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Research of Loop Transferred Structures on V-Bed Flat Knitting Machine

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***Abstract:** Today, the production of knitwear is developing at a faster pace. In industry, trade and the service sector, the production of knitwear, combining high technology and low cost, with good consumer properties is urgently required. Consumers today are looking for comfort, fashion and style, which results in ever-changing demands on the apparel market. As the consumer's requirements to quality and appearance of product are daily increasing, the attention to the question of replacement of a smooth cloth on wide assortment with pattern effect is sharply brought.*

This work deals with the analysis of technological parameters and physical-mechanical properties of the knit fabric with pattern effect. With the aim of to expand the assortments of knitwear and to use the technological capabilities of double-bed flat knitting machines in fullest extent possible, on the base of rib structure, by using of loop transference 2 new variants of combined structure were developed and recommended. Samples differ from each other by the rapport and pattern effect of the knit structure. Technological parameters, such as loop length, stitch density, surface and volume density, physical-mechanical properties, such as breaking strength and elongation of newly developed combined knit structures were also determined by experimental method. Loop length and stitch density are important variables, that by changing them, the surface and volume density can be changed, that can manage the raw material consumption and determine the quality of knit fabrics. Breaking strength and elongation are important and decisive parameters for end uses since low strength properties shorten the useful life time as well disable the functionality of these products. Patterns of influence of structural elements, such as transferred loops on the surface density and volume density of knitwear was established. It is found that offered structures have some advantages to compare to basic structure. On the aim of resource economy technology, they give a possibility of raw material expenditure decreasing 22-47%.

***Key words:** breaking strength and elongation, combined knit structure, flat machine, loop transference, rib structure, technological parameter.*

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I. INTRODUCTION

Knitted fabric is gaining popularity in the textile and clothing industry. The advantage of knitted fabrics is that they are able to meet consumer demand for such properties as a softer feel, good draping quality and wrinkle recovery.

Knitted fabric is therefore an ideal material for manufacturing sportswear, intimate garments and casual wear as it allows for stretch and free body movement [1].

Currently, there is a worldwide tendency in the application of knitwear in the manufacture of outerwear products. In the modern conditions of fierce competition in the market of knitwear, more than ever, their quality and consumer properties, including their pattern design, are relevant. These tasks are solved by developing various patterned or combined knit structures based on well-known main ones, that only with a detailed study of them, namely, by studying their structure, properties and methods of production [2]- [4].

I.I. Shalov divides combined knit structures into: simple ones, containing only one element of the loop structure - loops, cardigan ones that include two elements - loops and tuck stitches, inlaid or floated ones with loops and float loops, and mixed combined knit structures with three elements of the loop structure – knit, float and tuck stitches.

Prof. L.A. Kudryavin proposed dividing the weft and warp knit structures according to the combination methods into simple combined, combined patterned, derivatives, derivative-combined and complex combined knit structures [5].

Among the knitted fabrics that are successfully used in the manufacture of knitted outerwear, shoe, household knitted products, as well as technical products, of particular interest are the combined knit fabrics with loop transfer stitches, which have improved strength and aesthetics properties [6], [7].

Weft knitting offers considerable scope for the transfer of a full or part needle loop or sinker loop onto an adjacent needle, either in the same bed or in an opposing bed. The object of loop transfer is to achieve shaping, produce a design, or change the stitch structure.

There are four main types of transfer stitches.

1. Plain needle loop transfer stitches, produced by transference of a loop from one needle to another in the same bed.

2. Fancy lacing stitches, produced by modification of the plain loop stitch.

3. Rib loop transfer stitches, produced by transferring a loop from one needle bed to the other.

4. Sinker loop transfer stitches [8].

For the design of knitted outerwear a great interest have flat knitting machines [9], [10]. The typical flat machine has two stationary beds arranged in an inverted V formation. Latch needles and other elements slide in the tricks during the knitting action.

Their butts project and are controlled as they pass through the tracks formed by the angular cams of a bi-directional cam system. It is attached to the underside of a carriage that, with its selected yarn carriers, traverses in a reciprocating manner across the machine width.

Flat knitting machines, due to their high versatility in having a wide range of patterning capabilities, in the simplicity of the construction of selection mechanisms, and the ease of design preparation from one pattern to another, make it possible to diversify the assortment of manufactured products and ensure its quick update in accordance with the requirements of fashion.

On flat knitting machines, loops can be transferred from the needles of the front needle bar to the needles of the back needle bar and vice versa, and loops can be also transferred to adjacent needles of the same needle bar. The first type of transference is used to obtain a variety of patterned knit structures, the second type - for knitting knitwear with a-jour patterns and reducing the number of loops across the width of the product in order to narrow it. Due to the automatic loop transfer devices, the patterned capabilities of flat knitting machines are greatly expanded.

For the purpose of studying influence of loop transfer stitches to the technological parameters and properties [11] of combined knit fabric with pattern effect, on the base of detailed investigating facilities of V-bed flat knitting machine' PROTTI [12]- [14] and methods of producing combined knit fabric, new samples of combined knit structure have been created and produced at the laboratory of Department "Technology of textile fabrics" of Tashkent Institute of Textile and Light Industry (TITLI).

II. EXPERIMENTAL WORK

A. Materials and methods for developing new kinds of combined knit structure by using of loop transference.

Two kinds of combined structures have been created by using of loop transference. It is a one of the types of loop transfer stitches: Rib loop transfer stitches, produced by transferring a loop from one needle bed to the other. Therefore, samples of newly created combined knit structures were produced on V-bed rib machine on the base of rib 1x1 as called basic structure below. Due to the yarn properties and end use of knitwear with combine patterned knit structure to producing outerwear, used artificial yarn PAN 330 tex (Nm=3). The knit unit includes the course of rib stitches and loop transferred stitches. The knit structure and graphical notation for structure №1 are given on fig.1.

The needle set for structure №1: 1 needle with short butt, 1 needle with long butt. Producing way of structure №1 is following:

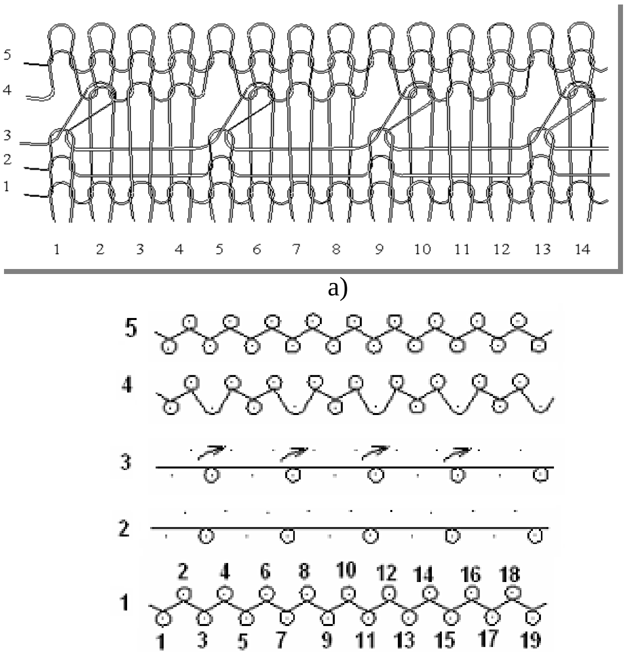
1-course. All needles of both front bed and back bed are working and rib 1x1 structure is knitting.

2-course. In this course all needles of back bed are out of work because of fully withdrawn of raising cam, into the cam-plate so that all butts pass undisturbed across the flat surface. In front bed all short butt needles are not working and all long butt needles are working because of partly withdrawn of raising cams into the cam-plate so that they miss the low (short) butts, which pass undisturbed across their surface. Plain structure throw one needle is knit in front bed.

3-course. Plain structure throw one needle is knit in front bed like at 2-course. Then loops of front bed needles 3, 7, 11, 15 etc. are transferred to back bed needles 4, 8, 12, 16 etc. As mentioned above there are some requirements to transference. For example, specially-designed latch needles, a delivering needle cam that lifts the needle higher than normal clearing-height.

4-course. All needles of both front bed and back bed are working. After transferring front bed needles 3, 7, 11, 15 etc. are empty and have not old loops, therefore they knit cardigan stitches.

5-course. Knitting process of 1-course is repeated and rib 1x1 structure is knit.



b)

Fig. 1. Structure №1

a- Structural notation; b- graphical notation

The knit structure and graphical notation for structure №2 are given on the fig. 2.

The needle set for structure №2: 1 needle with short butt, 1 needle with long butt. Producing way of structure №2 is following:

1-course. All needles of both front bed and back bed are working and rib 1x1 structure is knitting.

2-course. In this course all needles of back bad are out of work because of fully withdrawn of raising cam, into the cam-plate so that all butts pass undisturbed across the flat surface.

In front bed all short butt needles are not working and all long butt needles are working because of partly withdrawn of raising cams into the cam-plate so that they miss the low (short) butts, which pass undisturbed across their surface. Plain structure throw one needle is knit in front bed.

3-course. Plain structure throw one needle is knit in front bed like at 2-course. Then loops of front bed needles 3, 7, 11, 15 etc. are transferred to back bed needles 4, 8, 12, 16 etc. As mentioned above there are some requirements to transference. For example, specially-designed latch needles, a delivering needle cam that lifts the needle higher than normal clearing-height.

4-course. All needles of both front bed and back bed are working. After transferring front bed needles 3, 7, 11, 15 etc. are empty and have not old loops, therefore they knit cardigan stitches.

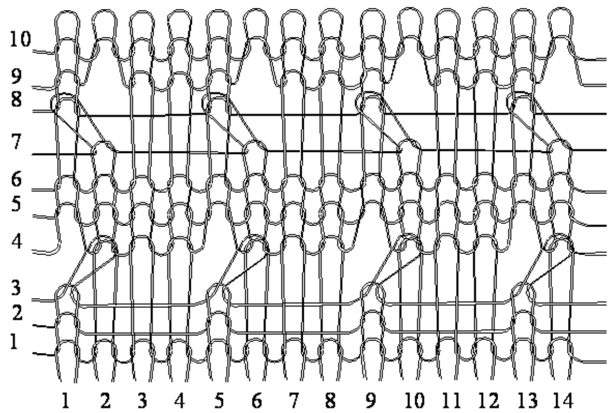
5-course. Knitting process of 1-course is repeated and rib 1x1 structure is knit.

6-course. In this course all needles of front bad are out of work because of fully withdrawn of raising cam, into the cam-plate so that all butts pass undisturbed across the flat surface. In back bed all short butt needles are not working and all long butt needles are working because of partly withdrawn of raising cams into the cam-plate so that they miss the low (short) butts, which pass undisturbed across their surface. Plain structure throw one needle is knit in back bed.

7-course. Plain structure throw one needle is knit in back bed like at 6-course. Then loops of back bed needles 4, 8, 12, 16 etc. are transferred to front bed needles 3, 7, 11, 15 etc. As mentioned above at 3-course there are some requirements to transference. For example, same as at 3-course specially-designed latch needles, a delivering needle cam that lifts the needle higher than normal clearing-height.

8-course. All needles of both front bed and back bed are working. After transferring back bed needles 4, 8, 12, 16 etc. are empty and have not old loops, therefore they knit cardigan stitches.

9-course. Knitting process of 5-course is repeated and rib 1x1 structure is knit.



a)

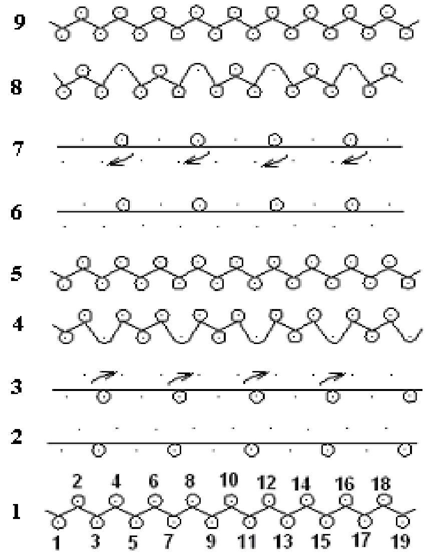


Fig. 2. Structure №2
a- Structural notation; b- graphical notation

B. Research on technological parameters and strength properties of combined knit fabric with transferred stitches on structure.

All samples were knitted with equal yarn input tension, on an identical set of needles, equal knitted fabric take-off and at identical environment conditions.

Research of the technological parameters and the physical-mechanical properties of the newly developed combined knit structures was carried out under standard conditions of CENTEXUZ certification laboratories at the TITLI.

Dimensional properties of knitted fabrics are an important property and determine the materials consumption during production, productions parameter, and applications of different knitted structures.

The sample fabrics have been conditioned for 24 hours in standard atmosphere 20±1°C temperature and 65±2% relative humidity.

Knitted fabric parameters were determined with laboratory tests. Loop width (A) and loop height (B) were measured with image analysis. Loop length (ℓ) was measured by uncurling the thread unraveled from the fabric on the crimp tester.

As a criterion of raw material expenditure traditionally consider surface density (GSM- Gram per square meter) of a fabric. Due to fabric GSM the knitted fabric may be heavier or lighter. GSM varies from fabric to fabric, especially with the count & stitch length of fabric. As is known, decrease of knit fabric's surface density GSM involves change of operational and hygienic characteristics. Therefore, the indicator which simultaneously characterizes and raw material expenditure of fabrics, and a quality indicator is entered. Such indicator is the lightness of knitting structures, in which along with surface density its thickness is considered also.

The method for measuring GSM was simply following the steps. Firstly, to take the conditioned fabric for test on the GSM cutter pad so that no crease or crinkle is formed. Secondly, to cut the fabric with GSM cutter (cut area was 100 square cm). Thirdly, to take the weight of the fabric by an electric balance. Fourthly, multiply the weight of the cut sample by 100.

Fabric thickness was measured with a fabric thickness tester.

As a lightness indicator of knitting structures it is possible to use volume density. Volume density is calculated from measuring surface density and thickness of fabric by following equation:

$$\delta = \frac{m_S}{M} \quad (1)$$

where, δ - volume density of knitting, mg/sm^3

ms - surface density of knitting, g/m^2

M - thickness of knitting, mm.

To confirm that the produced combine patterned knit structures with transferred stitches and a-jour effect on the texture of knitwear belong to the category of knit fabrics with reduced material consumption, comparisons were made with basic knitwear rib 1x1.

Knits with reduced material consumption are those, the volume density of which is lower than that of the base, developed with the optimal module of the loop from the identical yarn.

Thus, the absolute volumetric lightness of the knitted fabric of the sample compared to the base knit structure is calculated as follows:

$$\Delta\delta = \delta_b - \delta_s; \qquad \Delta\delta > 0 \quad (2)$$

Where, $\Delta\delta$ - absolute volumetric lightness absolute volumetric lightness, mg/sm^3;

δ_b - volume density of base structure rib1x1, mg/sm^3;

δ_s- volume density of new structure with loop transfer, mg/sm^3.

The relative lightness (θ) of the produced knitted fabrics is calculated as follows:

$$\theta = \left(1 - \frac{\delta_s}{\delta_b}\right) * 100\% \quad (3)$$

Where, θ- relative lightness of knit fabrics, %

The bursting strength is one of the most important mechanical properties of knitted fabrics and is difficult to predict before performing bursting strength tests. Fabric weight, yarn breaking strength and yarn breaking elongation as the major parameters that affect the bursting strength of knitted fabrics. They are decisive parameters for end uses since low strength properties shorten the useful life time as well disable the functionality of these products. The measuring these parameters carried out by standard test method for breaking strength and elongation of textile fabrics (grab test) on the universal test machines.

III. RESULTS AND DISCUSSION

Results of experimental works of new combined structures are shown at the table №1.

From table date it is seen that surface density of basic structure rib 1x1 is 830.3 g/m^2, of the combined structure with the loop transference from front bed to rear bed structure №1 is 438 g/m^2, and of the structure №2 with the loop transference from the front to the back bed and from the back to the front bed is 650.9g/m^2.

Difference between new structures №1 and basic structure's surface density is:

$$830.3 – 438.9 = 391.4 \text{ g/m}^2$$

In percentage it consists 47%. So it means that new structure №1 is lighter than basic structure to 47 %.

Difference between new structures №2 and basic structure's surface density is:

$$830.3 – 650.9 = 179.4 \text{ g/m}^2$$

In percentage it is 22 %. So the second variant of combined knit structure with loop transference is lighter to 22% than basic ones.

It means that surface density of new created structures is less then basic structure and raw material requiring is decreased to produce of them.

As stated above, decrease of knit fabric's surface density GSM involves change of operational and hygienic characteristics. As well as knit fabric is three-dimensional structure, in the characterized length, width and thickness, the lightness of this structure is necessary to define not two-dimensional criterion (surface density), but three-dimensional (volume density). Therefore, the thickness of knit fabric is also considered to characterize the raw material expenditure and quality of fabric.

Measuring of thickness shows that it consists on basic structure 3.13 mm, on structure №1 – 2.96 mm, on structure №2 – 3.11 mm. Difference is ≈5% that allows to offer a new created structures as strong knitwear well.

Because of loop transferred stitches in the combined knit structure, the thickness of knit fabric is varied.

Where the loops are transferred only by one direction, from front bed to rear bed, the thickness of knit fabric was lower, and where the loops are transferred in turns of courses by 2 directions, firstly from font bed to rear bed and then from back to front, the thickness of knit fabric was near to the thickness of basic ones. It means that transferring the loops give a relief pattern as rib structure but with a-jour eye pattern.

From the Eq. (1) the volume densities of knit structures are determined.

So, if surface density of basic structure is 830.3 g/m^2 and the thickness is 3.13 mm, then its volume density is equal to 265.27 mg/sm^3.

In this way, the volume density of the combined knit structure №1 is 148.27 mg/sm^3 and structure №2 – 209.29 mg/sm^3.

The absolute volumetric lightness (difference between basic structure's and newly developed knit structure's volume density) of knit structures is determined by Eq. (2):

$$265.27 – 148.27 = 117 \text{ mg/sm}^3$$

$$265.27 – 209.29 = 55.98 \text{ mg/sm}^3.$$

So, the absolute volume density of structure №1 is 117 mg/sm^3, and the structure №2 - 55.98 mg/sm^3.

The relative lightness (θ) of the produced knitted fabrics is calculated by Eq. (3), so it is equal for structure №1 - 44% and for structure №2 - 21%.

Table- I: Technological parameters and physical-mechanical properties of knitting samples

№	Yarn PAN 330 tex (Nm=3)	Surface density, g/m^2	Volume density, mg/sm^3	Thickness, mm	Breaking strength, N		Breaking elongation, %	
					On length	On width	On length	On width
1	Basic structure rib1x1	830,3	265,27	3,13	961,9	437,0	147,4	290,5
2	Structure №1	438,9	148,27	2,96	535,0	366,3	104,4	157,8
3	Structure №2	650,9	209,29	3,11	516,9	531,3	112,4	105,9

So, volume densities of combined knit structures with transferred loops are decreased to 21-44% in comparison with basic ones. It means that volume density of new created structures is less than basic structure and raw material requiring is decreased to produce of them.

The histogram of surface density and volume density change is given on fig.3.

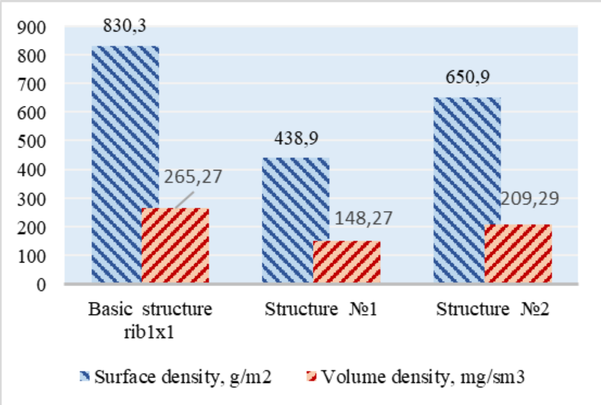


Fig. 3. Histogram of surface and volume density changes of knit structure

Breaking strength and elongation tests were performed to determine the strength characteristics. The graph of breaking strength and elongation changes of knit fabric are given on fig.4

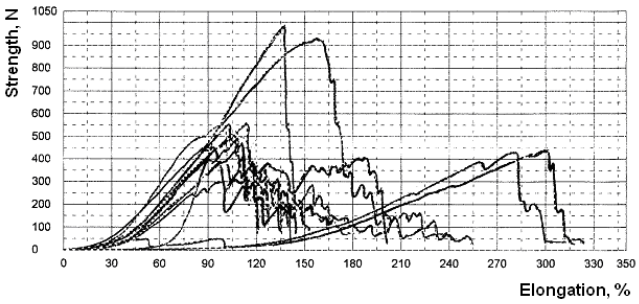


Fig. 4. The graph of breaking strength and elongation changes of knit fabric

The results of analysis show that, breaking strength of basic structure on length is 961.9 N and on width - 437,0 N. Due to pattern elements (transferred loops) of structure this indicator varied between 535.0-516.9 N on length and 366.3-531.3 N on width for the other variants of structure. From it, seen that, breaking strength of structure №1 is decreased 44% on length and 16 % on width compared with basic structure. Breaking strength of structure №2 is decreased 46% on length, but increased 22 % on width compared with basic structure. By comparison it is seen that, structure №2 is durable on width than others.

Tensile of a knitted fabric means elongation of a knit under the action of a force applied to it. Breaking elongation is characterized by elongation of the test sample at the moment of burst it.

The table date shows that, breaking elongation of basic structure on length is 147.4 % and on width – 290.5%, on the structure №1, it is 104.4 % on length and 157.8 % on width, as well as on the structure №2, it is 112.4 % on length and 105.9 % on width. From it seen that, breaking elongation is lower than basic structure.

Summing up, it can be said that, the indicators of elongation along the length and width of a knitted fabric depend on the structure and raw material composition of threads and yarn. Due to the loop transference is carried out by two directions from the front bed to rear bed and then from bed to front bed on the structure №2, resistance of fabric is increased, but the breaking elongation is decreased compared with structure №1. So, it shows that pattern elements, such as transferring loops have some advantages and disadvantages.

Advantages consist in that, by using transferring loops, there can be achieved pattern effect on surface of fabric, as surface and volume densities decrease, the expenditure of raw materials reduce.

Disadvantage is that, when the loop transference is carried out on one direction, the strength of fabric can be loosen a little, but elongation of fabric is extent.

VI. CONCLUSION

Results of analyses show that offered structures have some advantages to compare to basic structure. On the aim of resource economy technology, they give a possibility of raw material expenditure decreasing 22-47%. There is not lost strength parameters. Stabilization of elongation on length and width is possible due to structure and knitwear has more form stability. Structures consist of normal rib loops, plain structure loops, cardigan stitches and elongated loops. These elements are possible to make nice surface design of knitwear like relief pattern and are offering to the manufacture and market as well. Meanwhile they are offered to produce both at simple and modern computerized flat knitting machines like SHIMA-SEIKI, PROTTI, STOLL, UNIVERSAL that have loop transference possibility.

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