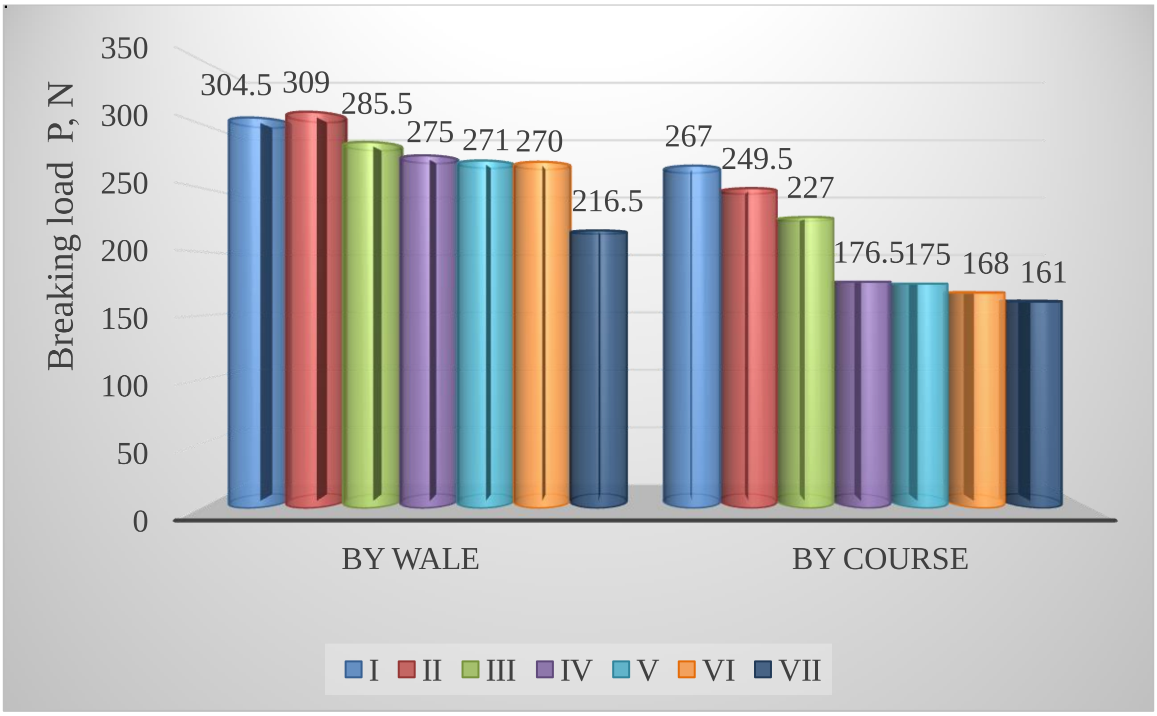

Fig. 2. Histogram of change in breaking load of two-layer jersey

The elongation of the tested samples of two-layer jersey at loads less than breaking loads (6 N) both in length and in width correspond to the first group of extensibility, i.e., it is form-stable.

The most important indicator of the quality of knitted fabrics is the ability of the knitted fabric (product) to restore its original size and shape after wearing.

For the studied samples of two-layer jersey, the proportion of reversible deformation ε_0 was determined, which includes elastic deformation and the main part of elastic deformation, and the proportion of irreversible deformations, including plastic deformation and a part of elastic deformation that did not have time to manifest itself within the time of "rest" established by the method sample.

According to [19], the residual deformation of the knitted fabric intended for upper garments should be no more than 5-20%. The proportion of reversible deformation of two-layer jersey samples along the length varies from 73% to 84%, while the proportion of reversible deformation along the width varies from 77% to 85% (Table 1). This means that the residual deformation of the samples under study meets the requirements.

The indicators of the proportion of reversible deformation indicate the ability of the samples of two-layer jersey under study to quickly take on their original dimensions after stretching. Hence, products made from them. will quickly regain their original shape after wearing.

Residual deformation increases with an increase in the length of the thread in the loop of the seamy side to a certain value, and then decreases. This is influenced by several factors. With an increase in the length of the thread in the loop of the seamy side, the orientation of the sections of the loops of the front side increases in the direction of the row and column. This in turn leads to an increase in the tensile resistance of the face layer. Residual deformation for this reason should decrease. On the other hand, as the density decreases horizontally and vertically, the number of stitch rows and columns in the stretched strip decreases. Since the load is the same for samples with different densities, in a less dense sample, a greater force acts on each loop of the front side; therefore, the deformation of the strip is greater. In the zone before and after $l_1 = l_2$, only one layer is actively involved in the work. For this reason, there is less permanent deformation.

One of the most important properties of knitted fabrics during the operation of products is the preservation of their linear dimensions after the action of wet heat treatments.

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When wetting, washing, dry cleaning, and under the influence of atmospheric moisture, the linear dimensions of the knitted fabric change, i.e. shrinkage occurs.

The shrinkage of knitted fabric, both during the manufacture of products and during their wearing, can manifest itself to a greater or lesser extent depending on the modes of wet-heat treatment of the fabric in the production process, the fibrous composition, structure and stresses obtained by it during knitting.

The main reasons for knitted fabric shrinkage are the reverse relaxation process and fiber swelling. During the knitting process, internal stresses are created in the threads forming the loops. These stresses arise even during the formation of threads, then in the knitting processes and especially during dyeing and finishing, where the jersey is constantly stretched along its length in a wet state, and then fixed in a stretched form in dryers. Stretching in the process of finishing production affects the further behavior of the fabric during the manufacture of products and their wear, since in a wet state the fibers stretch especially easily.

Shrinkage under the conditions of wearing products depends on the type of detergent compositions and their effect on jersey. Research shows that knitted fabrics will shrink more when soaked in warm soapy water than when washed and boiled. With repeated soaking, washing and boiling, shrinkage continues, but with a lower intensity.

For a two-layer jersey made from cotton yarn on a flat-fanged machine, the shrinkage rates are 6-8% in length, 8-10% in width, and draw rates are not more than 5%.

Textile materials, including knitted fabrics, intended for clothing, should provide comfortable conditions for use. Depending on the season, the products should protect the person from cooling or, conversely, facilitate better heat transfer.

Heat exchange between the human body and the environment through clothing is an extremely complex process. Heat is transferred from a warmer body to a less heated body directly by penetrating the clothing material. This type of heat transfer is called thermal conductivity.

The thermal resistance of the experimental jersey samples varies from 29.5% to 55.8%. With an increase in the length of the thread in the loop of the back layer of two-layer jersey, the thermal resistance indicators decrease, because the indicators of air permeability and jersey thickness decrease (Table 1).

IV. FINAL COMPARISON ANALYS AND CONCLUSION

To identify the best options for two-layer jersey, it is necessary to take into account a large number of factors that form the structure and properties of fabrics.

Therefore, to process the obtained test results, a method for constructing complex quality assessment diagrams was chosen.

The diagram is a graphical representation of the results of the analysis of the quality of knitted fabrics. The graph of the complex diagram is constructed in such a way that its largest contour shows the best quality indicators of the produced knitted fabrics, that is, the closer the contour to the outer one, the higher the quality indicators of the knitted fabrics and the closer they are to the requirements.

When distributing the obtained indicators of parameters and physical and mechanical properties of jersey, the purpose of the fabric, the compliance of indicators with established norms and specified requirements are taken into account. Because, for example, the breathability of linen jersey should be high, and jersey for outerwear should be low. When considering the strength characteristics of jersey, the purpose of the product is also important.

To construct diagrams and calculate the areas of the polygon, the results of testing the parameters and properties of knitted fabrics given in the table were used.

In this diagram, a comparative analysis of the qualitative indicators of seven samples of two-layer jersey is made.

In Fig. 3 shows a diagram of a comprehensive assessment of the quality of manufactured samples of two-layer jersey, and in Fig. 4 histogram of quality assessment.

The analyzed indicators were those indicators that form the consumer properties of outer jersey.

Such indicators are the surface and bulk density, as well as the lightness of the jersey, which characterize its material consumption: the thickness of the knitted fabric and the air permeability of the fabric, which characterize the heat-shielding properties, abrasion resistance and breaking load, which are characteristics of strength, tensile, reversible deformation and shrinkage, which characterize form stability.

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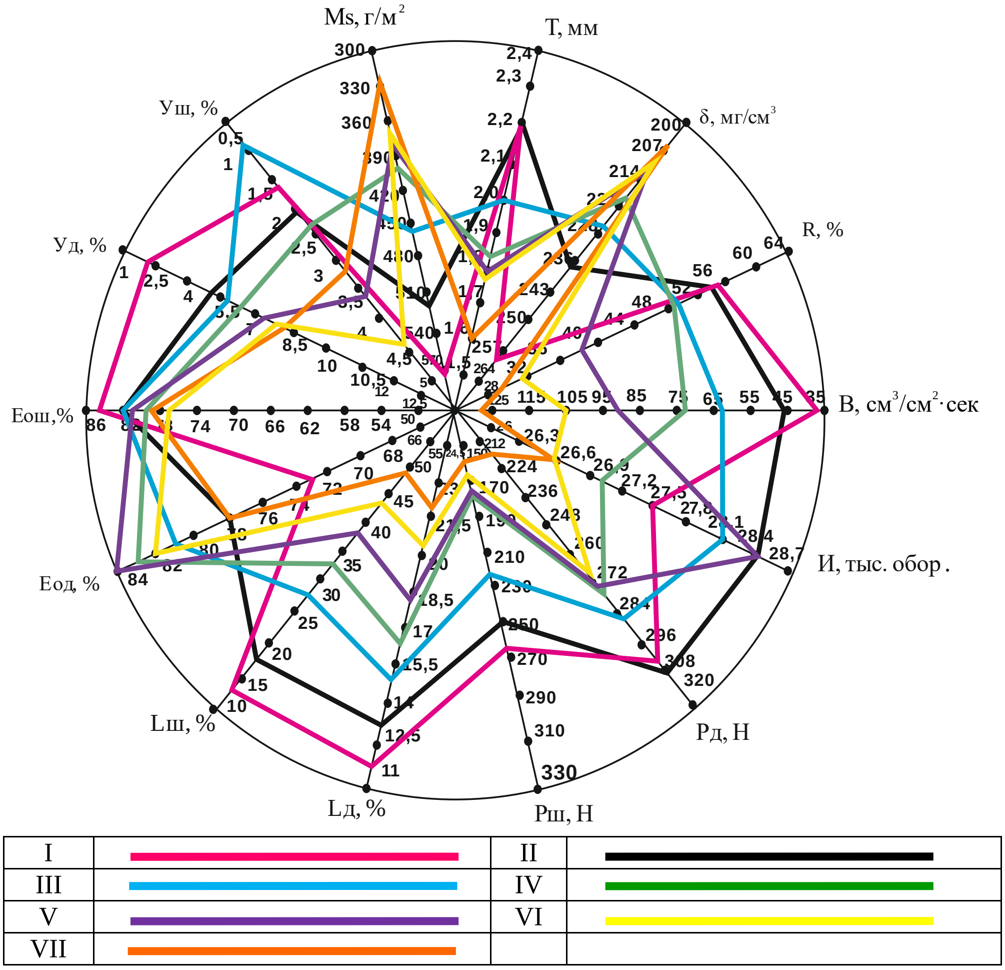

Fig. 3. Comprehensive diagram of the quality of two-layer jersey

The construction of a polygon for a comprehensive assessment of the quality of jersey consists in the sequential connection of points set aside for the radius - vectors that characterize each of the properties.

Consequently, the most polygon, built from the points of the indicators of the most rational version of two-layer jersey, will have the maximum area. The areas of the polygons are calculated as the sum of the areas of the triangles into which the radius vectors divide the polygon.

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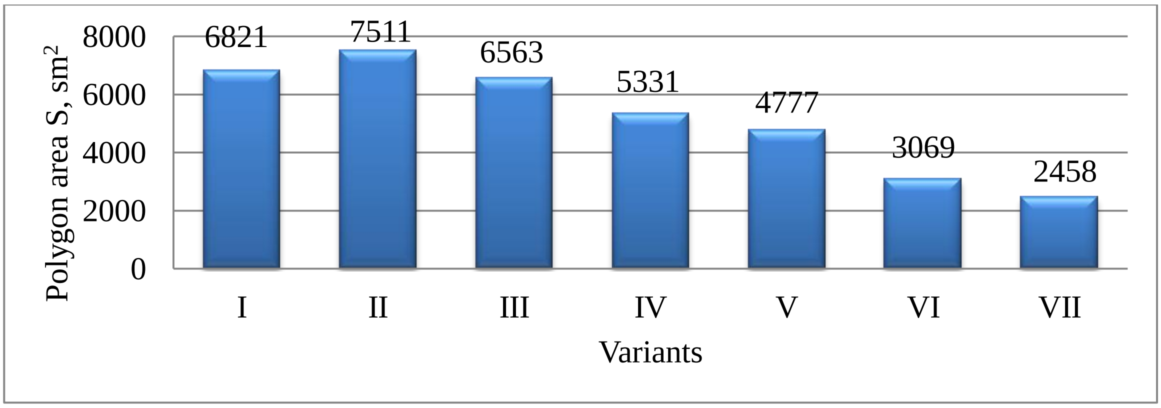

Fig. 4. Histograms for assessing the quality indicators of two-layer jersey

The results of the complex diagram and the histogram of the quality indicators of two-layer jersey showed that the best options for two-layer jersey obtained from cotton yarn with a linear density of 30 tex x 2 and polyacrylonitrile yarn with a linear density of 32 tex x 2 are options II, I and III. These options have high dimensional stability, appropriate hygienic properties and reduced material consumption.

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