THE EFFECT OF RAW MATERIALS ON THE STIFFNESS OF ELASTIC KNITTED FABRICS

MELNYK Liudmyla[1], KYZYMCHUK Olena[2]
[1]*Kyiv National University of Technologies and Design, Kyiv, Ukraine*
[2] *Technische Universität Dresden, Germany*
*Corresponding author: MELNYK Liudmyla: e-mail melnik.lm@knutd.com.ua

Abstract: *The purpose of this work is to determine an efect of the raw material content of an elastic knitted fabric on its stiffness. Experimental knitted fabrics were produced using three weft yarn differ by raw materials and with five repeat of elastomeric threading into guide bar. It was established that both the weft yarn type and set of elastomer changed significally the stiffness of elastic warp knitted fabric. The obtained results showed that an increase in the set of elastomer from 50% to full increased the bending rigidity of fabric two times for fabric with cotton weft yarn and five times for fabric with polyester weft yarn. For the fabric with the same set of elastomer (2 in, 1 out) the one with linen weft yarn got the highest bending regidity value. Within this study mathematical dependence of bending regidity on the set of elastomer and on mass per sq.meter were eatablished.*

Key words: *Elastic warp knitted fabric, stiffness, bending rigidity, set of elastomer, weft yarns.*

1. INTRODUCTION

Elastic knitted material is widely used in apparel production due to its ability to maintain its shape and linear dimensions for a long time. In addition, it is an indispensable material in the manufacturing of compression clothing, especially for medical purposes. Such products prevent or slow down the progression of the disease. They are used to compensate the lost functions, to fix, support or unload certain body`s parts or even to create the desired position of human body. The therapeutic and preventive effect occurs indirectly by creating the pressure on the body`s parts with the greatest curvature. This pressure has to be dosed to avoid a pain or even damage of the human body. Pressure dosage delivered and mechanical properties (stiffness, elasticity and hysteresis) are determined by material nature, stitches structures, fabrication technology and delivery modes. A special significance of stiffness was defined for elastic textiles in compression therapy [1].

Stiffness is traditionally used as a term to indicate fabric's bending resistance quantitatively measured by bending length, flexural rigidity and bending modulus, which is one of the earliest properties to be objectively measured to assess the subjective handling quality of textile materials [2]. The increased fabric`s stiffness complicates technological stages of cutting and stitching as well as wet-heat treatment. It leads to the reducing of the equipment productivity. The stiffness of textiles is affected by such factors [3] as the fibers stiffness; the structure of yarn and thread; the type of an interweaving or an interlooping, namely the number of intermeshed points between the threads; etc. There is a gap in stiffness investigation of elastic fabrics used for medical compression clothes. The elastomeric threads are mostly used to

ensure the necessary functional properties, as stretch ability and elasticity [4]. The properties of elastic materials depend on raw materials types and their composition in fabric [5]. Last decade there is the tendency to use the natural yarn because of greater hygienic properties and the sustainability in textile production. The novel elastic warp knitted fabrics for medical products were developed in order to improve comfort properties and reduce elastomer consumption [6]. The purpose for this study is to determine the influence of the raw material of the weft yarn and the elastomer threading on the stiffness of elastic knitted fabrics.

2. MATERIALS AND METHODS

The 11 variants of warp knitted fabrics with the pillar stitch from 16.7 tex polyester yarn as the ground were produced on 15 gauge Crochet knitting machine by T.C.H . Five variants of elastomer threading (1 in, 1 out; 2 in, 1 out; 2 in, 2 out; 3 in, 1 out; full) and three variants of weft yarn (33.4 tex polyester yarn, 29 tex cotton yarn and 29 tex linen yarn) were used. The 0.8 mm diameter elastomer was introduced walewise into structure. The two complex weft yarn in 4 ply each are located at two sides of fabric to cover the elastomer. All fabrics` samples were produced with the same technological setup of knitting machine: the number of used needles; the tensions of ground and weft threads; the take down forces of the fabric. All fabrics got a stabilization moisture-heat treatment after knitting. The standard test methods were used for this research. The ASTM D3776 standard [7] was used for the determination of the mass per unit area (per square meter). 10 parallel measurements were done for each fabrics variant and mean value was used for an analises. A form of the cantilever stiffness test is often used as a measure of a fabric's stiffness as it is an easy test to carry out. The research was carried out on the PT-2 device in accordance with the GOST 10550-93. 5 speciments were studied walewise (the direction of elastomer laying) for each fabric variant and mean value was used for future calculation. The bending rigidity was determined as following [8]:

$$EI = 42046 * (m / A), \quad (1)$$

where m – the total mass of 5 specimens, g;

A – the function of the relative sagging that determined from the table [8].

3. RESULTS AND DISCUSSION

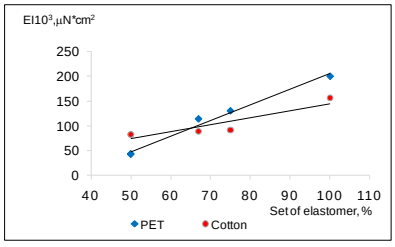
The fabric characteristics and study`s results are presented in table 1 and in Figure 1. It was observed that weight and stiffness of studied elastic warp knitted fabrics depends on both raw materials of weft yarn and the set of elastomer threaded into guide bar.

The obtained results (Table 1) show the effect the raw material of weft yarn on fabric`s stiffness. The bending rigidity of fabric with cotton weft yarn is smaller then fabric with polyester weft yarn for almost all variant of elastomer threading repeat exept those with half set of elastomer. The bending regidity of fabric with cotton weft yarn and repeat of elastomer threading 1 in, 1 out or 2 in, 2 out is two times more than fabric with polyester weft yarn and same repeat of elastomer threading. The bending rigidity of fabric with linen weft yarn is highest among fabrics with same repeat of elastomer threading 2 in, 1 out. This is due to the natural stiffness of flax fibers contained lignin.

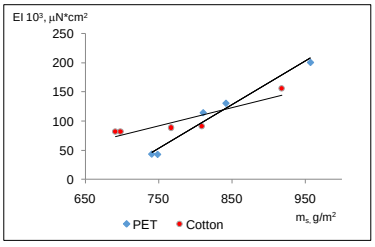
Table 1: Production data and properties of elastic warp knitted fabrics

Variant	Weft yarn	Elastomer threading	Set of elasto-mer	Mass per unit area	Sagging	Bending rigidity
			E, %	m_s, g/m²	sm	EI, 10^3 N*sm²
I PET	Polyester 33.4 tex	1 in, 1 out	50	749 ± 10	4.94 ± 0.18	42.9
II PET		2 in, 1 out	67	811 ± 8	3.08 ± 0.55	113.8
III PET		2 in, 2 out	50	741 ± 6	4.95 ± 0.29	42.4
IV PET		3 in, 1 out	75	842 ± 8	2.95 ± 0.70	130.1
V PET		full	100	957 ± 11	2.30 ± 0.47	200.1
I COT	Cotton 29 tex	1 in, 1 out	50	698 ± 10	3.45 ± 0.21	82.3
II COT		2 in, 1 out	67	767 ± 2	3.50 ± 0.22	88.8
III COT		2 in, 2 out	50	691 ± 9	3.44 ± 0.13	82.1
IV COT		3 in, 1 out	75	809 ± 8	3.60 ± 0.29	95.5
V COT		full	100	918 ± 10	2.73 ± 0.33	156.1
II LIN	Linen 29 tex	2 in, 1 out	67	723 ± 7	2.63 ± 0.46	123.3

The research results and plots in Figure 1 indicate that the bending rigidity of elastic fabrics depends on the repeat of elastomer threading and therefore on set of elastomer. The increase the set of elastomer from 50% to 100% leads to almost five times increasing in bending rigidity for fabric with the polyester yarn as weft. The bending rigidity for fabric with the cotton yarn as weft increases only two times. It is due to difference of the structure: polyester yarn is multifilament and cotton is staple fiber yarn.



a



b

Figure 1: Effect of set of elastomer (a) and of mass per unit area (b) on stiffness of elastic warp knitted fabric

Mathematical processing of experimental data made it possible to establish the following dependences of the bending rigidity (EI) on the set of elastomer (E) and mass per square meter (m_s):

- for fabric with 33.4 tex polyester yarn as weft (R^2=0.986÷0.973)

$$EI = 3.2\ E - 110.7\ [10^3\ \mu N*cm^2]; \quad (2)$$
$$EI = 0.75\ m_s - 505.9\ [10^3\ \mu N*cm^2]; \quad (3)$$

- for fabric with 29.0 tex cotton yarn as weft (R^2=0.863÷0.826)

$$EI = 1.4\ E + 5.3\ [10^3\ \mu N*cm^2];\quad (4)$$

$$EI = 0.31\ m_s - 139.4\ [10^3\ \mu N*cm^2].\quad (5)$$

The obtained dependences allow with high accuracy to determine the bending rigidity of elastic warp-knitted fabrics in case of changing the repeat of elastomer threading and the use of complex ratios.

4. CONCLUSIONS

The research results of bending rigidity of elastic wsrp knitted fsbric shows the following:

- the fabric`s stiffness depends on both raw matirials of weft yarn and the elastomer threading into guide bar;
- elastic fabric with elastomer in each wale has got highest stiffness;
- the bending rigidity decriases with decrising in set of elastomer;
- the bending regidity of fabric with linen yarn as a transverse weft has got highest value at the same set of elastomer;
- the dependence of bending regidity on mass per sq.meter of fabric were established.

5. References

1. Rong Liu, Xia Guo, Terence T Lao, Trevor Little A critical review on compression textiles for compression therapy: Textile-based compression interventions for chronic venous insufficiency. In:*Textile Research Journal,* 2017, Vol. 87(9), p.p. 1121–1141.
2. Zhao-Qun Du, Tianxian Zhou, Ni Yan, Shen Hua, Wei-Dong Yu Measurement and characterization of bending stiffness for fabrics. In: *Fiber and Polimers*, 2011,12, pp. 104-110.
3. O. Paraska, T. Rak, N. Radek Investigation of operating properties of textiles after processing by composition based on environmentally safe agents. In: *Herald of Khmelnytskyi national university*, Part 2, Issue 6, 2018 (267), pp. 103-108.
4. Kyzymchuk O & Melnyk L. Stretch properties of elastic knitted fabric with pillar stitch, *Journal of Engineered Fibers and Fabrics,* 2018; 13(4): 1-10. DOI : 10.1177/1558925018820722
5. Melnyk L., O. Kyzymchuk, O. Golikova The influence of weft filling yarn on the properties of warp knitted fabric In: Proceedings of International Scientific Conference UNITECH' 2016, 18-19 November 2016, Gabrovo.
6. Kyzymchuk O, Melnyk L, Marmarali A, Oğlakcıoğlu N, Ertekin G, Arabuli S, Arabuli A & Cüreklibatır Encan. The effect of weft yarn type and elastomer yarn threading on the properties of elastic warp knitted fabrics. Part 1: Structure and elasticity. In: *Journal of Engineered Fibers and Fabrics*. 2023. [In processing]
7. ASTM D3776 Standard Test Methods for Mass Per Unit Area (Weight) of Fabric
8. GOST 10550-93 Textiles. Cloth. Methods for determination of resistance to blend