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ANALYSIS OF THE TECHNOLOGY OF OBTAINING KNITTED FABRICS WITH PATTERNS AND THEIR PHYSICAL AND MECHANICAL PROPERTIES

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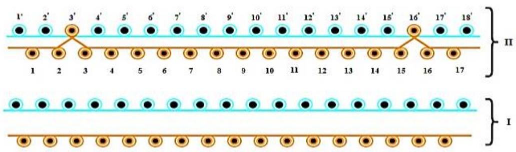
Abstract: This research primarily focuses on designing dual-layer knit fabric architecture with patterned warp on a scientific basis, improve the technology of their production, and analyze their mechanical and functional characteristics in depth. In particular, it is planned to determine the effect of the placement of warp yarn between the layers of the knitted structure on the operational performance of knitted products, and to determine the relationship between such factors as strength, form stability, elasticity, and air flow transmission on a test basis. Based on experimental tests, knitted fabric samples with a pattern were developed. 20-tex cotton yarn and 100-tex polyester warp yarn were used on a German "Mayer & Cie" jacquard machine. The tensile strength, elongation, air permeability, and deformation of the fabrics were measured on laboratory equipment in accordance with GOST requirements. Two-layer knitted structures with patterned warp yarns serve to create high-quality, durable and aesthetically attractive products. The placement of warp yarn between the layers ensures an increase in the overall quality and durability of the fabric. The results of the research allow the use of these structures in outerwear and sportswear.

Keywords: Knitted fabric, warp yarn, double-layer knitting, jacquard machine, physical and mechanical properties, shape retention, air permeability, deformation, tensile strength, knitted structure, warp-laying technology.

Introduction. In recent decades, the textile and apparel industry has experienced dynamic development, particularly in the field of knitted fabric production. This progress is closely linked to the evolving demands of consumers in terms of comfort, hygiene, aesthetics, and functionality, driven by changes in lifestyle and increased expectations for textile performance. As a result, there has been a growing emphasis on the development of knitted fabrics that meet both visual and functional criteria [1]. One area gaining significant attention is the innovation of double-layer knitted fabrics featuring integrated patterned warp yarns. These structures offer not only aesthetic enhancement but also improved physical and mechanical properties, such as tensile strength, elasticity, dimensional stability, and breathability [2]. The interplay between fiber composition and structural configuration plays a key role in determining the overall quality and performance of knitted products [3]. In this context, the insertion of warp yarns between the layers of a knitted fabric has emerged as a promising technique to reinforce the internal structure without affecting the visual or tactile qualities of the outer surface [4]. This approach enhances the mechanical durability of the fabric, contributing to greater shape retention, resistance to both reversible and irreversible deformation, thermal insulation, and optimized air permeability [5]. Furthermore, the strategic placement of warp yarns within the interstitial layer facilitates stronger interlocking between the upper and lower fabric surfaces. This method not only improves the cohesion and firmness of the final product but also ensures minimal disruption to the knitting process, making it suitable for large-scale industrial implementation [6]. The current study aims to explore the structural and functional advantages of incorporating warp yarns into two-layer knitted fabrics. By analyzing the interaction between yarn positioning and mechanical performance, the research provides a foundation for the development of new textile solutions suitable for outerwear, activewear, and other performance-based applications [7].

Methods. The manufacturing of knitted products using warp-knitted fabric structures enables a reduction in raw material usage while simultaneously enhancing the thermal insulation capabilities of the final textile. Incorporation of warp yarns into the fabric structure contributes to lowering the susceptibility to tearing, excessive elongation, and distortion under mechanical stress [8]. In knitted constructions containing warp yarns, those aligned in the longitudinal direction exhibit reduced elongation along the length, whereas those positioned transversely demonstrate limited stretch across the width [9].

The integration of front and rear loops in the fabric is facilitated through the dual-layered arrangement of warp yarns, achieved by carefully coordinating the filling and alignment of both loop systems. Within this configuration, a grooved texture is established by manipulating transverse and longitudinal rapports, as well as the spacing and placement parameters. Patterned warp knitted fabric samples were fabricated using OVJA 1.6 ER class 20 circular double-needle knitting machines within an industrial setting.



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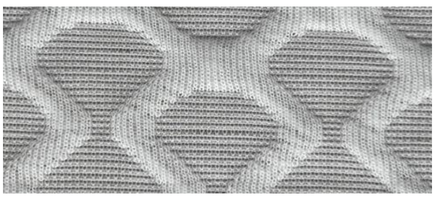

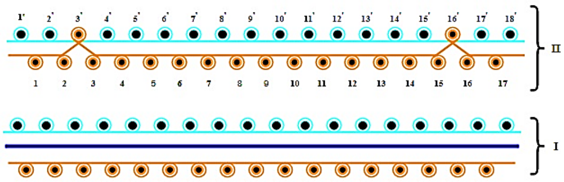

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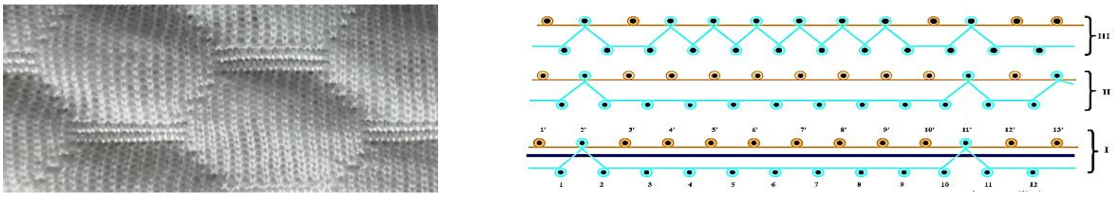

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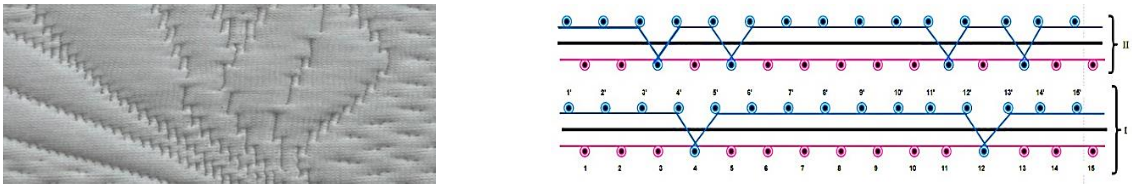

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Figure 1. Graphic representation of a warp knitted fabric

In the first sequence, a rib-knit fabric was produced using ribbed needles, where a uniform plain stitch was generated simultaneously on both the front and back needle beds. This configuration was identified as Variant I and served as the reference or base structure. The method employed to interconnect the layers is referred to as base yarn interjoining (Figure 1.a). For Variant II of the double-layer warp-knitted sample, a smooth texture was constructed by feeding yarn 1 to the front needles and yarn 2 to the rear needles, resulting in a differentiated double-sided fabric (Figure 2.2.b). In the case of Variant III, the double-layer fabric was engineered by inserting warp yarns between the two knitted layers, thereby forming a central reinforcement layer (Figure 2.2.v). In the structural configuration of Variant IV, yarn 1 was assigned to the front needle bed, and yarn 2 was designated for the back needle bed. A supplemental connecting yarn was employed to bond both layers. This connection was established by transferring the warp-knit fabric, originally created on rib needles, to the cylinder needle 4. The warp yarn was precisely positioned between the two knitted layers along the course direction and secured by the formation of closed loops on the back needle bed.

Due to its embedded placement, the warp yarn remains fully internal and does not emerge on the visible fabric surface. When the looper mechanism is activated, the weft yarn is accurately introduced between the front and rear needle beds using an auxiliary yarn guide. At this point, the needle heads are situated beneath the plane of the needle bed. The weft insertion system operates in tandem with the full looper assembly. The formation of the second course follows a similar technique, with the only difference being an increased number of interconnecting threads between the layers. For instance, in a double-layer warp-knitted fabric with a cross-sectional rapport of 15, two loops are used for layer connection in the first row, while four loops are applied in the second row. To enhance interlayer bonding, loops are created on cylinder needles corresponding to the 3rd, 5th, 11th, and 13th rib needles. Increasing the number of connecting threads improves the fabric's bonding strength and generates a distinctive grooved surface design.

As a result, the constructed two-layer fabric exhibits compositional diversity based on the type of yarns used. Furthermore, the loops of the front layer remain concealed from the rear side, and vice versa, ensuring clear layer separation without surface intrusion (Figure 2.2.d).By using natural cotton yarn as raw material for both layers of the knitted fabric and polyester yarn as warp yarn, depending on the function of the knitted fabric being obtained, it is possible to obtain a two-layer warp knitted fabric with high quality indicators, high hygienic properties and low raw material consumption per unit of product. Since this method is simple, it is practically carried out without affecting the productivity of the machine and without making changes to its design, taking full advantage of its technological capabilities. The presence of warp yarn in the knitted fabric reduces the stretchability of the knitted fabric and increases its shape retention. The fact that the warp yarn is located between the layers of the knitted fabric and is woven together with the base ring ensures that the warp yarn is firmly fixed in the knitted fabric. The inclusion of arrack yarn in the fabric composition meets the operational requirements for the fabric's elasticity, shape retention, heat retention, deformation properties, and recommended product range. The introduction of warp yarn into the fabric structure leads to a sharp decrease in machine productivity. However, it effectively serves the purpose of expanding the range of knitted products.

Results. A double-needle jacquard knitting machine was employed to fabricate the samples, utilizing polyester yarn with a linear density of 100 tex as the warp component and cotton yarn of 20 tex for both outer layers of the knitted structure. In examining raw material consumption standards for both outerwear and innerwear manufacturing, GOST and TS regulatory metrics highlight two key strategies for minimizing material usage per unit of knitted fabric:

lowering the quantity of raw materials required for each fabric unit;

reducing production-related waste throughout all stages of the technological workflow.

To meet these goals, it is essential to design knitted structures that are more economically optimized and to implement technologies that are both resource-efficient and minimize waste generation. At present, there is a notable increase in demand for knitted fabrics produced using circular double-needle jacquard machines, particularly within local industries focused on outerwear production. In this context, the influence of integrating warp yarns into a dual-layer knitted base—attached in alignment with the fabric’s pattern design—was analyzed. The performance characteristics of the final knitted product are primarily governed by the properties of the raw materials employed, the configuration of the knit structure, and the specific processing techniques. The strategic incorporation of warp yarns alters the internal construction and enhances the visual and functional patterning, thereby affecting the physical and mechanical behavior of weft-patterned knitted fabrics [10,11,12].

Table 1. Physical and mechanical properties of knitted fabric with patterned warp

Indicators		Options I	II	III	IV
Yarn types and linear densities	Front and back	Cotton yarn 20 tex			
	Weft yarn	Polyester ip 100 tex			
Air permeability V (sm^3/sm^2·sec)		45,7	40,6	40,2	35
Breaking strength R (N)	height	213	249	256	264
	width	205	306	344	370
Stretching until breaking l (%)	height	90,09	97,75	95,5	95,12
	width	72,5	65,6	65,7	68,15
Reversible deformation ε_o (%)	height	81	85	87	88
	width	80	86	88	90
Irreversible deformation ε_n (%)	height	19	15	13	12
	width	20	14	12	10
Fabric shrinkage K (%)	height	6	5	4	4
	width	8	6	4	3
Abrasion resistance I(thousand/rotation)		40	50	52	56

The fabric's surface texture is developed through the use of yarns that differ in color, thickness, and degree of twist. In the construction of double-layer jacquard fabrics, two distinct thread systems are involved—warp and weft—and by alternating their respective functions and vertically displacing the upper and lower layer yarns, the overall texture and dimensional effect of the fabric are enhanced. During the design process of large-patterned, dual-layer fabrics, particular emphasis is placed on the visual appearance of the outer surface. Various decorative effects—such as wrinkled, embossed, and elevated surface elements—are intentionally incorporated to create aesthetic diversity and richness [13,14]. These types of knitted fabrics are predominantly recommended for use in manufacturing both women's and men's outerwear garments.

Discussions. Air permeability is considered a critical physical and mechanical parameter that reflects the hygienic performance of knitted fabrics, and it is significantly influenced by the structural configuration, surface mass, and thickness of the textile [15]. In the case of knitted fabrics incorporating patterned warp yarns, air permeability was observed to range between 35 and 45.7 sm^3/sm^2·sec (Figure 1). Experimental evaluation of air permeability in double-layer jacquard knitted fabrics—engineered with warp yarn insertion to enhance both the pattern definition and mechanical robustness—revealed that the sample corresponding to Variant IV exhibited the lowest air permeability value at 37.5 sm^3/sm^2·sec. This measurement represents a 32.5% reduction in comparison to the base fabric (Variant I), indicating that warp yarn integration significantly reduces airflow through the fabric structure.

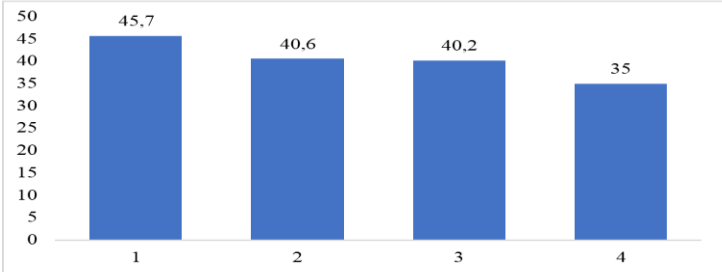

Figure 2. Histogram of the change in air permeability index of knitted fabrics with a patterned warp

The variation in air permeability observed in knitted fabrics with patterned warp insertion can be attributed to the influence of the warp yarns—introduced into the jacquard double-layer fabric using the pattern-guided attachment technique—on the fabric's porosity, as well as the geometry, dimensions, and quantity of its pores [16,17,18].

The tensile strength of the patterned weft-knitted fabrics was assessed using the standardized "YG-026T" dynamometer. The evaluation showed that the breaking strength was 24% higher than that of Variant I. Specifically, Variant II demonstrated a peak strength of 332 N in the width direction. This improvement is linked to the application of polyester as the weft yarn within the patterned structure and the resulting modifications in fabric construction, which caused variations in the loop pitch across Variants I, II, and III. The assessment of tensile strength across all patterned warp variants of the double-layer jacquard knitted fabrics confirmed that the presence of a warp yarn consistently enhanced the strength performance. All fabric types developed in this study fulfilled the established mechanical criteria for upper garment applications. In terms of elongation classification under GOST standards, the samples fell within the second and third categories. Moreover, the elongation at break was notably lower, indicating improved dimensional stability and shape retention for the patterned knitted structures [19,20].

The elongation values measured along the length of the fabric ranged from 90.09% to 97.75%, whereas in the width direction, the values varied between 65.6% and 72.5%. The comparatively reduced elongation across the width is primarily attributed to the integration of weft yarns and the double-layer knitting approach employed in fabric formation.

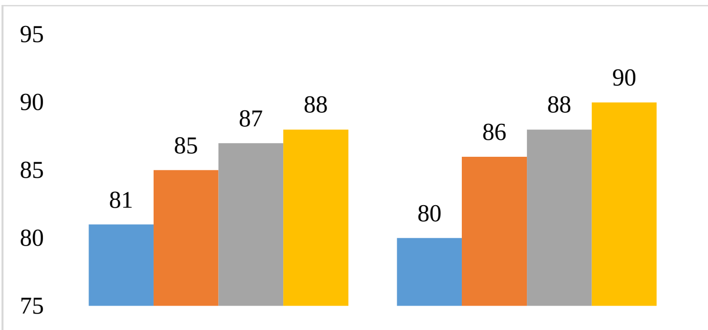

Figure 3. Histogram of the reversible deformation change of knitted fabrics with a patterned warp

The elastic behavior of knitted fabrics is evaluated based on their recovery percentage following deformation. A greater recovery percentage reflects superior elasticity, which in this case is attributed to the presence of warp yarns in the fabric structure [21,22]. The recovery percentage in the longitudinal direction for fabrics with patterned warp varied between 82% and 89%, while in the transverse direction it ranged from 80% to 90% (Figure 3).

These values of reversible deformation demonstrate that the tested patterned knitted samples were capable of returning to their original dimensions efficiently after stretching. The tensile characteristics of the patterned fabric were examined using the YG026A–III testing instrument. Test specimens were prepared in dimensions of 30 × 5 cm, subjected to an 850 g (8 N) load for 30 minutes, followed by a 10-minute recovery period during which reversible deformation was recorded. Results indicated that irreversible deformation in the lengthwise direction varied from 18% to 25%. The highest longitudinal rigidity was exhibited by Variant IV. In the widthwise direction, values ranged from 17% to 20%, aligning with the GOST and TSh regulatory standards.

The longitudinal shrinkage of the double-layer fabric ranged from 3% to 8%. Variant IV demonstrated the greatest resistance to abrasion, achieving 56,000 cycles, which is a 40% improvement over the baseline sample. Rapid elastic deformation is often difficult to capture during mechanical testing, as it depends on the specific relaxation period and environmental conditions. The test protocol quantified the percentage of reversible deformation, encompassing the principal elastic response, plastic deformation, and a residual elastic component that did not fully manifest during the fabric's post-load relaxation phase, as defined by standardized procedures [23].

These results affirm the high elastic performance of the knitted fabrics studied. The greater the proportion of reversible deformation, the more effectively the resulting garments retain their shape. The inherently high elastic deformation range (typically 60–90% of total strain) is a distinguishing characteristic of knitted structures. This property plays a critical role in product functionality, particularly in applications requiring form stability, such as outerwear and athletic apparel. The development of a novel warp-knitted structure—utilizing centrally embedded warp yarns and hygienic cotton yarns in the outer layers—enables efficient material use and enhances durability through secure fixation of the warp yarn within the knit base.

Conclusion. This research thoroughly examined the structure, manufacturing methodology, and physicomechanical characteristics of double-layer knitted fabrics incorporating patterned warp yarns. The experimental findings confirmed that placing a warp yarn between the two layers significantly enhances key performance indicators such as dimensional stability, deformation resistance, shrinkage control, air permeability, and thermal insulation. These improvements were attributed to the impact of the embedded warp thread on the fabric's pore structure, leading to better heat retention properties. Abrasion resistance was also notably improved, with Variant IV achieving 56,000 cycles—representing a 40% increase over the 40,000 cycles recorded in Variant I. Furthermore, the incorporation of warp yarns contributed to reinforced bonding between fabric layers, the formation of decorative surface patterns, and an overall enhancement in the fabric's visual and functional quality. Because the warp yarns are securely anchored within the fabric's loop structure, the resulting textile maintains its shape for extended periods, resists elongation under stress, and exhibits high standards of hygiene and thermal regulation. The outcomes of this study demonstrate that such dual-layer structures with patterned warp integration provide effective solutions to meet the evolving demands of contemporary textile manufacturing. These innovations have broad applicability in the development of outerwear, sports garments, and specialized fabrics requiring insulation. The structural and technological advancements derived from this work are instrumental in improving product quality, minimizing raw material usage, and elevating production efficiency across the textile sector.

References

1. Mamatqulov Q.X. *Yengil sanoatda innovatsion texnologiyalar*. Toshkent: Fan va texnologiya, 2020. – 228 b.
2. Hsieh Y.L. Moisture transport in textile materials. Annual Review of Materials Science. 1995; 25: 567–589.
3. Maity S., Saha B., Nayak R. Advanced Knitting Technology. Elsevier, 2022. – 336 p.
4. Qurbonov U.A., Tursunov A.T. Trikotaj to‘qimalar fizikasi va ularning xossalari. Toshkent: TTITB, 2015. – 184 b.
5. Tokarska M. Structure and properties of multilayer knitted fabrics. Fibres & Textiles in Eastern Europe. 2017; 25(4): 57–64.
6. Jo‘rayev A.J. To‘qimachilikda iplarning xususiyatlari va ishlatilishi. Namangan: NMTI nashriyoti, 2018. – 150 b.
7. Tokarska M. Structure and properties of multilayer knitted fabrics. Fibres & Textiles in Eastern Europe, 2017, Vol. 25, No. 4, pp. 57–64. ISSN: 1230-3666
8. Jassal M., Ghosh A. Development of double-layer knitted fabrics with improved thermal resistance. Indian Journal of Fibre & Textile Research, 2002, Vol. 27, No. 3, pp. 243–248. ISSN: 0971-0426
9. Hsieh Y.L.Moisture transport in textile materials. Annual Review of Materials Science, 1995, Vol. 25, pp. 567–589. ISSN: 0084-6600, DOI: 10.1146/annurev.ms.25.080195.003031
10. Ozdil N., Anand S.C. Effect of elastane and knit structures on knitted fabric properties. Journal of Textile Institute, 2015;106(4):393–403. ISSN:0040-5000, DOI:10.1080/00405000.2014.904016
11. Behera B.K., Hari P.K. Objective evaluation of fabric handle from mechanical properties. Journal of Textile Institute, 1994; 85(1): 10–23. ISSN: 0040-5000 DOI: 10.1080/00405009408688989
12. Wang F., Li X. Flat knitting structures for seamless garments. IEEE Transactions on Industry Applications, 2013; 49(2): 1117–1122. ISSN: 0093-9994 DOI: 10.1109/TIA.2013.2245032
13. Jurabayev.N.N, Shogofurov.Sh.Sh, Kholikov.K.M, Meliboev.U.X (2021). Study of the fabric structure influence on the physical-mechanical and technological properties of knitted products. In E3S Web of Conferences (Vol. 304, p. 03030). EDP Sciences.
14. Shogofurov.Sh.Sh. Kamalova.I.I, Xolikov.K.M, (2021). Study of the Effect of Changes on the Technological and Physical-Mechanical Properties of Knitting in a New Structure. Engineering, 13(6), 287-299.
15. Shogofurov, Sh.Sh; Kamalova, I.I; Xoliqov, Q.M; Meliboev, U.X. (2020) Structure And Methods For Producing Refined Two-Layer Knitted Sheets. Solid State Technology. Vol. 63 No. 6 (2020). Pages 11798-11807.

16. Juraboev, A.T; Kholiqov, Q.M; Shog'ofurov, Sh. Sh (2020) The study of the technological parameters of double layer knitwear with various methods of connecting layers.ACADEMICIA: An International Multidisciplinary Research Journal. Year: 2020, V10.Issue4. Pages 397-404.

17. Kholikov, K.M; Zhuraboev, A.T; Shogofurov, Sh.Sh; Abduvaliev, D.M. (2020)Comprehensive assessment of the two-layer knitwear quality. The Way of Science. 2020. № 1(71).

18. Shogofurov, Sh.Sh., Xolikov, Q. M. (2021). Pattern effects of knitwear fabrics on jackard knitwear. In Экономика. Социология. Право (pp. 29-31).

19. A.T Juraboev, Q.M Kholiqov, Sh.Sh.Shogofurov, The study of the technological parameters of double layer knitwear with various methods of connecting layers. ACADEMICIA: An International Multidisciplinary Research Journal. Year: 2020, V10. Issue 4

20. Shogofurov.Sh.Sh, Umarjonovna.R.S., Ibroximovna.K.I, Madaminovich.K.K, (2021). Analysis of physical-mechanical performance of two-level. South Asian Journal of Marketing & Management Research, 11(2), 68-73.

21. Shogofurov, Sh.Sh; Kamalova, I.I; Xoliqov, Q.M; Study of the Effect of Changes on the Technological and Physical-Mechanical Properties of Knitting in a New Structure, Engineering, tom-13, nomer-6, page 287-299

22. Shogofurov, Sh; Xolikov, QM, RESEARCH OF PATTERN IN A NEW STRUCTURE KNITTING FABRICS, ЭКОНОМИКА. СОЦИОЛОГИЯ. ПРАВО, 2021, page 26-28

23. Shokirjonugli, Shogofurov Shaxboz; Madaminovich, Kholikov Kurbonali, Study of technological indicators of ornamental knitted fabrics with high formal properties, Asian Journal of Multidimensional Research (AJMR), tom 10, nomer 2, page 119-124, year 2021

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