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# Investigation Of Technological Parameters Of Patterned Knitted Fabrics

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**Abstract:** In this study, the technological parameters of patterned knitted fabrics were investigated. Experimental samples were produced on a LONG-XING SM-252 flat knitting machine of 12-gauge using polyacrylonitrile-based yarn (35 tex × 2) in three variants. The variants differed by integrating independent layers through the ground yarn, modifying the pattern repeat, and adjusting the loop spacing, which led to a reduction in raw material consumption and an improvement in shape retention. During the experiment, key parameters such as surface density, thickness, loop spacing, course height, loop length, horizontal and vertical densities, and volumetric density were measured for each sample. The results demonstrated that constructive design solutions in patterned knitting significantly contribute to reducing material consumption, enhancing shape stability, and broadening the product range.

**Keywords:** Knitting, double-layer fabric, pattern, loop length, loop spacing, polyacrylonitrile, surface density, volumetric density, flat knitting machine, shape retention, pattern repeat.

## INTRODUCTION

Patterned knitted fabrics are decorative and functional textile structures formed by the interlacing of yarns through needles and by the arrangement of loops in various configurations [1]. The structure of such fabrics is influenced by the loop rows, yarn interconnections, needle operation sequence, yarn selection, and machine settings acting in combination. In addition to serving as a decorative element in garments, patterned knits determine key functional properties such as shape retention, softness, air permeability, thermal insulation, and elasticity. Therefore, the pattern in knitting is not only an aesthetic feature but also a fundamental factor shaping the practical performance of the fabric [2–3].

The loop is the primary structural element in creating knitted patterns. The size, height, and interconnection of each loop define the overall texture of the fabric. The type of yarn used in pattern formation also plays an important role. Cotton yarn is known for its softness, though its shape-retention capability is relatively low [4]. Wool yarn provides good thermal insulation and increases fabric bulkiness, while synthetic fibers improve strength and elongation resistance. Frequently, blended yarns are employed, combining the advantages of both materials and enhancing the overall performance of the fabric.

One of the key processes in pattern creation is the selective needle operation mechanism. In a knitting machine, the movement of needles is controlled by a specific system in which only the required needles catch the yarn and form loops, while others remain inactive or hold the yarn. As a result, desired shapes, lines, or color variations appear on the fabric surface [5]. Moreover, multilayer knitted fabrics can be produced by using multiple yarns simultaneously, thereby improving thermal insulation and shape retention properties. Modern flat knitting machines provide wide possibilities for pattern formation. Electronic control enables precise sequencing of loops, timely yarn feeding, and independent needle actuation, allowing the production of complex patterns with high quality. The machine components—such as the yarn feeder, needle, needle bed, sinker, and take-down mechanism—collectively affect the quality of the pattern and the physical properties of the knitted fabric [6].

**Materials and Methods**

Patterned knitted fabrics are widely used in applications ranging from everyday clothing to technical textiles. In apparel, patterns serve as an expression of personal style. Most sweaters, cardigans, socks, gloves, and hats are produced in patterned designs. Likewise, household items such as pillow covers, quilt cases, and table decorations are often made with decorative knit structures [7–8]. Technical knitted fabrics, however, require a denser and stronger structure, which is typically achieved by incorporating a greater number of transfer loops. In contrast, medical knitted fabrics must provide flexibility and resistance to bending and elongation; therefore, elasticity is a key parameter. Patterns determine not only the aesthetic but also the hygienic and comfort properties of a fabric. For instance, fabrics with a higher proportion of press loops trap more air, enhancing thermal insulation, which makes them suitable for winter clothing. Knits incorporating stretch loops tend to be thicker, quicker to dry, and maintain their shape better, while transfer loops increase stiffness and prevent deformation. Thus, the selection of pattern type is determined by the intended end-use of the fabric [9].

Color also plays an essential role in pattern formation. The combination of yarns in different colors enables the creation of various shapes, lines, and geometric motifs on the fabric surface. Appropriate color matching enhances the visual appeal of the fabric. However, in multicolor patterns, the proper sequencing of yarn delivery, feeder operation, and needle selection must be accurately controlled to prevent yarn tangling. In recent years, the process of patterned knitting has increasingly been managed through computer-aided design (CAD) systems. These programs define the shape, color sequence, loop arrangement, and fabric density in advance, thereby accelerating production, reducing errors, and facilitating the exact repetition of identical patterns [10]. Patterned knitting continues to evolve, with current research focusing on improving yarn composition, testing novel decorative techniques, enhancing knitting machine design, and optimizing fabric performance. The integration of new yarn materials, expanded electronic control, and advanced design software significantly increases the creative and functional potential of knitted structures, enabling the production of fabrics that are aesthetically appealing, durable, hygienic, and highly functional [11].

In the design of new knitted structures or finished knitted products, several key parameters—such as loop step (A), loop course height (V), and loop yarn length (L)—are taken into account. These parameters determine the surface density, volumetric characteristics, and other technological properties of the fabric. Understanding the interrelationship between these parameters allows the selection of optimal knitting regimes during production [12].

Patterned knitted fabrics produced in transverse or longitudinal directions with varying mechanical structures are suitable for both technical and outerwear applications. The type of raw material, structure of the fabric, and post-processing methods are the principal factors determining the technological and performance characteristics of any knitted fabric [13]. Typically, patterned knitted fabrics consist of two independent layers that may have identical or differing structures and properties. When these layers are interconnected, the properties of each layer can change—the alteration in one layer affects the performance indicators of the other. Therefore, the calculation methods used for single-layer fabrics are not directly applicable to multilayer or patterned knits, as their loop length and density depend on the method of interconnection and the nature of interlayer bonding.

To determine the technological parameters of knitted fabrics, three main approaches are employed.

(1) The standard-based method relies on established norms (e.g., GOST, OST, or technical specifications) and is applied when precise calculations are not critical or when formula-based values deviate significantly from actual measurements. This method is particularly used for newly developed structures or fabrics made from unconventional raw materials. However, due to the limited coverage of existing standards, this approach cannot always be applied universally.

(2) The experimental method is used when developing new knitted structures. Its advantage lies in obtaining accurate data under real manufacturing conditions. However, it requires specialized equipment, testing devices, and suitable raw materials.

(3) The analytical (calculation) method is applied at nearly all design stages. This approach primarily focuses on determining the loop yarn length, from which density and other interrelated parameters can be derived.

To improve material efficiency, diversify knitted fabric assortments, and enhance the technological potential of Chinese-made LONG-XING SM-252 flat knitting machines, three constructive variants of patterned knitted structures and corresponding knitting technologies were proposed. In these variants, interlayer bonding was achieved through the main knitting yarn. The variants differ in terms of pattern shape, repeat interval, degree of shape retention, and several other structural and technological characteristics.

Results and Discussion

According to the experimental results, the technological characteristics of the developed patterned knitted fabric were determined in the laboratory of Namangan Institute of Engineering and Technology. The measured data are presented in Table 1. The study examined the physical properties, visual appearance, and structural configuration of the knitted fabric.

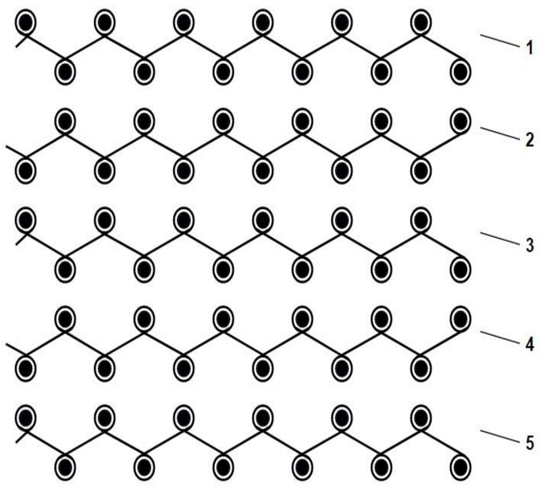
The principal parameters used to characterize knitted fabrics include surface density, volumetric density, longitudinal and transverse loop density (i.e., the number of loops per unit length and width), loop yarn length, the intersection angle of loop courses and wales, and fabric thickness. The graphical representation of the developed patterned knitted structure is shown in Figure 1.

During the experiments, polyacrylonitrile yarn of 35 tex × 2 was used as the raw material. The selection of this yarn was based on its elasticity, shape-retention ability, and high thermal insulation capacity. Polyacrylonitrile-based yarns also exhibit excellent hygienic properties, contributing to increased durability and extended service life of the final product.

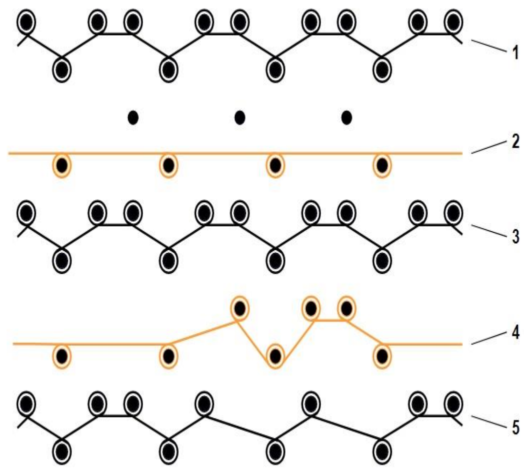
This experimental–practical approach enabled a detailed study of the interrelationships among the main parameters of patterned knitted fabrics, applying experimentally obtained indicators to analytical calculations, and integrating empirical and theoretical methods in the development of new constructions. As a result, both product quality and raw material efficiency were significantly improved.

The first variant (Variant I) of the patterned knitted fabric was produced by interconnecting two independent layers through an auxiliary yarn serving as the base structure (Figure 1). This configuration ensured stable pattern formation, improved dimensional stability, and reduced yarn consumption compared to conventional plain knits.

**Variant I**




**Variant II**




**Variant III**

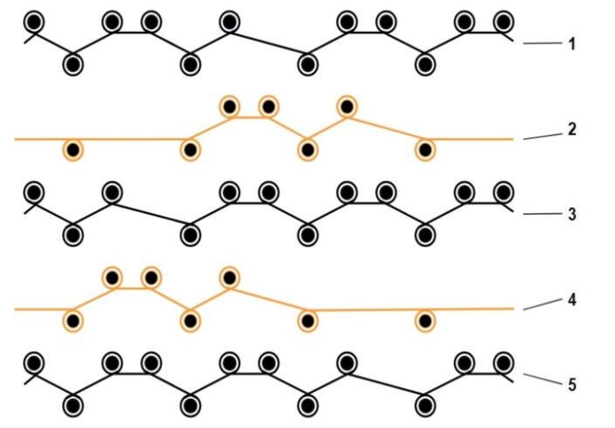



**Figure 1. Graphic representation of knitted fabrics with patterns**

In variant I, a knitted fabric was created by interweaving independent layers with an additional yarn, along with a fabric that acts as the main layer (Figure 1). As a result of changing the structure of the knitted structure and using raw materials of different compositions, it was found that the bulk density of the knitted fabric in all variants significantly decreased compared to the main fabric. During the study, a change in the bulk density of knitted fabrics from 177 mg/cm³ to 144 mg/cm³ was noted (Table 1).

**Table 1. Technological indicators of knitted fabric with embroidery**

| Indicators | | Variations | | |
|---|---|---|---|---|
| | | I | II | III |
| Yarn type, linear density and % content in fabric | Back layer | PAN 35teks x2 | PAN 35teks x2 | PAN 35teks x2 |
| | Front layer | PAN 35teks x2 | PAN 35teks x2 | PAN 35teks x2 |
| Loop pitch A (mm) | | 0.91 | 0.86 | 1.02 |
| Loop row height B (mm) | | 1.31 | 0.94 | 1.39 |
| Horizontal density Pg (number of loops) | | 55 | 58 | 49 |
| Vertical density Pv (number of loops) | | 38 | 53 | 36 |
| Loop yarn length L (mm) | | 6,5 | 6.3 | 6.7 |
| Knitting surface density Ms (gr/m$^2$) | | 425 | 436 | 402 |
| Knitting thickness T (mm) | | 2.4 | 2.6 | 2.8 |
| Bulk density δ (mg/cm$^3$) | | 177 | 167 | 144 |

For the patterned knitted fabric of Variant II, the measured surface density was Ms = 436 g/m² and the thickness T = 2.6 mm, resulting in a volumetric density of 167 mg/cm³.
In comparison, the base knitted fabric (Variant I) exhibited a surface density of Ms = 425 g/m², thickness T = 2.4 mm, and volumetric density of 177 mg/cm³ (see Figure 2).
The absolute volumetric lightness of the experimental fabric relative to the base fabric was calculated using Equation (1):

$$\Delta\delta = \delta_b - \delta = 177 - 167 = 10\mathrm{mg/cm^3} \quad (1)$$

where:
Δδ – absolute volumetric lightness, mg/cm³;
δb – volumetric density of the base fabric, mg/cm³;
δ\deltaδ – volumetric density of the experimental fabric, mg/cm³.
The relative lightness coefficient was determined as follows (see Figure 3):

$$\theta = \left(1 - \frac{\delta}{\delta_b}\right) \times 100 = \left(1 - \frac{167}{177}\right) \times 100 = 5.6\% \quad (2)$$

For the Variant III knitted fabric, the surface density was Ms = 402 g/m² and thickness T = 2.8 mm, corresponding to a volumetric density of 144 mg/cm³. The volumetric density of the base knitted fabric (Variant I) remained 177 mg/cm³.

Hence, the absolute volumetric lightness relative to the base fabric was:

$$\Delta\delta = \delta_b - \delta = 177 - 144 = 33 \text{mg}/\text{cm}^3 \quad (3)$$

and the relative lightness was obtained as:

$$\theta = \left(1 - \frac{\delta}{\delta_b}\right) \times 100 = \left(1 - \frac{144}{177}\right) \times 100 = 18.6\% \quad (4)$$

These results indicate that as the structural modification of the patterned knitted fabric becomes more pronounced (from Variant I to Variant III), the volumetric density decreases while the relative lightness increases significantly. This reduction in volumetric density implies lower raw material consumption and improved fabric elasticity without compromising dimensional stability. Thus, structural optimization through pattern variation can effectively enhance both the aesthetic and functional characteristics of knitted fabrics.


**Figure 2. Variation in bulk density of knitted fabric with pattern**

The volumetric density of knitted fabric is one of the principal technological parameters, as it reflects the amount of raw material consumed in the knitted structure. Changes in the surface density of the fabric lead to variations in its thickness and other physico-mechanical properties.

The volumetric density of a knitted fabric can vary within a wide range depending on several factors — such as the type and linear density of the yarn used, the knitting density, the fabric structure, and the machine gauge.

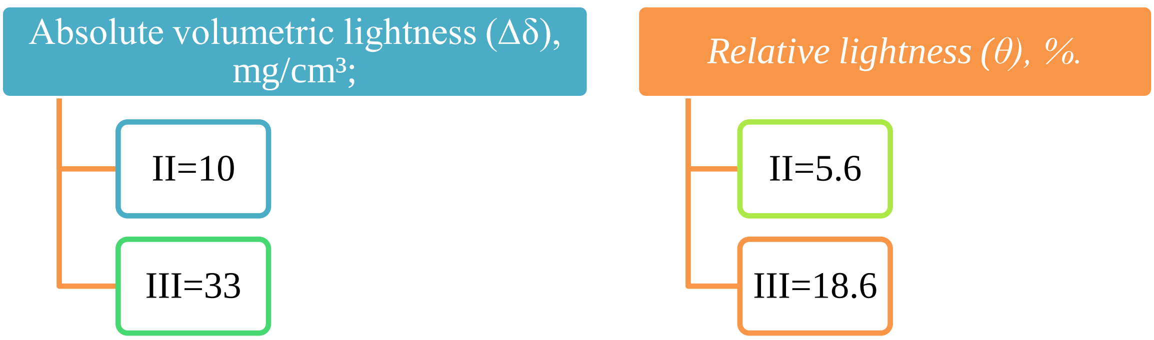



**Figure 3. Absolute and relative volumetric lightness of patterned knitted fabric**

In the proposed design of the patterned knitted fabric, the modification of the layer structure and their interconnection through the base yarn resulted in a significant reduction in raw material consumption. The integration of the two layers using the base yarn ensured strong interlayer bonding and contributed to more efficient utilization of the material.

In the second and third variants of the patterned knit, changes in the pattern repeat led to gradual variations in the loop step compared to the first variant. An increase or decrease in the loop step directly affected the fabric's density parameters. It was found that as density increased, both the surface density and the thickness of the fabric rose accordingly, thereby influencing the weight-related characteristics of the material.

According to the measurement results, compared with the first variant, the surface density of the second variant increased by 2.5%, while that of the third variant decreased by 5.5%. These differences indicate the influence of the pattern repeat and interlayer structural modifications on the formation of surface mass in knitted fabrics.

Variations in thickness were also determined to depend on the pattern repeat. When compared to the first variant, the thickness of the second variant was 7.7% higher, and that of the third variant increased by 14.3%. These changes are associated with differences in interlayer construction, directional variations during loop formation, and the density of yarn placement within the structure.

To evaluate raw material consumption in knitted products, the volumetric density parameters were analyzed. It was observed that the changes in surface density for the second and third variants were smaller relative to the changes in thickness; therefore, their volumetric densities were lower than that of the first variant. It was found that the volumetric density of the patterned pile knitted fabric in the third variant was 19% lower compared to the first variant. This result indicates that raw material consumption in the production of Variant III can be reduced by approximately 19% relative to Variant I.

## Conclusions

The results of the present study show that integrating the layers of a double-layer patterned knitted structure through a base yarn ensures constructive stability and leads to a significant reduction in raw material consumption. Modifications in the pattern repeat were found to influence key technological parameters, including loop step, fabric thickness, surface density, and volumetric density.

In Variant II, the volumetric density decreased by up to 5.6%, while in Variant III it dropped by 18.6%, confirming that the optimization of layer connection and pattern structure can result in up to 19% savings in raw material usage. An increase in fabric thickness was also observed to improve the shape-retention capacity and dimensional stability, enhancing the overall performance of knitted products.

These findings highlight that through structural and pattern-based modifications, double-layer knitted fabrics can be engineered to combine economy, functionality, and aesthetics, offering new opportunities for efficient and high-quality textile production.

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