**Study of Physical, Mechanical and Deformation Properties of Knitted Fabrics**

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**Abstract:** The article examines the single-stage cyclic stretching test of two-layer knitted fabric samples for outerwear. An important feature of technical knitted products when using them is the stability of their dimensions. Analysis of the results of studying the characteristics of dimensional stability and determining the service life of products showed that the structure of knitted fabrics is subjected to maximum tensile deformation, which leads to an increase in residual deformation, which changes the dimensional characteristics of the product. In the article, the physical and mechanical properties and single-cycle tensile deformation of double-layer knitted fabrics for technical knitted products, obtained on a flat knitting machine of the 10th class with electronic control, were studied. The composition of the fabric samples, woven from PAN yarn with a linear density of 32x2 tex and consisting of various structural variants of patterned knitted fabric, was studied according to the analysis of the influence of the fabric structure on technological parameters, physical and mechanical indicators, deformation properties, according to the requirements for loop pitch, loop height, loop length, surface density, bulk density, and technical textile products.

**Keywords:** single-cycle stretching deformation, longitudinal, transverse, dispersion, elastic deformation, elastic plastic deformation.

**INTRODUCTION**

An important and pressing issue in the knitwear industry is improving product quality, expanding product range, and satisfying consumer demand. Theoretically, the solution to this problem lies in further developing the theory of knitwear production, creating new types of knitted fabrics, and developing highly efficient knitting [1-2] processes with optimal knitting properties.

A significant part of scientific research is devoted to the development and improvement of methods for designing automated knitted products. Recently, "computer-integrated production" in developed countries - called CIM production in the EU, USA, and Japan - has become effective and competitive in the complex, rapidly changing textile market. All stages of such production are carried out using computer technologies.

The production of the most modern equipment used in various industries is currently impossible without the use of new materials obtained on the basis of textile technologies - technical textiles. As a rule, these materials are created using high-strength glass, coal, metal, high-strength polyamide, and other threads.

In the composition of technical knitted products, functional fibers, structural elements with high durability, stable types of knitted fabrics, and combined blended fibers are increasingly used. The trend towards the production of energy-saving fabrics and environmentally safe products is growing. This requires a deep study of the capabilities of warp knitting machines and the improvement of existing technologies. In this regard, the improvement of the technology for obtaining technical knitted fabric on multi-threaded warp knitting machines is one of the most relevant and promising scientific and practical areas [3].

When characterizing the quality of knitted fabrics, it is important to consider their structure and physical and mechanical properties, such as stretch ability and elasticity, which not only determine the valuable consumer properties of knitted products [4, 5], but also determine the shelf life of certain types of products.

One promising area for developing new knitted fabric ranges is the production of double-layer knitted fabrics [6, 7]. In double-layer knitted fabrics, one yarn is knitted on the right side of the fabric, and the second on the left. Such fabrics are used primarily in the production of knitted outerwear.

The quality indicators of four new double-layer knitted fabric variants, produced through the efficient use of the technological capabilities of LONG SING electronically controlled Class 10 flat knitting machines, were studied. The impact of fabric structure modifications on raw material consumption, service life, and service life was also examined.

**METHODS**

Samples of the presented two-layer knitted fabric variants were selected in accordance with the requirements of GOST 8844 and stored for 24 hours in accordance with ISO 139:2019. Technological parameters and physical and mechanical properties were determined in the CentexUz quality laboratory at TTIS using standard methods. The results are presented in Table 1. This helps increase [6, 7] the reliability of test results by ensuring uniform conditions for assessing the quality of textile products.

According to GOST 8847-85, five samples are cut from a point sample along a loop post and a loop row. The experiment is conducted on a WDW-5E machine. The specimen is clamped in the upper clamp with a working length of 100 mm, and the specimen is clamped in the lower clamp (horizontally and vertically) [8].

**RESULTS AND DISCUSSION**

**TABLE 1.** Technological parameters of double-layer knitted fabric

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| Indicators | | | Options | | | |
| I | II | III | IV |
| Yarn type and linear density,teks | | Face layer | PAN32,5  teks x2 | PAN32,5  teks x2 | PAN32,5  teks x2 | PAN32,5  teks x2 |
| Back layer | PAN35  teks x2 | PAN35  teks x2 | PAN35  teks x2 | PAN35  teks x2 |
| Ring pitch, A (mm) | | | 2,0/2,0 | 1,60/1,42 | 2/1,66 | 1.66/1,25 |
| Ring row height V(mm) | | | 1,25/1,25 | 1,11/1,0 | 1,11/1,0 | 1.66/1,25 |
| Horizontal density, Rg  (Number of rings per 50 mm) | | | 25/25 | 30/35 | 25/30 | 30/40 |
| Vertical density, Rv  (50 number of loops in mm) | | | 40/40 | 45/50 | 45/50 | 30/40 |
| Back layer | Face layer | | 1,19 | 0,61 | 0,60 | 1,5 |
| Back layer | | 1,11 | 0,55 | 0,64 | 1,29 |
| Knitting surface density,  Ms (g/m²) | | | 383,0 | 472,6 | 465,5 | 440,2 |
| Thickness, T (mm) | | | 1,8 | 2,0 | 2,1 | 1,75 |
| Bulk density, δ (mg/cm³) | | | 212,7 | 236,3 | 221,6 | 251,5 |
| Absolute lightness,  ∆δ (mg/mm³) | | | - | 23,6 | 8,9 | 38,8 |
| Relative brightness, θ (%) | | | - | 11 | 4 | 18 |

**FIGURE 1.** Histogram of changes in surface density of two-layer knitted fabrics

Based on the comparison of the bulk density of two-layer knitted fabrics, it can be concluded that the surface density of the two-layer knitted fabric of option I is 383.0 g / m2, and the thickness. With a thickness of 1.8 mm, the bulk density was 212.7 mg / mm3. When comparing this option with other options, the surface density of the two-layer knitted fabric of option II was 472.6 g / m2, and the thickness was 2.0 mm, and the bulk density was 236.3 mg / sm3. With the surface density of the two-layer knitted fabric of option III was 465.5 g / m2, and the thickness was 2.1 mm, and the bulk density was 221.6 mg / sm3. The surface density of the two-layer knitted sample of variant IV was 440.2 g/m2, the thickness was 1.75 mm, and the bulk density was 251.5 mg/sm3 (Fig. 1-2).

**FIGURE 2.** Histogram of changes in bulk density of two-layer knitted fabrics.

Based on the results of the technological analysis presented in Table 1, it was found that when comparing the two-layer knitted fabric samples by bulk density, the lowest bulk density was found in Sample 1 of the two-layer knitted fabric, which was obtained by knitting rows of knit stitches on both knit and purl needles.

The physical and mechanical properties of the resulting fabric samples were determined, and the results are presented in Table 2.

**TABLE 2.** Physical and mechanical properties of two-layer knitted fabrics

|  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- |
| Indicators | | | Options | | | | GOST |
| I | II | III | IV |
| Type of yarn and linear density, teks | Front layer | | PAN 32,5  teks x2 | PAN32,5  teks x2 | PAN 32,5teks x2 | PAN 32,5  teks x2 |  |
| Back layer | | PAN 35teks x2 | PAN 35teks x2 | PAN 35  teks x2 | PAN 35  teks x2 |  |
| Air permeability  V, sm3/sm2⋅sek | | | 180,9 | 99,6 | 95,5 | 98,2 | GOST  12088-77  30 -100 |
| Heat retention | | | 26% | 37,5% | 38% | 28% |  |
| Abrasion resistance I, thousand cycles | | | 28500 | 35000 | 36000 | 32500 | GOST  16486-93  30-60 |
| pilling | | | - | - | 1 | 12 |  |
| Introduction,  K, % | | Longitudinal | 0,8 | 1,4 | 1,6 | 1,2 | GOST 26667-85  Maximum 5-8% |
| Transverse | 1,5 | 2 | 1,8 | 2 | Maximum 8-10% |
| Tearing strength, R, N | | Longitudinal | 289,76 | 354,66 | 452,665 | 479,26 | 479,26 |
| Transverse | 415,4 | 321,73 | 363,435 | 301,03 | 301,03 |
| Elongation at break, L, % | | Longitudinal | 14 | 13 | 17 | 16 | [GOST 8847-85](http://docs.cntd.ru/document/1200019736)  6 N  40-100% |
| Transverse | 15 | 22 | 18 | 20 |
| Irreversible deformation, εI, % | | Longitudinal | 14 | 14 | 8,3 (17,1) | 14 | GOST  28882-90  15-20% |
| Transverse | 15 | 13 | 16(0,19) | 30 |
| Bulky deformation, εb, % | | Longitudinal | 43 | 28 | 32,7(67,8) | 39 |
| Transverse | 29 | 49 | 52,3(0,63) | 78 |
| Elastic deformation, εe , % | | Longitudinal | 16 | 11 | 7,3(15,1) | 10 |
| Transverse | 16 | 15 | 15(0,18) | 30 |

The air permeability of the two-layer knitted fabric samples changed from 180.9 to 95.5 cm³/cm² s due to changes in the knit structure, representing a 48% change in air permeability (Table 2). A comparison of the two-layer knitted fabric variants by heat retention revealed that Variant III had the highest heat retention capacity of all the other variants, at 38% (Fig. 3).

Changes in the air permeability of knitted fabric depend on the weaving method, the porosity of the fabric, and the shape and ratio of the pores. The air permeability of the two-layer knitted fabrics changed as follows.

**FIGURE 3.** Change in air permeability of two-layer knitted fabrics.

Among these variants of double-layer knitted fabric, the sample of variant III had the highest abrasion resistance, which amounted to 36 thousand circular cycles (Table 2).

The deformation properties of knitted garments are important not only for determining the consumer properties of knitted garments but also for predicting the suitability of knitted fabrics for certain types of products. Minor deformation of knitted fabrics relative to the main fabric is important in the manufacturing process and in terms of raw material consumption. Therefore, it is important to determine the deformation after changes in linear dimensions during wet-heat treatment. Minor deformation of knitted fabrics complicates the preparation and cutting of garments, and the elongation of knitted fabrics is also important in the design of garments, requiring a study of their deformation upon elongation.

According to GOST 8847-85, five samples are cut from a spot sample, each representing a ring and a series of rings. The experiment is conducted using a WDW-5E tester. The sample is clamped in the upper clamp with a working length of 100 mm and in the lower clamp in horizontal and vertical positions [9-12].

**FIGURE 4.** Graphic representation of the change in the tensile strength of two-layer knitted fabrics.

The longitudinal tensile strength of the two-layer knitted fabric ranged from 479.26 to 289.76 N, with fabric Option 4 showing a 39.6% increase over fabric Option 1. The transverse tensile strength of the two-layer knitted fabric ranged from 415.4 to 301.03 N, with fabric Option 1 showing a 28% increase over fabric Option 1 (Table 2).

**FIGURE 5.** Graphic representation of a two-layer knitted fabric by quality indicator – elongation at break.

**CONCLUSION**

When analyzing single-cycle deformation of the samples along the length, the total tensile strain in the first sample was 73%, of which the elastic deformation was 43% (58.9%), elastic - 16% (21.9%) and plastic - 14% (19.2%). In the second sample, the total strain was 48%, of which the elastic - 23% (47.9%), elastic - 11% (22.9%) and plastic - 14% (29.2%). The total strain of the sample of the third variant was 79%, of which the elastic - 64.4% (81.5%), elastic - 8.6% (10.9%) and plastic - 6% (7.6%). The total deformation of the fourth variant was 63%, of which elastic deformation was 37% (58.7%), elastic deformation was 12% (19.1%) and plastic deformation was 14% (19.1%).

In conclusion, it can be noted that the physical and mechanical properties of the recommended options of double-layer knitted fabric have been studied, and these fabrics are recommended for the manufacture of outerwear for adults.

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