Influence of Structural and Process Parameters on Mechanical Behaviour of Elastane Yarns

Cruz J.[1,a] Carvalho R.[1,a], Sohel R.[1,a], Fangueiro R.[1,a], Coutinho G.[2,b] and Pereira M.[2,b]

[1] *University of Minho, Center for Textile and Technology, Campus de Azurém, Guimarães, Portugal*

[2] *Barcelcom, Tamel S. Veríssimo, Barcelos, Portugal*

julianacruz@det.uminho.pt

Abstract

In this work, the influence of various structural and process parameters (such as linear density of core and cover and draw ratio) on the mechanical behaviour of elastane yarn has been thoroughly investigated. According to the experimental results, elastane yarns with high linear density core and cover and produced using higher draw ratio showed the best mechanical properties in terms of both strength and extension.

Keywords: Compression garment, elastane yarn, mechanical properties

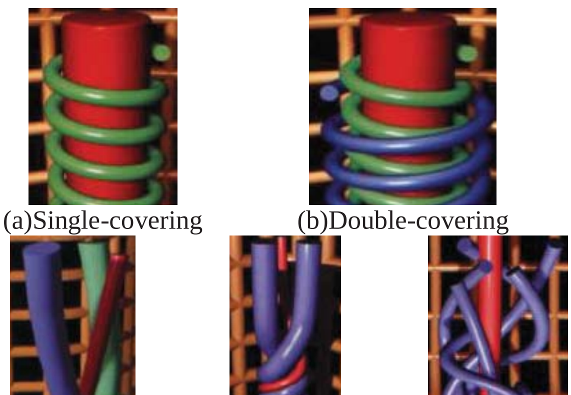
1. Introduction

Compression garments are frequently applied in two main areas: medical, which includes different sub-sectors such as orthopedics, aesthetics, rheumatology, among others, and sports involving different modalities [1-3]. The main application of compression garment is for treating venous insufficiency, for example, treatment of varicose veins. However, it has many other applications such as for treating burns, fatigue, dislocations, muscle fatigue, sprains and low blood pressure. It is also used and recommended for long flights to avoid the occurrence of deep vein thrombosis and postpartum recovery [3].

Compression garment helps to control unforeseen, sudden and uncomfortable movements due to the act of coughing or sneezing and this is very important, for example, during the post-operative period. These products are also widely used in patients undergoing plastic surgery and / or cosmetic and orthopedic surgeries. After surgery the use of this type of garment helps to improve blood circulation, minimize swelling, and prevents the accumulation of potentially harmful fluids to the human body, allows quick recovery so that the patient can return to normal life in a relatively short period. Additionally, they are used to support the areas which were subjected to surgery and help the skin to regain its previous contours and new features [3].

Compression garments are also used in the sports clothing to improve the performance of athletes. The use of knitted fabrics composed of elastane inlay yarns in combination with other type of knitting yarns (e.g. polyamide) is a common practice to produce these garments, in order to achieve required degree of compression and elasticity. Elastic fibre such as spandex has very high extension, more than 200%/ and excellent elastic recovery [4]. Elastic fibers are opening new paths in search of more comfortable clothing. Properties such as elasticity and recovery have become key features in almost all types of clothing, from fashion to ready-to-wear, high-performance sportswear and medical garments.

Elastane yarns used in compression garments are usually wrapped by cotton or polyamide cover yarns. Different types of wrapping process are used to produce these yarns such as single covering, double covering, core-spun, core twisting and air covering [5]. These processes are schematically shown in Fig. 1.



(a)Single-covering (b)Double-covering (c)Core-spun (d)Core-twisting (e)Air-covering

Fig. 1- Different types of wrapping process

The wrapping process as well as the properties of core and the cover can be adjusted to tailor the properties (stiffness and elasticity) of the hybrid yarns, which in turn, control the performance of the compression garment [6]. To address this issue, in the present paper, the influence of structure (linear density of elastane core and polyamide cover) and production parameters (drawing ratio during covering) on the mechanical behaviour of elastane yarns have been thoroughly investigated and discussed.

2. Experimental

Materials and methods

Elastane yarns were produced in a conventional double covering machine varying the linear density of elastane core (285 dtex, 420 dtex and 620 dtex), polyamide cover (44/13 dtex and 78/23 dtex) and also the draw ratio of elastane core during double covering (200% and 300%). Different types of yarn produced varying these parameters and their sample codes are listed in table 1.

Table 1: Types of elastane yarn and their codes

Identification	Core	Covered (PA)		Drawing (%)
	EA (dtex)	Mass (dtex)	Number of Filaments	
EA420_PA78/23_300%	420	78	23	300
EA285_PA78/23_300%	285	78	23	300
EA620_PA78/23_300%	620	78	23	300
EA420_ PA44/13_300%	420	44	13	300
EA620_ PA44/13_300%	620	44	13	300
EA285_ PA44/13_300%	285	44	13	300
EA620_PA78/23_200%	620	78	23	200
EA620_PA44/13_200%	620	44	13	200
EA420_PA78/23_200%	420	78	23	200
EA420_ PA44/13_200%	420	44	13	200
EA285_PA78/23_200%	285	78	23	200
EA285_ PA44/13_200%	285	44	13	200

Test Methods

The yarns were characterized for mass per unit length according to NP EN ISO 2060 standard. Characterization of the tensile properties was performed in Hounsfield N-5000 universal testing machine according to NP EN ISO 2060 standard at 100 mm/min crosshead speeds using 10 cm gauge length.

4. Results and Discussion

Analyzing the tensile test results presented in Table 2, it is possible to conclude that the yarn with code, EA620_PA78/23_300% has the highest resistance to rupture among all types of yarn, whereas the yarn, EA285_ PA44/13_200% has the lowest mechanical resistance. Also, the yarn EA285_PA78/23_300% shows the highest elongation percentage (1160%), whereas the EA420_ PA44/13_200% gives the lowest elongation (440%).

From Table 2, it can be seen that at lower force (0.5N) also EA285_PA78/23_300% showed the highest elongation, while EA420_PA78/23_200% showed the lowest elongation. Same behavior is also observed at 1N force.

Table 2: Tensile test results

Identification	Tensile test			
	Break		Elongation	
	Load (N)	Elongation (%)	0,5 N	1N
EA285_ PA44/13_200%	4,0	492	244	276
EA285_ PA44/13_300%	5,5	528	342	401
EA285_PA78/23_200%	6,0	569	323	371
EA285_PA78/23_300%	6,0	1160	671	798
EA420_ PA44/13_200%	4,0	440	264	338
EA420_ PA44/13_300%	5,0	547	257	341
EA420_PA78/23_200%	7,0	540	98	195
EA420_PA78/23_300%	6,0	526	254	350
EA620_PA44/13_200%	4,0	836	417	546
EA620_ PA44/13_300%	8,0	650	254	370
EA620_PA78/23_200%	8,0	578	248	334
EA620_PA78/23_300%	9,0	620	215	319

Fig. 2 shows the influence of cover yarn and draw ratio on the tensile behaviour in case of 285 dtex elastane core. It can be seen that the yarns with higher linear density polyamide cover (78/23 dtex) presented better mechanical resistance than with 44/13 dtex polyamide cover. In case of finer polyamide cover (44/13 dtex); mechanical resistance is better for higher draw ratio (300%). The highest elongation is shown by the yarn with 78/23 dtex polyamide cover and produced with higher draw ratio (300%).

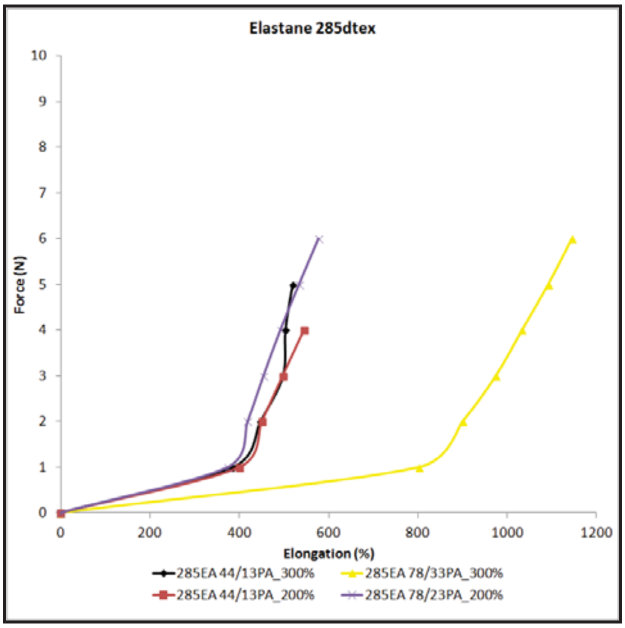


Fig.2 – Load elogation behaviour of yarns with 285 dtex elastane core

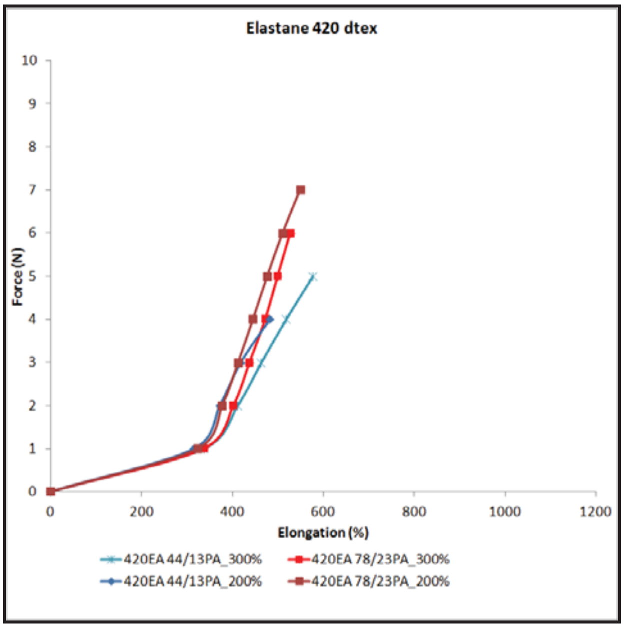


Fig.3 – Load elogation behaviour of yarns with 420 dtex elastane core

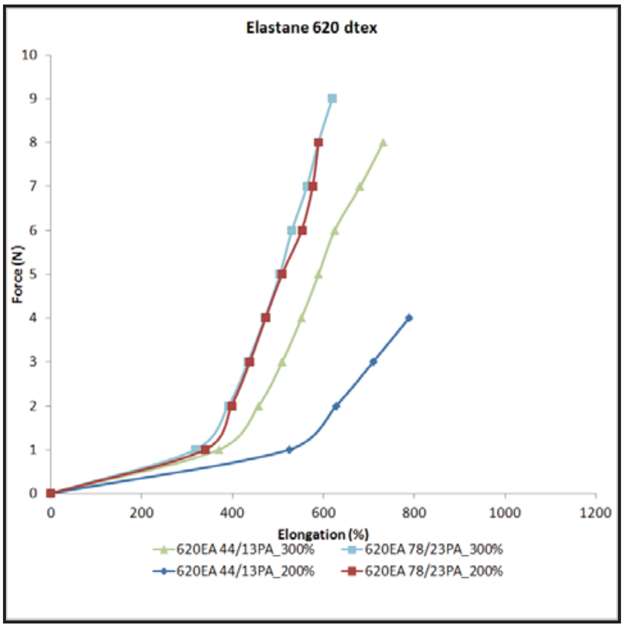


Fig.4 - Load elogation behaviour of yarns with 620 dtex elastane core

The tensile force elongation curves for 420 dtex elastane core are presented in Fig. 3. It can be noticed that the higher mechanical resistance is achieved in case of 78/23 dtex polyamide cover, similarly as observed in case of 285 dtex elastane core. Moreover, in case of finer polyamide cover, an increase in draw ratio led to higher force to rupture. However, in this case, all yarns showed almost similar breaking extension.

Similar tensile behaviour can also be observed in case of 620 dtex elastane core, as shown in Fig. 4. Better tensile behaviour is observed in case of high linear density polyamide cover and an improvement in the tensile behaviour of finer cover yarns can be obtained using higher draw ratio. However, the finer cover yarns showed higher breaking elongation in this case and the yarn produced with lower draw ratio (EA620_PA78/23_200%) presented the highest breaking elongation among all types of yarn.

When using these yarns in compression garment, it would be important to analyze their ability of load bearing for a given stretch. In the present study, the load bearing capacity of the elastic yarns at 30% elongation has been studied and the results are presented in Fig. 5. The behavior is similar to what was observed in case of extension up to rupture. The highest strength is given by EA620_PA78/23_300%, while the lowest strength is observed in case of EA285_ PA44/13_200%.

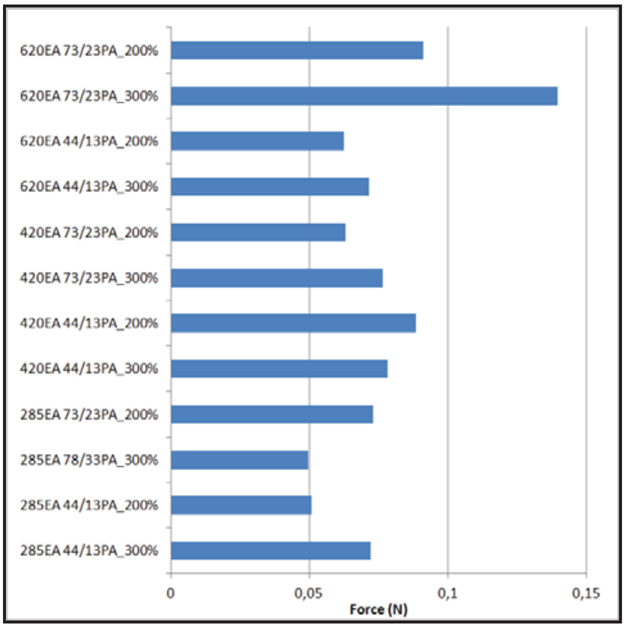


Fig.5 - Force at 30% extension

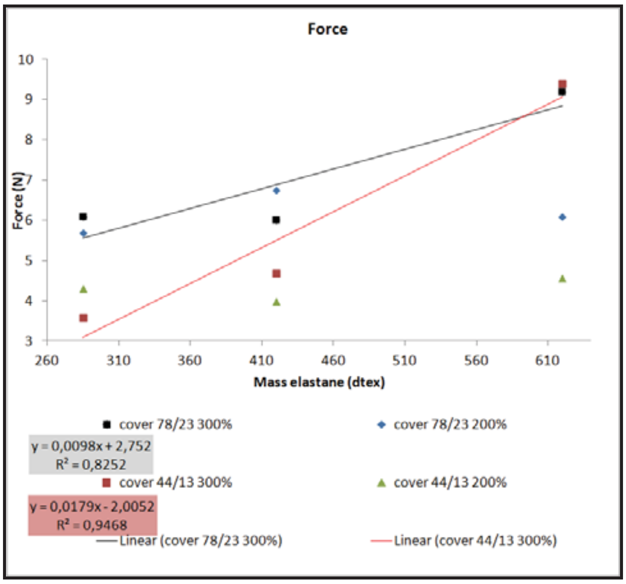


Fig. 6 - Influence of various paremeters on breaking force of elastane yarn

Fig. 6 presents the dependence of breaking force of elastane yarn on various parameters. It can be seen that the breaking force of elastane yarn tends to increase with the increase in linear density of core and cover as well as with draw ratio. The highest force was achieved in case of elastane yarn with 620 dtex core, 78/23 dtex cover and produced at 300% draw ratio.

3. Conclusions

The present study demonstrated that the mechanical behaviour of elastane yarn is strongly dependent on the structural and production parameters. The yarns produced using higher liner density core and cover and higher draw ratio during covering showed the highest breaking force and elongation. Therefore, it is extremely important to optimize these parameters of elastane yarns to achieve required properties for producing compression garments.

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