STRETCH CHARACTERISTICS OF FILLET WARP KNIT WITH ELASTOMERIC IN-LAYED YARN

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Abstract: *This paper presents results of an investigation on the stretch characteristics (full strain and its parts) of fillet warp knitted fabric with elastomeric yarn longwise inlaying. In order to undertake the study of the influence of in-layed yarn positioning and of fillet interloping repeat different types of fillet warp knit fabrics with in-lay yarn were produced. The array of data for the various design options provide analytical tool for making comparisons about the mechanical properties of the warp knit fillet structures with elastomeric inlayed yarn. It is observed that the repeat of fillet interloping and the position of in-laying yarn have some effect on stretch characteristics of warp knit structures. It is a consequence of a different relaxation of inlayed yarn in structure. Elastic strain is the largest part of the full strain of warp knit fabric and the part of residual strain does not exceed 0.11.*

Key words*: fillet structure, in-laying, elastomeric yarn, full strain, residual strain*

1. INTRODUCTION

The elastomeric yarns are used in the knitting industry as reinforced monofilaments and as multi plied yarn with elastomeric component. The using of elastomeric yarn allows creating new types of textile materials and it is a major force to achieve their functional properties. The structure of elastic knitted fabric with an elastomeric yarn should provide the maximum use of their specific properties: the ability to more than 100% stretch and almost completely relaxation the length after stretching.

It is well known that, there are the difficulties of elastomeric yarn feeding at knitting zone of the warp knitting machines and an elastomeric is usually use as filling yarn. It significantly changes the structure parameters and the properties of the ground interlooping. The filling yarn, which are positioning between the ground loops and junctures, greatly reduces shrinkage of knitted fabric. It changes an unroving of knit and an inclination of ground loops. The elongation and the durability of knit fabric change depending on the direction of elastomeric yarn position in the knit structure. (Shalov I. et all, 1986).

The using of elastomeric yarn as a longitudinal inlaid yarn in the warp knit structure does not only change a stretch of fabric in the direction of in-laying, but it also changes the shape and the size of the unit cell of fillet interlooping. As a result, net fabric with a hexagonal cell gets an unusual ability to become wider at a stretching. (Ugbolue S. et all, 2010 and 2012).

The study of structure parameters and mechanical properties of filling-fillet warp knit, which is made by alternation of tricot and atlas courses at repeat with different variants of elastomeric yarns position in the structure, showed that the variant of in-laying influences as to its breaking characteristics (Kyzymchuk O., Ugbolue S., 2012), as to the full deformation of warp knit fabric and to its components (Kyzymchuk O. et all, 2011). The value of the full deformation decreases with increasing amount of contacts between the ground yarn and inlaid yarn. Residual deformation of such warp knitted fabric is from 2 to 6% and it is independent of the variant of inlaid yarn position.

At the same time, the influence of the repeat of fillet interloping only at the structure parameters and at Poisson's ratio of auxetic warp knitted fabrics have been investigated (Ugbolue S. et all, 2011; Kyzymchuk O., Nedogibchenko O. 2011; Kyzymchuk O. 2012).

The main field of using of the warp knitted fabric with longwise inlaid elastomeric yarn is the products for medical and rehabilitation purpose which during operation have strain significantly less than breaking loads. Small in size, alternating with the unloading and rest, it affects the structure of knitted fabrics and leads to its deformation, changes its size and shape. For that reason, it is important to study the deformation characteristics at the cycle “load-unload-rest”.
The work purpose is a research the deformation characteristics of fillet warp knit fabric with inlaid elastomeric yarn and an establishment of its dependences on a repeat of a fillet interlooping and a variant of in-laying.

2. EXPERIMENTAL SAMPLES

In order to undertake the study of the influence of in-lay yarn positioning, eight types of fillet warp knit fabrics with in-lay yarn were produced. The guide bars with in-lay yarn are placed behind the guide bars with the ground yarn. In order to undertake the detailed study of the influence of a repeat of fillet interlooping nine variants of fillet warp knit fabrics each position of in-lay yarn were produced. Amount of tricot courses n_t at a repeat are 3, 5 or 7 and amount of chain courses n_c are 1, 2 or 3. These fabrics were made on a 10 gauge crochet knitting machine with one needle bed.

The warp knit fabrics were made from 250 denier polyester yarn as ground. The linear density of the polyester yarn is 250 den x 2. It is manufactured by Du Pont and its tenacity is 1.454 gf/den based on a test gauge length of 25.4 cm (10in), and a crosshead speed of 10.16 cm/min (4in/min). The 150 denier (96 filaments) polyester sheath serving as the cover yarn for polyurethane core yarn provided a high elastic in-lay component. The yarn is supplied by Unifi Inc. and the linear density of polyurethane core yarn is 70 deniers.

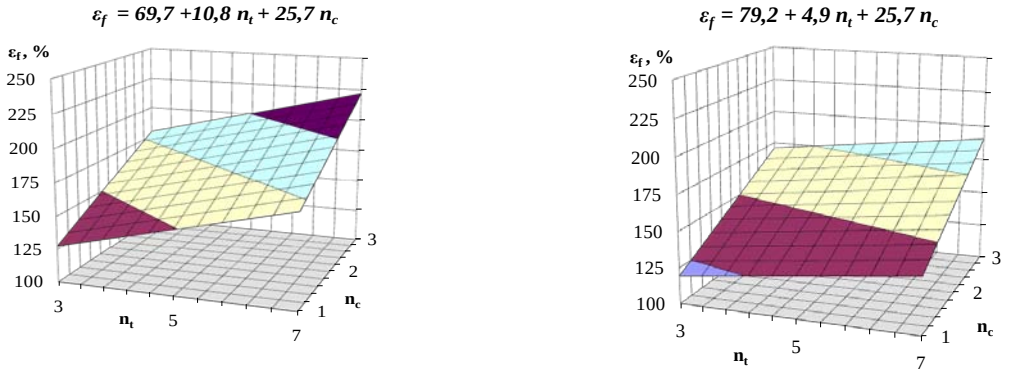
3. METHODS

The research of the deformation characteristics of warp knit fabric at stretching with constant load have been carried out according to GOST at relaxometer. Clamping length was 100 mm. Measurements the length of the specimen was made before loading, after 1, 5, 15, 30, 60 min of the loading, after the unloading and after 60 min of rest. The load of the knitted fabric specimen was determined depending on the elastomeric yarn diameter and the number of elastomeric yarns in the specimen according to GOST 16218.9-89. 3 parallel specimens have been used on tests for each variant of warp knit. The convergence of results defines their adequacy and reliability.

4. RESULTS AND DISCUSSION

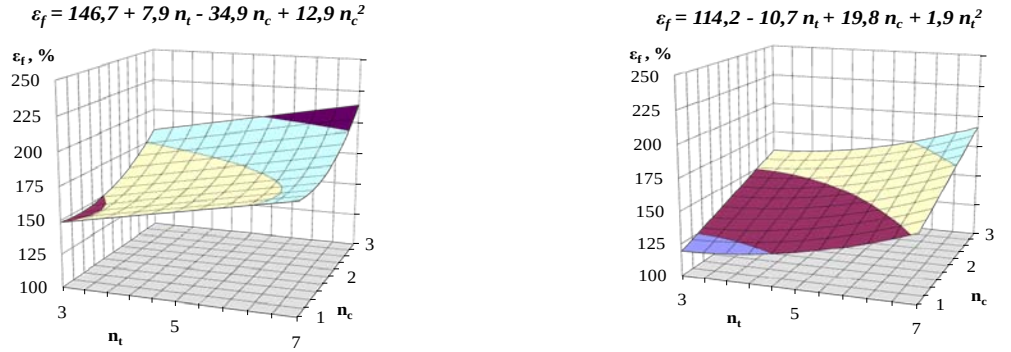
Full strain and its components are characteristics that are most often used for an estimation of mechanical properties of textile materials when tested on a cycle "load-unload-rest". Full strain is the strain of the sample at the end of the first part of the cycle (loading). It is calculated as the percentage difference between the lengths of the sample before and after loading for 60 minutes. The results of research of full strain of fillet warp knit fabric with different position of in-layed yarn are presented on Fig. 1-4. The diagrams show that the full strain of warp knitted fabric depends on the repeat of fillet interlooping. Its value increases with quantity increase as the tricot courses and as the chain courses in the repeat for all variants of the inlaying. It is a consequence of a different relaxation of inlayed yarn in structure. In all variants of warp knitted fabrics the inlayed yarn is fixed in the structure in the vertical ribs of the cell, which is formed by tricot loops, and then stretches inside the cell freely. If the repeat of fillet interlooping has increased, a length of elastomeric inlayed yarn, which is capable to full recovery length after unloading, increases too. As a result tensile strain increases.
It is obvious, that full strain of fillet warp knitted fabric in which structure elastomeric inlayed yarn is fixed at two courses of the repeat (fig. 1.б, 2.б, 3.б and 4.б) is less full strain of fillet warp knitted fabric in which structure elastomeric inlayed yarn is fixed at one course of the repeat (fig. 1.a, 2.a, 3.a and 4.a). This statement is true for all variants of inlaying position in the fillet structure and it is connected with a different relaxation of elastomeric yarn in the structure. For warp knitted fabric in which structure an inlayed yarn is fixed at two courses, elastomeric yarn has more contacts with the

ground yarns. The elastomeric yarn at such structure is slightly stretched consequently the friction forces arising that leads to a decrease in tensile strain.



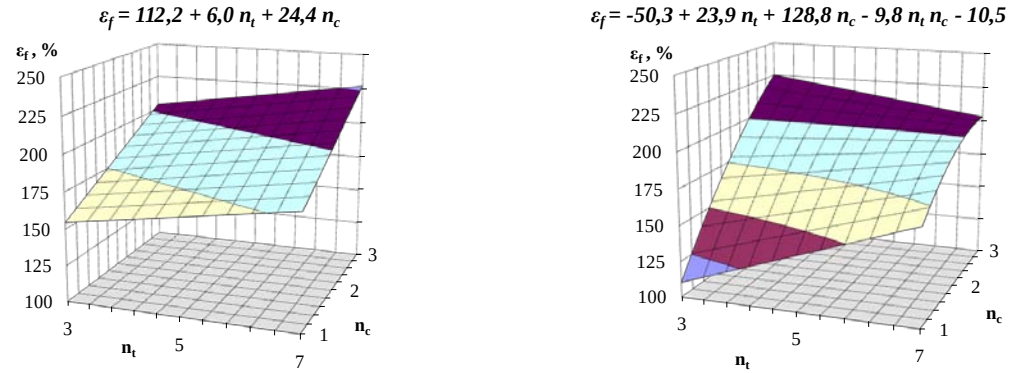
a) at one course of repeat *b) at two courses of repeat*

Figure 1: Full strain of warp knit fabric in which in-laying yarn turns from the back to the front side



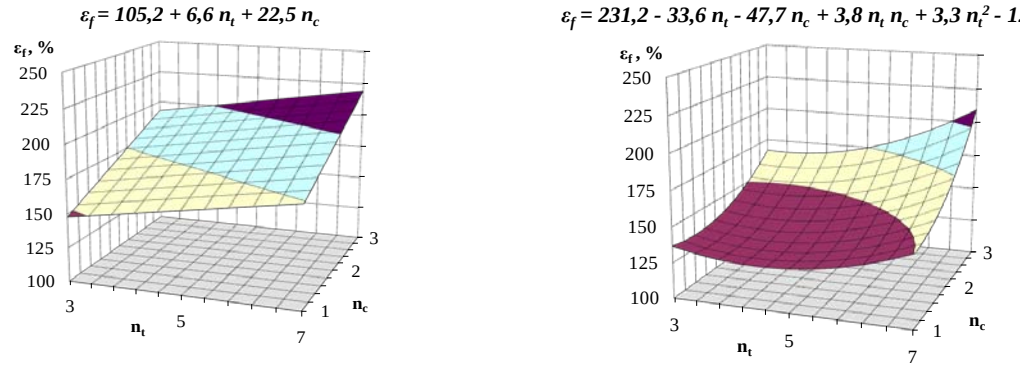
a) at one course of repeat *b) at two courses of repeat*

Figure 2: Full strain of warp knit fabric in which in-laying yarn is between the tricot's junctures



a) at one course of repeat *b) at two courses of repeat*

Figure 3: Full strain of warp knit fabric in which in-laying yarn wraps one tricot's juncture



a) at one course of repeat *b) at two courses of repeat*

Figure 4: Full strain of warp knit fabric in which in-laying yarn wraps two tricot's junctures

It should be noted a higher value of full strain of warp knit, in which the inlayed yarn wrapped the junctures of tricot loops (Fig. 3 and 4), compared to warp knit, in which the inlayed yarn is in a structure without wrapping the junctures of tricot loops (Fig. 1 and 2).
There are following components in full strain of fabric:

- elastic strain which disappears right after unloading. It is calculated as the percentage difference to the initial length between the length of the sample after the load for 60 minutes and after removing the load;
- plastic strain with a long period of relaxation;
- residual strain that remains after removal of the load. It is calculated as the percentage difference between the lengths of the sample before loading and after 60 minutes rest after unloading.

The analysis of research results has shown that the dependences of elastic strain on the repeat of a fillet interlooping and on a variant of inlaying in a structure are a similar to dependences of full strain and only value is different: elastic strain is lower at 10-25%. Therefore, elastic strain, as well as full strain mainly depends on the degree of relaxation of elastomeric inlayed yarns in the structure of fillet warp knitted fabric.

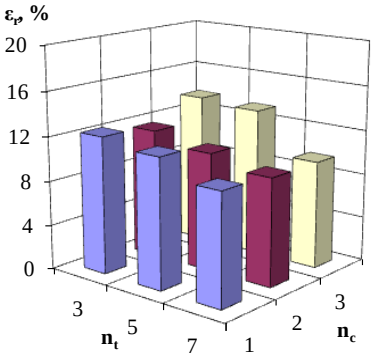
Plastic strain of warp knitted fabric is insignificant: it changes in the range of 4-10%. This strain does not depend neither on repeat of fillet interloping nor on a variant of inlaying positions in the structure.
The value of the residual strain determines a shape stability of the textile material. The research result have showed (Fig. 5 to 8) that the residual strain of warp knitted fabric varies widely (from 2 to 20%) and depends on both factors: the repeat of fillet interloping and inlaying position in the structure.

It should be noted that the knitted fabric in which the elastomeric inlayed yarn wrapped the junctures of tricot loops (Fig.7, 8) has considerably lower residual strain than the knitted fabric in which elastomeric inlayed yarn is fixed in structure without wrapping the junctures of tricot loops (fig.5-6). This can be explained by the fact that processes during the load-unload cycle are associated only with the extension of the elastomeric yarns under load and its subsequent relaxation after unloading and rest. In addition to these processes in the warp knitted fabric, in which inlayed yarn is fixed in structure without wrapping the junctures of tricot loops, there is also an irreversible redistribution of the elastomeric yarn that results an increase of residual strain. For these variants of warp knit (Fig. 5 and 6) the residual strain depends on amount of tricot courses at the repeat because the contacts between inlayed yarn and ground yarns are at the vertical rib of cell which forms by tricot loops.

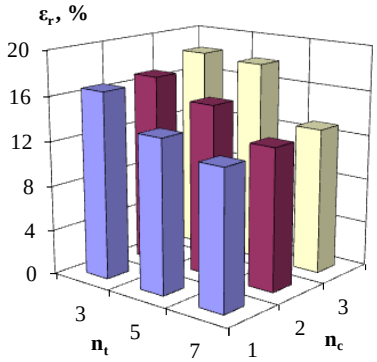
The relation between different deformations in the full strain is important in order to characterize mechanical properties of the textile materials. If the share of elastic strain is larger, the material retains the dimensions and a shape better. At the same time, residual strain's dominance is leading to a change in a shape and the sizes of knitted fabric. Analysis of the research results (Table) of fillet warp knitting fabric with different position of inlayed yarn shows that elastic strain is the largest part (> 0.86) of the full strain. Value of residual strain's part varies widely, but generally it does not exceed 0.11.

Table: Parts of full stretch of fillet warp knit with elastomeric in-laying yarn

The position of inlayed yarn in fillet warp knit structure		Parts of full strain	
		elastic $\Delta\varepsilon_e$	residual $\Delta\varepsilon_r$
in-laying yarn turns from the back to the front side	at one course of repeat	0,884 ÷ 0,936	0,045÷ 0,097
	at two courses of repeat	0,860 ÷ 0,920	0,070 ÷ 0,110
in-laying yarn is between the tricot's junctures	at one course of repeat	0,891 ÷ 0,934	0,046 ÷ 0,089
	at two courses of repeat	0,915 ÷ 0,956	0,028 ÷ 0,058
in-laying yarn wraps one tricot's juncture	at one course of repeat	0,940 ÷ 0,970	0,014 ÷ 0,031
	at two courses of repeat	0,905 ÷ 0,957	0,021 ÷ 0,057
in-laying yarn wraps two tricot's junctures	at one course of repeat	0.920 ÷ 0,945	0,008 ÷ 0,036
	at two courses of repeat	0,860 ÷ 0,952	0,013 ÷ 0,049

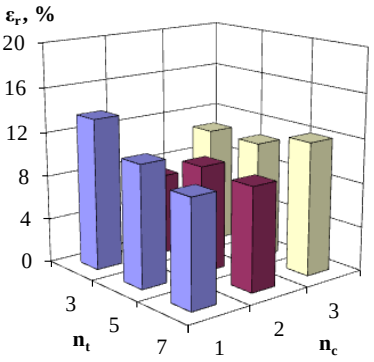


a) at one course of repeat

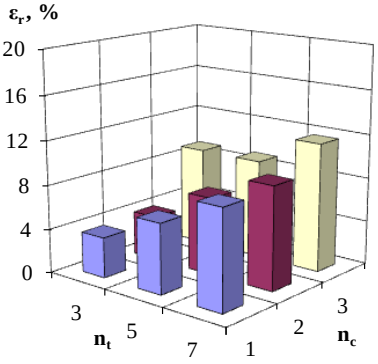


b) at two courses of repeat

Figure 5: Residual strain of warp knit fabric in which in-laying yarn turns from back to front side

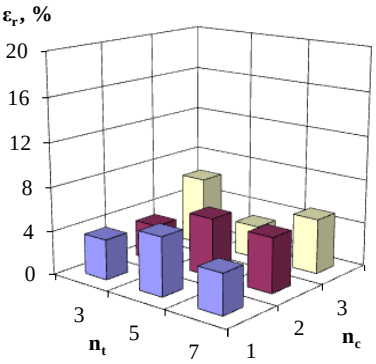


a) at one course of repeat

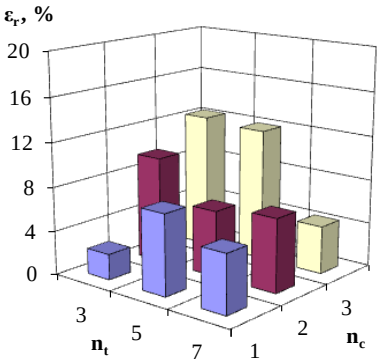


b) at two courses of repeat

Figure 6: Residual strain of warp knit fabric in which in-laying yarn is between the tricot's junctures

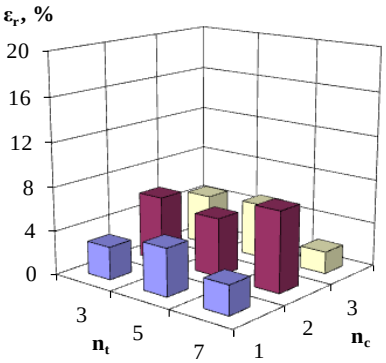


a) at one course of repeat

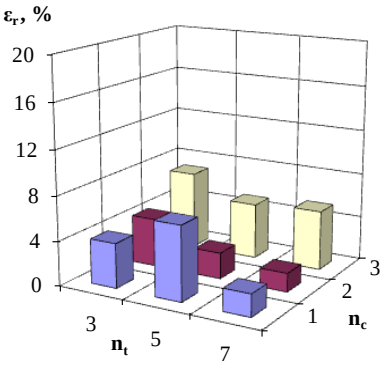


b) at two courses of repeat

Figure 7: Residual strain of warp knit fabric in which in-laying yarn wraps one tricot's juncture



a) at one course of repeat



b) at two courses of repeat

Figure 8: Residual strain of warp knit fabric in which in-laying yarn wraps two tricot's junctures

5. CONCLUSION

The array of data for the various design options provide analytical tool for making comparisons about the mechanical properties of the warp knit fillet structures with elastomeric inlayed yarn. It is observed that the repeat of fillet interloping and the position of in-laying yarn have some effect on stretch characteristics of warp knit structures. It is a consequence of a different relaxation of inlayed yarn in structure. Elastic strain is the largest part (> 0.86) of the full strain of warp knit fabric and the part of residual strain does not exceed 0.11. Thus, the different positions of the inlaid yarn within the structures and the different amount of tricot and chain courses on repeat of fillet interloping offer other possibilities that could be explored when designing warp knit structures.

REFERENCES

Kyzymchuk O. (2012) The structure parameters of the warp knitted fabric of fillet-inlay interlacing with filling yarn which wrapped the junctures. *Bulletin of Kyiv National University of Technologies and Design*, 3, 158-163. In Ukrainian

Kyzymchuk O. Kovalenko M., Ugbolue S.C. (2011) The mechanical properties of the warp knitted fabric of fillet-inlay interlacing with different disposition of warp in-lay thread in the knit structure. *Bulletin of Kyiv National University of Technologies and Design*, 3, 91-97. In Ukrainian

Kyzymchuk O., Nedogibchenko O. (2011) The properties of inlay-fillet warp knitting fabric. *Bulletin of Khmelnitsky National University*, 3, 141-145. In Ukrainian

Kyzymchuk O., Ugbolue S. (2012) The effect of positioning of inlaid yarns in fillet warp knit structures. ***The 46th*** *International Federation of Knitting Technologists Congress***,** Book of proceedings, Sinaia, Romania, 764-769

Shalov I.I., Dalidovych A.S., Kudryavin L.A. (1986) *Knitting Technology*, Legprombytizdat, Moscow. In Russian

Ugbolue S,. Kim Y, Warner S, Fan Q, Yang Ch, Kyzymchuk O, Feng Y (2010) The formation and performance of auxetic textiles. Part I: theoretical and technical considerations, *Journal of the Textile Institute*, 101 (7), 660 – 667

Ugbolue S,. Kim Y, Warner S, Fan Q, Yang Ch, Kyzymchuk O, Feng Y, Lord J, (2011) The formation and performance of auxetic textiles. Part II: geometry and structural properties. *Journal of the Textile Institute*, 102 (5), 424 – 433

Ugbolue S,. Kim Y, Warner S, Fan Q, Yang Ch, Kyzymchuk O, Feng Y, Lord J, (2012) Engineered Warp Knit Auxetic Fabrics. *Journal of Textile Science & Engineering*. 2 (1).