ANNALS OF THE UNIVERSITY OF ORADEA
FASCICLE OF TEXTILES, LEATHERWORK

EFFECT OF ELASTANE ON DIMENSIONAL AND THERMAL PROPERTIES OF SPORTSWEAR FABRICS

CODĂU Elena[1], CODĂU Teodor-Cezar[2]

[1]Technical University "Gheorghe Asachi" of Iasi, Faculty of Industrial Design and Business Management, 29 Professor Dimitrie Mangeron Blvd., 700050 Iasi, Romania, elena.codau@academic.tuiasi.ro

[2]University of Minho, Fibrenamics, Guimaraes, Portugal, cezarcodau@fibrenamics.pt

Corresponding author: Codău, Elena, E-mail: elena.codau@academic.tuiasi.ro

Abstract: *In recent years, the use of woven and knitted fabrics with elastane has increased remarkably. This is due to the particular fact that these articles are characterized by excellent wear comfort and fit. In addition to extensibility, thermo-physiological comfort properties such as air permeability and thermal properties can be influenced by elastane yarn. This paper aimed to investigate the relation between elastane yarn linear density and fabric dimensional and thermal properties. Two series of 3 knitted fabrics were produced using the 8-feed Single-Jersey Circular Knitting Machine MERZ – MBS. The ground yarns were: 30% Outlast®Viscose / 70% Cotton, 14.75 tex, and a Dacron® 702 WSD 1.7/38, 14.30 tex (Coolmax®). The plating yarns were 22 dtex, 44 dtex, and 77 dtex Creora®, plated at every feeder by using the electronic feeder. The results indicated that the linear density of elastane has a significant effect on the dimensional and thermal properties of Coolmax®/Creora® and Outlast®/Creora® plated plain knitted fabric. The elastane yarn linear density mainly influences the number of courses per cm and consequently the number of stitches per cm^2, and respectively the weight of knitted fabrics. The linear density of elastane yarn influences mostly the air permeability, thermal conductivity, and thermal absorptivity of Single-Jersey fabrics. The higher the linear density of the elastane yarn, the lower the air permeability and the higher the thermal conductivity and thermal absorptivity of the fabrics. These findings are an important tool in the design of a product tailored to thermal management requirements.*

Keywords: *knitted structure, thermal resistance, thermal conductivity, thermal absorptivity, air permeability.*

1. INTRODUCTION

Nowadays, more and more articles for sportswear, underwear or outer clothing include elastane yarn. Stretch garments play an important role in optimizing an athlete's performance by providing freedom of movement, maximizing comfort, minimizing the risk of injury or muscle fatigue, and reducing friction. According to the literature, to improve fabric elasticity and shape retention, 2% of elastane is enough but for high-performance garments, such as swimwear and active sportswear, the elastane content can increase up to 30% [1], [2].

Elastane fibers are synthetic fibers made of polyether-polyurea copolymer, known for their exceptional elasticity. The stretch elasticity of elastane can be as high as 500% while the elastic recovery reaches 95%. The first process of the industrial-scale production of elastane was developed in 1958 by Joseph Shivers, a chemist at DuPont's Benger Laboratory, in Waynesboro, Virginia, US.

Initially, DuPont chose the name „Lycra" to distinguish its brand of elastane fiber [3]. Nowadays brand names for elastane fiber include Lycra® and Elaspan® (Lycra Company, previously a division of DuPont Textiles and Interiors), Acepora® (Taekwang Group), Creora® (Hyosung Corporation), INVIYA® (Indorama Corporation), ESPA® (Toyobo Co., Ltd.), ROICA®, Dorlastan® (Asahi Kasei Group), Linel® (Fillattice Group), etc. For articles with high elasticity (tights, underwear, swimwear, beachwear, sportswear, corsets, and medical support stockings, etc.) elastane fibers are always mixed with one or more other fibers, and the most used technological method for obtaining these products is that of knitting. If bare elastane yarn is processed to form a loop it must always be knitted together with ground yarn [3].

Plating (the simultaneous formation of the loop from two threads) is a common way of processing stretch-knitted fabrics. Some research available in the literature described the relation between the rate of elastane (respectively elastane yarn tension) and the dimensional and elastic properties of the fabric [4], [5], [6]. Other studies focused on the behavior of fabric with elastane yarn during stretching. The results of these studies demonstrated that elastane changes the dimensional characteristics of the fabric and the stretch properties [7]. Anyway, the relation between elastane proportion and fabric characteristics has not been enough studied, and generally, in practice, the experience is used during machine adjustments to reach the required fabric characteristics. Moreover, the changes in the dimensional characteristics of fabric can affect its thermal properties and little work has been done on the study of the effect of elastane on the thermo-physiological comfort properties.

In this paper, the relation between elastane yarn linear density and fabric dimensional and thermal properties was investigated.

2. MATERIALS AND METHODS

Two series of 3 single jersey knitted fabrics were produced using the 8-feed Single-Jersey Circular Knitting Machine MERZ – MBS. The ground yarns were: 30% Outlast®Viscose / 70% Cotton, 14.75 tex, and a Dacron® 702 WSD 1.7/38, 14.30 tex (Coolmax®). The plating yarns were 22 dtex, 44 dtex, and 77 dtex Creora®, plated at every feeder by using an electronic feeder BTSR KTF 100 HP. The plating yarn input tension was 4 cN and for the main yarn 2 cN.

Dry relaxation was made by laying the samples on a flat surface under atmospheric conditions (20 ± 2°C and 65 ± 5% relative humidity) for 48 hours.

The single jersey knitted fabric characteristics measured were wales density, courses density, loop length, fabric weight per unit area, and fabric thickness. The wales and courses density of knitted fabrics were measured according to the ASTM D-3887-2008 standard. Maillemètre was used to determine the loop length following BS EN 14970-2006 – „Textiles. Knitted fabrics. Determination of stitch length and yarn linear density in weft knitted fabrics". The length of ten unrow courses, each of them containing 100 wales, was measured on a Maillemètre tester, and an average was calculated. This average value was divided by 100 to find the length of one loop. The tightness factor was also calculated as follows [8]:

$$Tightness\ factor = \frac{\sqrt{T_{tex}}}{L} \tag{1}$$

where: T_{tex} is the linear density of the yarn, and L - the loop length, in mm.

The fabric mass per unit area was measured according to ASTMD 3776/D 3776M - 09a using an electronic balance KERN-770 with an accuracy of 0.1 mg. The thickness of the knitted fabrics was determined with SDL – Digital Thickness Gauge M034A, according to NP EN ISO 5084-1996.

The thermal properties of the fabrics were measured by the ALAMBETA instrument [9] according to ISO EN 31092-1994. The measurements were repeated 10 times on randomly chosen parts of the fabrics, and average values were calculated. The measuring head temperature of the ALAMBETA was 32 °C, and the contact pressure was 200 Pa.

Thermal comfort is characterized by three important properties: thermal conductivity, thermal resistance, and thermal absorptivity.

Thermal conductivity, λ (W/mK), is considered to be dominant in determining heat transfer through fabrics and garments. The measurement result of thermal conductivity is based on Eq. (2):

$$\lambda = \frac{Q}{F\tau\frac{\Delta T}{\sigma}} \quad (W/mK) \tag{2}$$

where: Q is the amount of conducted heat, F - the area through which the heat is conducted, τ - the time of heat conducting, ΔT - the drop in temperature, and σ - the fabric thickness.

Thermal resistance, R (m^2K/W), mainly depends on the thickness and porosity of the fabric. Thermal resistance is connected with fabric thickness by the relationship:

$$R = \frac{\sigma}{\lambda} \quad (m^2K/W) \tag{3}$$

where: σ is the fabric thickness, and λ - the thermal conductivity.

Thermal absorptivity, b ($Ws^{1/2}/Km^2$), is the heat flow q (W/m^2) which passes between the human skin and the contacting textile fabric. The higher this value, the cooler the feeling represented.

$$b = \sqrt{\lambda\,\rho\,c} \quad (Ws^{1/2}/Km^2) \tag{4}$$

where: λ is the thermal conductivity, ρ - the fabric density, and c - the specific heat of the fabric.

The air permeability of the samples was measured according to ISO 9237-1999 with a Textest FX-3300 air permeability tester. The air pressure differential between the two surfaces of material was 100 Pa, the measurements were carried out 10 times and the average and standard deviation of the test values were calculated.

3. RESULTS AND DISCUSSION

One-way ANOVA analysis was carried out to determine the influence of elastane linear density on the dimensional and thermal properties of knitted fabrics, using the professional statistical software PASW Statistics 17.

3.1. Dimensional properties

The dimensional parameters of the fabrics are given in Table 1.

Table 1. Dimensional properties of knitted fabrics

Elastane linear density	Wales/cm		Courses/cm		Stitch/cm^2		Tightness factor, $T_{tex}^{1/2}$/mm		Weight, g/m^2	
	Coolmax® + Elastane	*Outlast® + Elastane*	Coolmax® + Elastane	*Outlast® + Elastane*	Coolmax® + Elastane	*Outlast® + Elastane*	Coolmax® +Elastane	*Outlast® + Elastane*	Coolmax® +Elastane	*Outlast® +Elastane*
77 dtex	17,5	*17,5*	40	*40*	700	*700*	1,67	*1,66*	307,59	*313,2*
44 dtex	17	*17*	34	*34*	578	*578*	1,49	*1,48*	253,78	*253,2*
22 dtex	16,5	*16,5*	27	*28*	445,5	*462*	1,37	*1,37*	182,24	*206,46*

The elastane yarn linear density mainly influences the number of courses per cm and consequently the number of stitches per cm^2. Higher linear density gives a higher value of courses per cm and respectively stitches per cm^2 because the tension applied by elastane yarn is higher and makes stitches closer to each other.

The loop length of ground yarn decreases when the elastane yarn linear density increases (Fig. 1). The influence of elastane yarn linear density on loop length is significant at a 95% confidence interval. Ground yarn consumption is constant but stitch geometric configuration is modulated by the tension applied by the elastane plating yarn. The tension applied by thicker elastane yarn is higher and consequently, the loop length is lower. This reduction in loop length with increasing the linear density of the elastane yarn also accounts for the variation in the density of the courses and stitches.

The tightness factor is directly proportional to the linear density of the elastane yarn.

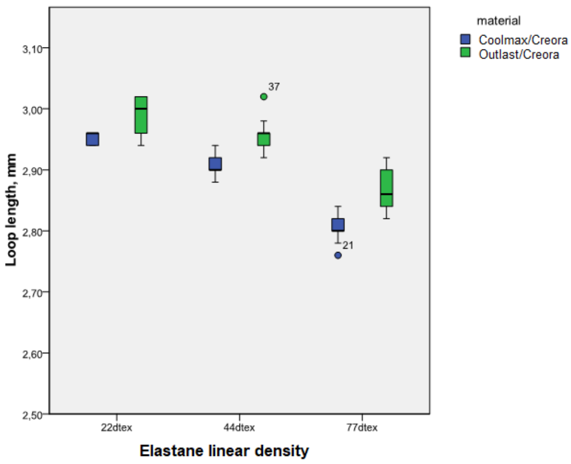

Fig. 1: Loop length

The thickness of the fabrics increases slightly with the linear density of the elastane yarn due to the higher tension exerted by the elastane yarns (Fig. 2). The thickness of Coolmax® fabrics is higher than that of Outlast® ones, although the fineness of the Outlast® yarns is slightly lower (Table 1). This is due to the characteristics of the yarns (eg stiffness) related to the type of raw material and the internal structure of the yarn (eg fiber stiffness, twist).

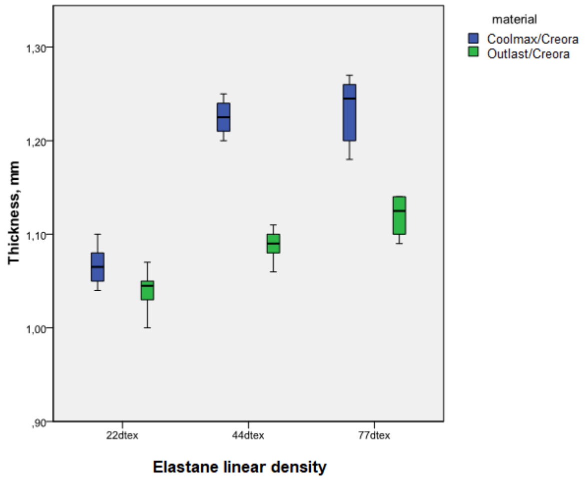

Fig. 2: Thickness

The weight of the samples also increases as the linear density of elastane yarn increases because the loop length decreases and, the greater the amount of elastane percentage the tighter the fabric (Table 1). Thus, the fabric becomes thicker and heavier as the proportion (yarn linear density) of elastane increases.

3.2. The thermal properties

Thermal conductivity

The Outlast® fabrics have higher thermal conductivity than Coolmax® fabrics (Fig. 3), and the differences are significant at a 95% confidence interval.

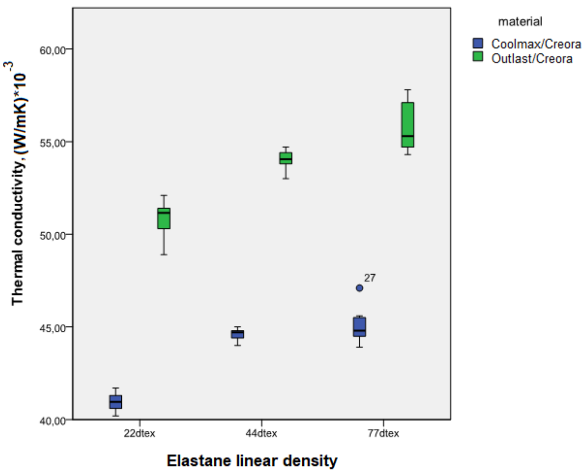

Fig. 3: Thermal conductivity

One-way ANOVA analysis revealed that there is a significant influence of the elastane linear density on the thermal conductivity of Single Jersey fabrics**.** The lower the linear density of elastane yarn (or the lower the tightness factor**)** the lower the thermal conductivity.

In the case of the Alambeta device, heat transfer through fabric mainly depends on thermal conductions, whereas heat loss by convection and radiations is negligible. For textile materials, still air in the fabric structure is the most important factor for thermal conductivity value, as still air has the lowest thermal conductivity value compared to all fibers (λ_{air} = 0.025 $W/(m{\cdot}K)$) [10]. Therefore, for fabrics with a lower tightness factor (lower linear density of elastane yarn), the enclosed air carries a reduced amount of energy by conduction, and the thermal conductivity also decreases.

Thermal resistance

Coolmax® fabrics have a higher thermal resistance (Fig. 4), so better thermal insulation properties. The elastane linear density does not have a significant influence on the thermal resistance of these knitted fabrics. Even if small differences are reported among the thermal resistance values, the differences are not statistically significant at a 95% confidence interval, and the influence of elastane yarn linear density on the thermal resistance of this type of fabric can be ignored.

According to Eq. (3), there should have been an inverse relationship between thermal resistance and thermal conductivity. However, the results revealed that as thermal conductivity increases, thermal resistance also increases slightly. This contradiction might be explained by the fabric thickness. A significant increase is registered in the fabric thickness, confirmed by ANOVA results. Thus, the increment in thermal resistance and thermal conductivity is normal.

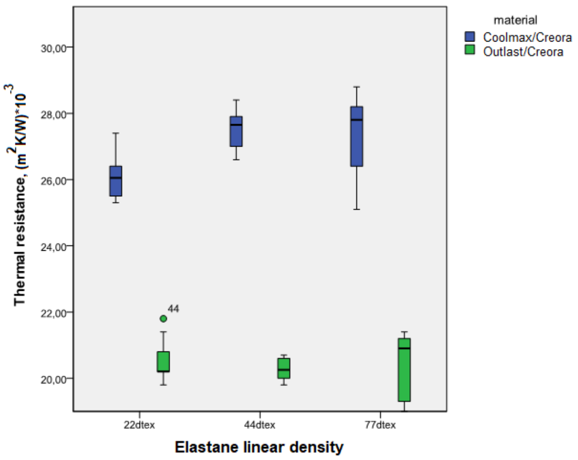

Fig. 4: Thermal resistance

Thermal absorptivity

Thermal absorptivity is the objective measurement of the warm-cool feeling of fabrics. When a human touch a garment that has a different temperature than the skin, heat exchange occurs between the hand and the fabric. If the thermal absorptivity of clothing is high, it gives a cooler feeling at first contact. The surface character of the fabric greatly influences this sensation. A rough fabric surface reduces the area of contact appreciably giving a warm feeling, and a smoother surface increases the area of contact and the heat flow, thereby creating a cooler feeling [7].

The raw material has a significant influence on thermal absorptivity. The Coolmax® fabrics having lower thermal absorptivity provide a warmer sensation at contact with the skin.

The ANOVA analysis showed that there is a significant influence of the elastane linear density on the thermal absorptivity of Single-Jersey fabrics**.** The higher the linear density of elastane yarn the higher the thermal absorptivity of the fabrics (Fig. 9). This is due to the fact that with thicker elastane yarn the surface of the fabric becomes smoother.

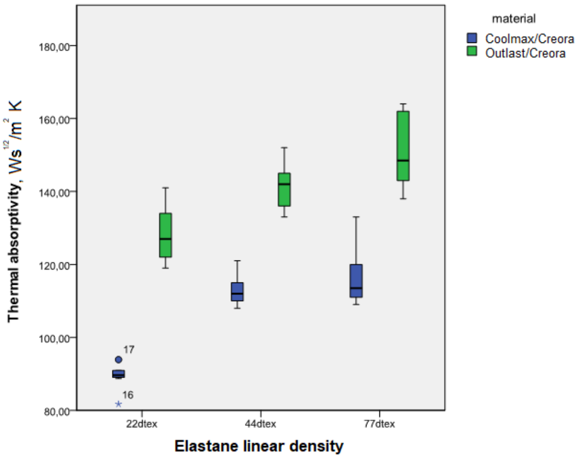

Fig. 9: Thermal absorptivity

Air permeability

Air permeability is described as the rate of air flow passing perpendicularly through a known area under a prescribed air pressure differential between the two surfaces of a material. Air permeability has a direct relationship with pores size. An increase in pores size led to an increase in air permeability. The fabric with the lowest stitch density has the best air permeability.

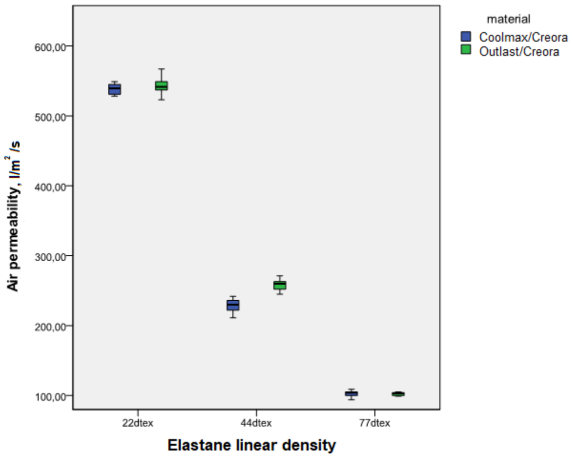

Fig. 10: Air permeability

One-way ANOVA analysis showed that there is a significant influence of the linear density of elastane on the air permeability of knitted fabrics. Air permeability decreases with the increasing linear density of elastane yarn (Fig. 10). This can be explained by the shrinkage of the fabric after knitting due to the relaxation of the elastane yarn. Greater yarn shrinkage at a higher percentage of elastane (higher linear density) provides a more compact and thicker structure, which results in less free space available for air movement.

4. CONCLUSIONS

The results obtained in the present work indicated that the linear density of elastane yarn has a significant effect on the dimensional and thermal comfort properties of Coolmax®/Creora® and Outlast®/ Creora® Single-Jersey plated knitted fabric.

The elastane yarn linear density mainly influences the course density and consequently the number of stitches per cm^2 and respectively the weight of knitted fabrics. The weight and thickness of the elastane-containing fabrics are higher as the linear density of elastane yarn increases and fabrics tend to be tighter.

The linear density of elastane yarn significantly influences the air permeability of the fabrics. The higher the linear density of the elastane yarn the lower the air permeability.

The linear density of elastane yarn has a significant influence on the thermal conductivity and thermal absorptivity of Single-Jersey fabrics**.** The higher the linear density of elastane yarn the higher the thermal conductivity and absorptivity of the fabrics. On the contrary, the significance values of the F test in the ANOVA for thermal resistance are above 0.05 for all samples, and this means that the elastane linear density does not have a significant influence on thermal resistance.

These results represent an important tool in the design of structures with specific thermal management requirements, to be used in functional sports clothing.

REFERENCES

[1] J. Voyce, P. Dafniotis and S. Towlson, “*Elastic textile*”. In: R. Shishoo (Ed) Textiles in sport, Woodhead Publishing Limited and CRC Press LLC©, 2005, Cambridge England, pp.204-230.

[2] O. R. K. Nilay, A. Z. A. Candas and G. ZENGIN, "*Stretch fabrics in leather manufacturing: performance properties of stretch leathers*", Annals of the University of Oradea Fascicle of Textiles, Leatherwork, vol. 17, pp. 189–194, 2016.

[3] A. Y. M. A. Azim, K. Sowrov, M. Ahmed, H. R. U. Hasan and M. A. Al Faruque, "*Effect of elastane on single jersey knit fabric properties-physical & dimensional properties*", International Journal of Textile Science, vol. 3, pp. 12–16, 2014.

[4] A. P. Čuden, M. Srdjak and H. Pelko, "*Optimization of the Cotton/Lycra Plain Knitted Fabric Parameters*", International Journal of Polymeric Materials and Polymeric Biomaterials, vol. 47, pp. 633–648, October 2000.

[5] S. B. Abdessalem, Y. B. Abdelkader, S. Mokhtar and S. Elmarzougui, "*Influence of Elastane Consumption on Plated Plain Knitted Fabric Characteristics*", Journal of Engineered Fibers and Fabrics, vol. 4, Issue 4, pp. 30-35, December 2009.

[6] S. Sahu and A. Goel, "*Effect of spandex denier on structural properties of single jersey knitted fabric*", International Journal of Engineering Sciences & Research Technology. September, pp. 407–412, 2017.

[7] D. Š. Gorjanc and V. Bukosek, "*The behaviour of fabric with elastane yarn during stretching*", Fibres and Textiles in Eastern Europe, vol. 16, pp. 63–68, 2008.

[8] A. Pavko-Cuden, A. Hladnik and F. Sluga, "*Loop length of plain single weft knitted structure with elastane*", Journal of Engineered Fibers and Fabrics, vol. 8, Issue 2, pp. 110-120, 2013.

[9] L. Hes, "*Thermal properties of nonwovens*", in " Proc. Congress INDEX 87," Part 2B, Genf, 1987.

[10] N. Oglakcioglu, P. Celik, T. B. Ute, A. Marmarali and H. Kadoglu, "*Thermal comfort properties of angora rabbit/cotton fiber blended knitted fabrics*", Textile Research Journal, vol. 79, pp. 888–894, 2009.