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INFLUENCE OF TECHNOLOGICAL PARAMETERS ON THE BASIS WEIGHT OF ELASTICIZED FABRIC

Purpose. *The study of the influence of knitting technological parameters on the structure and the basis weight of elasticized warp knitted fabric for the rehabilitation and prevention goods manufacture.*

Methodology. *The mathematical planning of an experiment, standard test methods of the knitted fabric, as well as statistical methods for processing and analyzing of an experimental data were used to achieve this goal.*

Results. *The regression dependences between the knitting technological parameters and the properties of knitted fabric were obtained based on the planned and conducted experiment. The tension of the ground yarn, the linear density of the weft thread and the preliminary elongation of the elastomeric thread were chosen as input factors. The dependences determine the influence of the selected factors on the structural characteristics of elasticized warp knitted fabric, especially its basis weight.*

Scientific novelty. *Mathematical models for prediction the basic structural parameters and the basis weight of warp knitted elasticized fabric are proposed based on the following technological parameters of knitting: the tension of the ground yarn, the preliminary elongation of the elastomeric thread and the linear density of the weft inserted yarn.*

Practical value. *The research results increase the knowledge of the effect of knitting technological parameters on the material consumption of elasticized warp knitted fabric of filling interlooping and can be used at the design stage of rehabilitation and prevention goods to provide high quality.*

Keywords: *technological parameters of knitting, structural parameters, elasticized warp knitted fabric, elastomeric thread, medical textile.*

Introduction. Resent decades the range and scope of medical textiles are significantly expanded worldwide. There are several reasons for this. The main one is: significant increase of requirements for social welfare and environmental safety rights [1]. Other important thing is the rapid development of basic research in chemistry, physics, biology, and in engineering and applied science. The choice of fiber composition, structural features and production technology of medical textile is determined by its functionality and specific requirements for materials and products for various purposes.

Elastic compressing and fixing goods are identified as a separate group of medical textiles [2]. This group includes elastic bandages, abdominal binders, posture correctors, corsets, recliners, etc. The design of products [3, 4] and their design features [5] are the topic of number of studies carried out. The analysis of physical-mechanical and hygienic properties of abdominal bandages at the Ukrainian market and the elastic bands used for their production are another topic of the research publication in this field [6, 7]. The main attention during design of new elastic fabric for rehabilitation goods is paid to such physical-mechanical properties as extensibility and deformation characteristics, since they provide the basic functional properties of the medical compressing goods.

On the other hand, the materials consumption and resource-saving is the main task of today’s economy. The resources cost is being reduced as result of scientific and technical activities using the new energy saving technologies and new types of equipment, and introduction the lowwaste processes and sustainable methods for raw materials use. The reducing of materials consumption is the result of a successful technology or design and proper account of social, functional and ergonomic requirements. Thus the design of elasticized fabric which would reduce the raw material consumption throughout the combination of the structural parameters and physical and mechanical properties is an actual task.

Objectives. The aim of this research is to create the elasticized knitted fabrics and to investigate their structural parameters as well as to establish the properties dependence on basic knitting parameters. The warp knitting has been chosen for fabrics manufacturing as the most productive way. Modern warp knitting equipment [8] provides an interlooping variety for high-quality fabric.

Research results. Elasticized warp knitted fabrics was an object of this research. The chain with closed loops is the ground interlooping. The elastomeric thread is laying walewise at each wale. The weft filling yarn is using for connection the separate chains into fabric. The weft yarns are laying on both sides of elastomeric threads to cover them better. The weft guides movements are in opposite direction to prevent the buckling.

All samples were made on a 15 gauge TCH Crochet Knitting machine [9]. The polyester yarn 16.7 tex was used as ground and the polyester yarn 33.4 tex was used as weft. The polyurethane with 0.8 mm diameter has been used as elastomeric thread. The number of using needles are 150 that provides 240 mm fabrics wide.

In order to research the influence of technological parameters on the properties of fabric three factors have been chosen: x_1 - the linier density of weft inserted yarn; x_2 - the tension of the ground yarn; x_3 – the pre-elongation of elastomeric thread (Table 1). The linier density of weft inserted yarn has been changed by yarn ends (k) that inlaying at each side of fabric: 2, 3 or 4. The tension of ground yarn has been changed by the additional load (q) on the yarn: 2, 6 or 10 g. The pre-elongation of elastomeric thread (ε) has been fixed at 210, 240 and 270 %. 27 variants of elasticized warp knitted fabric have been produced totally (Table 2).

Table 1

Experimental Conditions

	Weft yarn ends, **k**	Additional load on the ground yarn, **q**, g	Pre-elongation of elastomeric thread, **ε**, %
Factors level	x_1	x_2	x_3
Low (-1)	2	2	210
Middle (0)	3	6	240
High (+1)	4	10	270
The variation interval	1	4	30

The structural parameters are the main characteristics that affect the basis weight at other equal conditions. Therefore, the number of wales and courses per 100 mm as well as fabric thickness have been tested according standard methods [10]. The ten parallel measurements were made for each option, which average values are presented in Table 2.

Experimental results have shown that the number of wales per 100 mm of knitted fabric (horizontal density) varies slightly with the changing of elastomeric yarn pre-elongation. So, the number of wales per 100 mm is 62-63 for fabric made with 270% pre-elongation, while it is 64 for fabric made with 210% pre-elongation of elastomeric yarn that laid walewise. Mathematical processing of experimental data has revealed no adequate regressions describing the process. The filling interlooping on the chain base have been chosen for elasticized fabric production. In this case the loop step, which is the inverse characteristic of N_w, is defined by the machine gauge. It is logical that all fabric samples have a practically the same value of the number of wales per 100 mm of the knitted fabric since they are made on the same knitting machine with the same fixed tension of the weft filling yarn. The difference in measurement results that does not exceed 3% can be attributed to the measurement error.

Table 2

Structural parameters of warp knitted fabrics

Variant	Conditions			Number per 100 mm		Thickness, T, mm	Basis weight, m_s, g/sq.m
	x_1	x_2	x_3	wales, N_w	courses, N_c		
1.	+	+	+	62	87	1.58	912.9
2.	-	+	+	64	104	1.43	792.5
3.	+	-	+	61	91	1.66	957.5
4.	-	-	+	64	105	1.45	817.9
5.	+	0	+	62	90	1.60	943.2
6.	-	0	+	62	106	1.42	812.8
7.	0	+	+	62	96	1.54	894.6
8.	0	-	+	63	97	1.50	887.8
9.	0	0	+	63	96	1.50	864.7
10.	+	+	0	64	87	1.60	948.8
11.	-	+	0	64	100	1.42	793.8
12.	+	-	0	63	90	1.64	979.7
13.	-	-	0	64	102	1.43	809.1
14.	+	0	0	63	88	1.60	958.2
15.	-	0	0	64	101	1.42	806.6
16.	0	+	0	64	96	1.54	883.2
17.	0	-	0	63	96	1.52	901.4
18.	0	0	0	64	94	1.52	893.0
19.	+	+	-	64	86	1.60	935.1
20.	-	+	-	64	98	1.40	788.1
21.	+	-	-	64	90	1.68	973.5
22.	-	-	-	64	101	1.46	810.9
23.	+	0	-	64	88	1.63	952.6
24.	-	0	-	64	99	1.44	795.9
25.	0	+	-	63	95	1.56	906.2
26.	0	-	-	64	93	1.53	881.8
27.	0	0	-	64	93	1.50	881.2

As regards to the number of courses per 100 mm of knitted fabric, a wide spread of data from 86 to 106 (table 2) is observed. The regression dependences were obtained as a result of mathematical processing of the experimental data. The regression dependences on two parameters for a fixed value of third factor that adequately reflect the dependence of N_c on the variable process parameters are presented in Table 3. It is observed that the number of courses per 100 mm of knitted fabric (vertical density) depends on all three factors x_1, x_2 and x_3, but their effects are different.

It is obvious that the number of weft inserted threads has the greatest influence on N_c that is, the linear density of the weft yarn is very important factor. When it is doubled (from 2 to 4 ends), the number of courses per 100 mm of the knitted fabric decreases by 12-15%, which is directly related to the increase in the loop height to the positioning of weft threads.

Table 3

Regression Dependences

Fixed factors level	Number of courses per 100 mm	Thickness, mm
ε = 210 %	N_c = 111,8 - 5.8 k - 0.2 q	T = 1,242 + 0,102 k - 0.004 q
ε = 240 %	N_c = 114,6 - 6,2 k - 0,2 q	T = 1,223 + 0,097 k
ε = 270%	N_c = 119,7 - 7,7 k	T = 1,235 + 0,089 k
q = 2 g	N_c = 105,8 - 6.2 k + 0,03 ε	T = 1,208 + 0.108 k
q = 6 g	N_c = 68,7 + 2.8 k + 0,2 ε - 0,04 k ε	T = 1,236 + 0.092 k
q = 10 g	N_c = 81,0 + 0.3 k + 0,14 ε - 0,03 k ε	T = 1,240 + 0.091 k
k = 2	N_c = 82,0 + 0,08 ε - 0,2 q	T = 1,418
k = 3	N_c = 84,7 + 0.04 ε	T = 1,550 - 0.005 q
k = 4	N_c = 84,0 + 0,03 ε - 0.4 q	T = 1,656 - 0.008 q

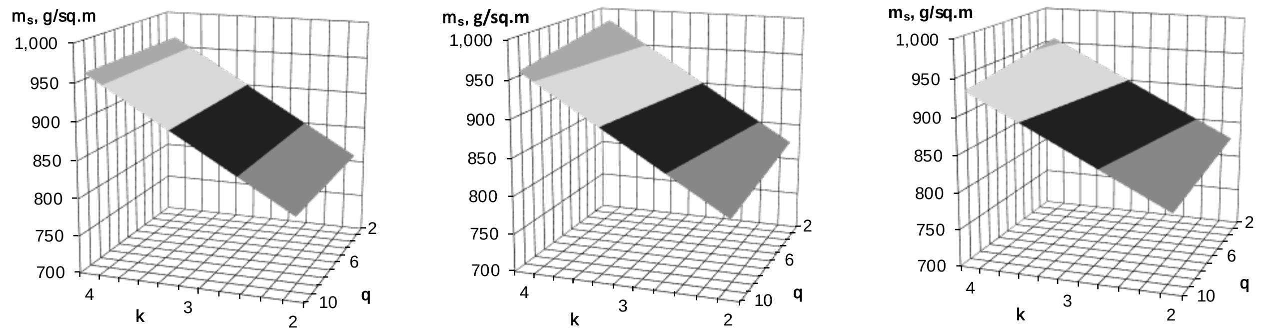
The effect of the pre-elongation of the elastomeric thread on the vertical density of knitted fabric is directly related to the linier density of weft inserted yarn. Thus, for fabrics with two yarn ends (k = 2), the pre-elongation change from 210 to 270 % leads to an increase of the vertical density by 5 %, while for fabrics with k = 3 or k = 4 the number of courses per 100 mm increases by 3 % only. This is due the fact that the relaxation processes of elongated elastomeric threads occur better conditions in knitted structure with a smaller number of threads as the weft. In such structure, the chain loops of wale are tilted in opposite direction at neighboring courses and the loop slope to the vertical increases with relaxation degree of elastomeric threads.

The tension of the ground yarn has the least influence on the number of courses per 100 mm of fabric (vertical density). The change of additional loads from 2 to 10 leads to a decrease in the number of courses N_c by 1.5-3.0% only, which is associated with a change of the loop length. But due to loops slope changing the loop length leads to a change of the slope angle and not the height of the course. It should be noted that the effect of this factor was not fixed when pre-elongation of the elastomeric threads was 270%. In this case, the loop configuration depends on the relaxation degree of the elastomeric thread only and not on the tension of the ground yarn itself.

The thickness of knit is an essential factor determining the performance of elasticized fabrics, and their raw material consumption particularly. The regression equations which adequately describe the process under study have been obtained based on the mathematical processing of the experimental data (Table 3). It is obvious and predictable that the thickness of the fabric depends on the linear density and the number of weft threads. The doubling of the linear density (from 2 to 4 yarn ends) of the weft leads to an increase by 15% the fabric thickness. As a result of the studies, it has been established that the pre-elongation value of the elastomeric thread does not affect the thickness of the elasticized fabrics, which indicates an equal degree of its relaxation in the knitted structure: the thickness of the elastomeric yarn is the same for all fabric variants.

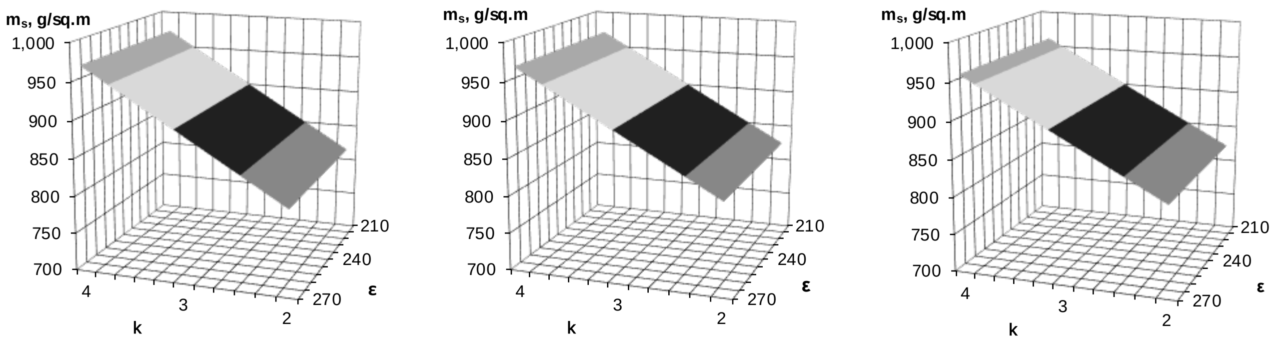
The influence of the ground yarn tension on the fabric thickness is directly related to the weft inserted threads. With an increase in the number of threads in the weft as the pre-tension of the ground yarn increases, the thickness of the elasticized knitted fabric is varying: there is no change for k = 2; the thickness decreases within 3 % for k = 3, and the thickness decreases by 5 % for k = 4. It can be assumed that with decrease of the loop length, which occurs due to the increase of the additional weight on the thread, the loop is tightened and it presses the weft yarns to the elastomeric thread that laid longwise. When using 3 and 4 threads as a weft, they can position in several modes, which will depend on the loop size. When using 2 ends of weft yarn, they are arranged one above the other anyway.

Previous studies [7] have detected that the above indicators determine the basis weight of knitted fabrics in one or another way. Ehe mathematical dependences of the basis weight of knitted fabrics on technological factors were obtained by mathematical processing of the experimental data (Table 2). The graphical representations of dependences are showed on Fig.1 for a fixed value of one of the technological parameters x_1, x_2 or x_3.



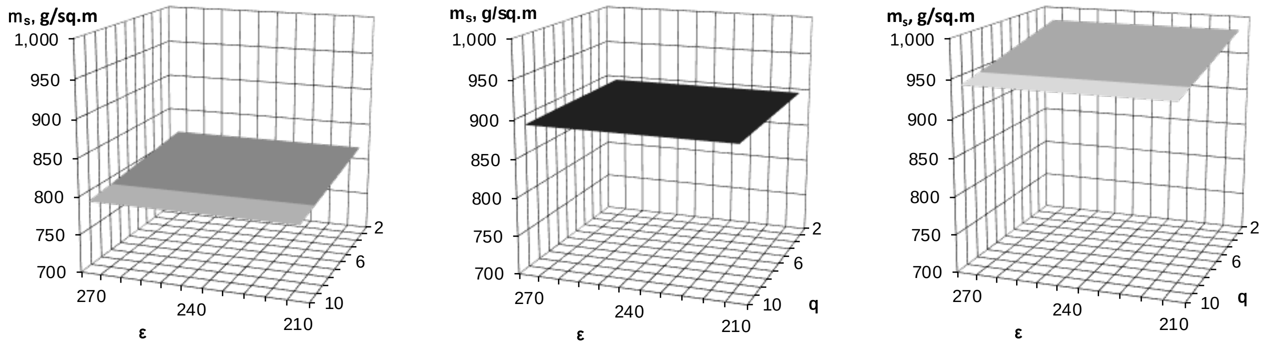
m_s = 652.7 + 77.7 k **m_s = 670.1 + 79.5 k - 2.7 q** **m_s = 700.6 + 65.1 k - 2.6 q**

a. ε = 210 % **b. ε = 240 %** **c. ε = 270%**



m_s = 656.5 + 78.8 k **m_s = 677.5 + 73.1 k** **m_s = 681.2 + 69.9 k**

d. q = 2 g **e. q = 6 g** **f. q = 10 g**



$m_s = 820.7 - 2.5\ q$ $m_s = 894.7$ $m_s = 990.8 - 4.7\ q$

g. k = 2 **h. k = 3** **i. k = 4**

Fig. 1. **Basis weight dependences**

Obviously, the number of yarn ends in the weft (Fig.1.a-f) has the greatest influence on the basis weight of the elasticized knitted fabric. Reducing the ends number from 4 to 2 leads to a significant (up to 20 %) reduction of the fabric weight, which naturally and without doubt. In some cases, the effect of the pre-tension of the ground yarn (q) on the basis weight has been revealed. This influence is very insignificant: a change of the additional load on the filament from 2 to 10 g leads to a decrease of the basis weight by 3 ÷ 4 % only (Fig.1.b, c, g), and by 5 % in case of using 4 yarn ends in the weft (Fig.1.i). Such influence of the tension of the ground yarn occurs by changing the loop length of the chain interlooping. As for the pre-elongation of the elastomeric threads (ε), no effect on basic weight of elasticized knitted fabric has been established in this study.

It should be noted that the elasticized knitted fabric has the smallest basis weight when only 2 yarns ends are used as the weft and the additional load on the ground yarn is 8 ÷ 10 g. From 0.25 to 0.35 m^2 of elasticized fabric is used for one abdominal binder production. Consequently, the using of fabric with up to 800 g / m^2 basis weight instead the traditional 900 ÷ 1000 g / m^2 leads to an average decrease the items weight by 50 g.

Conclusion. Design of elastic materials for medical purposes is aimed not only at improving the structural and functional properties, but also at reducing the material consumption as well as the items weight. It has been established as a result of the study that the linier density of weft inserted yarn has the greatest influence on the characteristics of knitted fabric, especially on the basis weight of fabric. Twice increase of linear density leads to increase by 15% the number of courses per 100 mm as well as the fabric thickness and by 20% the basis weight. The influence of the tension of the ground yarn and the pre-elongation of elastomeric thread does not exceed 5%. Therefore, in order to reduce the material consumption, it is necessary to reduce the linear density of the weft yarn, which used as a binding element and as the cover to prevent the elastomeric yarn contact with the human body also.

References

1. Galyk I.S. Semak V.D. Using of nanotechnology for the medical textile production // Bulletin of KNUTD. – 2014. – № 3 (77). – P. 176÷186.
2. GOST 31509 – 2012. Medical elastic manufactured articles for the fixation and compression. General technical requirements. Test methods. – Moscow: Izdatelstvo Standartov, 2013. – 28 p.

3. Omelchenko V.D., Sazonova T. Problems of antenatal knitted bandages design // Bulletin of KNUTD. – 2014. – № 4 (78). – P. 182÷188.

4. Pecherska A., Sadretdinova N. Optimization properties bandage products are intended for rehabilitation // Technologies and Design. – 2015. – № 3. – http://nbuv.gov.ua/UJRN/td_2015_3_5.

5. Melnyk L.M., Kyzymchuk O.P. The utilization of elastic knitted materials in the medical-preventive goods // Bulletin of KNUTD. – 2012. – № 4 (66). – P. 139÷145.

6. Prodanchuk I. The Investigation of elastic band properties of preventive corset for posture correction of high school juniors // Bulletin of KNUTD. 2013. №4 – P. 62÷65.

7. Kyzymchuk O.P., Pozhyvyl O.V., Golikova O.Y. Properties of elastic filling warp knitted fabric. // Bulletin of Khmelnitsky National University. – 2012. – №4. – P. 217÷221.

8. Kyzymchuk O., Melnyk L., Ermolenko I. Power-intensity and technological capability of modern warp knitting machines. // Bulletin of KNUTD. – 2015. – № 5. – P.106÷112.

9. Ermolenko I.V., Kyzymchuk O.P The development prospects of warp knitting machines for the lace production. // Problems of Light and Textile Industry of Ukraine. – 2012. – № 2 (20). – P. 162÷167.

10. GOST 8846-87 Knitted fabrics and garments. Methods for determination of linear demensions, distortion number of courses and wales and yarn length in the loop – Moscow: Izdatelstvo Standartov, 1988. – 18 p.

ВЛИЯНИЕ ТЕХНОЛОГИЧЕСКИХ ПАРАМЕТРОВ НА ПОВЕРХНОСТНУЮ ПЛОТНОСТЬ ЭЛАСТИЧНЫХ ПОЛОТЕН

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Цель. *Изучение влияния технологических параметров вязания на структуру и материалоемкость основовязаного эластичного трикотажа для изготовления изделий реабилитационного назначения.*

Методика. *Для достижения поставленной цели использованы методы математического планирования эксперимента, стандартные методы исследования параметров структуры трикотажа, а также статистические методы обработки и анализа экспериментальных данных.*

Результаты. *На основании спланированного и проведенного эксперимента, в котором в качестве входных факторов были выбраны натяжение грунтовой нити, линейная плотность поперечной уточной нити и предварительное удлинение эластомерной нити, получены математические зависимости, позволяющие определить степень влияния выбранных технологических параметров вязания на структурные характеристики трикотажа, особенно его поверхностную плотность.*

Научная новизна. *Предложены математические модели для проектирования основных параметров структуры и поверхностной плотности основовязаного эластичного трикотажа, в основу которых положены следующие технологические параметры вязания: натяжение грунтовой нити, предварительное удлинение эластомерной нити и линейная плотность поперечной уточной нити.*

Практическая значимость. *Полученные результаты исследования расширяют знания о влиянии технологических параметров вязания на материалоемкость основовязаных эластичных полотен уточного переплетения и могут использоваться на этапе проектирования реабилитационных изделия обеспечивая прогнозируемые показатели качества.*

Ключевые слова: *технологические параметры вязания, параметры структуры, основовязаный эластичный трикотаж, эластомерная нить.*

ВПЛИВ ТЕХНОЛОГІЧНИХ ПАРАМЕТРІВ НА ПОВЕРХНЕВУ ГУСТИНУ ЕЛАСТИЧНИХ ПОЛОТЕН

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Мета. *Встановлення впливу технологічних параметрів в'язання на параметри структури та матеріалоємність основов'язаного еластичного трикотажу призначеного для виготовлення реабілітаційних виробів.*

Методика. *Для досягнення поставленої мети використано методи математичного планування експерименту, стандартні методи дослідження параметрів структури трикотажу та статистичні методи обробки та аналізу експериментальних даних.*

Результати. *На основі спланованого та проведеного експерименту, в якому як вхідні фактори обрано натяг грунтової нитки, лінійну густину поперечної утокової нитки та попереднє видовження еластомерної нитки, розроблено математичні залежності, що дозволяють визначити ступінь впливу технологічних параметрів в'язання на структурні характеристики трикотажу, особливо його поверхневу густину.*

Наукова новизна. *Запропоновано математичні моделі для проектування основних параметрів структури основов'язаного еластичного трикотажу, в основу яких закладено наступні технологічні параметри: натяг грунтової нитки, попереднє видовження еластомерної нитки та лінійна густина поперечного утоку.*

Практична значимість. *Отримані результати, дозволяють розширити знання про вплив технологічних параметрів в'язання на матеріалоємність основов'язаних еластичних тасьм утокового переплетення та можуть бути використані на етапі проектування виробів забезпечуючи прогнозовані показники якості.*

Ключові слова: *технологічні параметри в'язання, параметри структури, основов'язаний еластичний трикотаж, еластомерна нитка.*