# Influence of Elastane Consumption on Plated Plain Knitted Fabric Characteristics

Saber Ben Abdessalem[1], Youssef Ben Abdelkader[2], Sofiene Mokhtar, Ph.D[1]., Saber Elmarzougui, Ph.D[1].

[1]Textile Research Unit of Technology High School of Ksar Hellal, Monastir, Tunisia

[2]National Engineering School of Monastir, Tunisia

Correspondence to:

Saber Ben Abdessalem, email: **saber_ba@yahoo.fr**

## ABSTRACT

The requirements in terms of wearing comfort with sportswear underwear and outerwear are widely linked to the use of elastane fibers. Today, elastomeric plated jersey fabric is one of the most common fabrics produced with large-diameter circular knitting machine (LCKM). However, the relation between elastane proportion and fabric characteristics has not been enough studied in literature and knitters generally use experience during machines adjustments in to order reach needed fabric characteristics. The aim of this paper was to investigate the relation between Lycra® consumption and fabric dimensional and elastic behavior. The obtained results showed that Lycra® proportion inside fabric has an incidence on fabric width, weight and elasticity. The origin of this behaviour has been discussed.

## INTRODUCTION

The wear comfort of underwear, outer clothing, leisurewear and sportswear is generally ensured by the use of knitted fabrics containing elastane fibers. Today, more and more articles including elastane yarn are available in the circular knit fabric collections. An important number of patents describing the design of new plated fabrics was registered during the last decades [1-4]

Elastane fibers are synthetic fibers made up of linear macromolecules of high molecular weight. The first process for the industrial-scale production of elastane fibers by dry spinning was developed in 1962 by J.C. Shevers and colleagues in the Pioneering Research Division of E.I. Du Pont de Nemours & Co., Inc. (U.S.A.). This multifilament has since been on the market under the name "Lycra". The outstanding property of elastanes is their very good stretch elasticity that can be as high as 500%, while the elastic recovery reaches 95%. In recent years the use of woven and knitted fabrics with elastane fibers has increased sharply. This is due in particular to the fact that these articles are characterized by excellent wear comfort and fit. The industry anticipates an annual increase of 8-10% for the coming years [5]. The elastanes are predominantly used in tights, underwear, swimwear and beachwear, sports articles, corsets and medical support stockings.

Elastanes are always processed with one or more other fibers and never individually. If bare elastane is processed to form a loop it must always be knitted together with a ground yarn. This measure is necessary because there is the risk that the elastane yarn may break if the knitted fabric is stretched too far. Blending elastane with native or man-made fibers is called plating. Plating means the simultaneous formation of one loop from two threads, so that one thread will lie on the face of the fabric while the other thread is fed to the needles in such a way that it forms the back or reverse of the final fabric. In the case of single-bed circular knitting machines elastane must always be fed in via a plating yarn guide. This guide presents generally a feeding roll permitting Lycra® guiding with minimum friction [6, 7]. Positive feed mechanisms where the unwinding elastane bobbin is driven have become the most common feed systems in large-diameter circular knitting when processing elastane yarn. The bobbin is driven positively in these delivery systems. After unwinding, the yarn passes through an electric stopping device and is then fed to the needle through the plating roll.

Elastane yarn proportion is one of the most important parameter of single jersey plated fabric. The proportion of elastane inside fabric influences fabric characteristics [7]. The adjustment of elastane proportion is obtained through the setting elastane delivery system speed. There is no rigorous physical law that enables to determine with precision the necessary elastane consumption for given fabric properties. The relation between elasthane proportion and fabric width, weight or elasticity is generally not well known. Most of knitters have to carry out some tests and adjust gradually knitting parameters in order to reach the needed elastane proportion and the right fabric properties. The obtained adjustments serves generally as a base for furthers settings.
In the literature, some studies aimed to conceive new plating devices or to design new plated fabrics [8, 9]. Other studies focused on the measurement of plated fabric properties such as elasticity and shrinkage before and after laundering [10]. Studies which specifically treat the relation between elastane proportion and plated fabric performances are extremely rare. Some researchs available in literature [11, 12] described the relation between the rate of elastane and some fabric properties such as extensibility and fatigue but they concerned only weaved fabrics made with Lycra® core-spun weft yarns. Cuden *et al.* [10] studied experimentally the evolution of the characteristics of Lycra® plated plain knitted fabric after finishing and relaxation but did not investigated the effect of elastane ratio on these characteristics.

The aims of this research were, therefore, to study the effect of elastane consumption on three main parameters of plated plain knitted fabric: width, weight and elasticity. This would help commercial knitter understand the relation between elastane proportion and fabric behaviour. The prediction of plated fabric properties according to the proportion of elastane inside fabric would permit to reduce machines adjustment duration.

**MATERIAL AND METHODS**

We produced a series of 5 cotton/Lycra® plated plain knitted fabrics commonly used in the clothing industry by using an industrial single jersey circular knitting machine (MV4-3.2 from Mayer & Cie, $Diameter = 30 inch, gauge = 28, total number of feeders = 96). Ground yarn was a 100% combed cotton yarn (Nm=60) and plating yarn was a 22 dtex Lycra® monofilament plated at every feeder by using a Memminger elastane feeder (MER) and a plating roll fixed on the ground yarn guide. The laying position is shown in *Figure 1*.

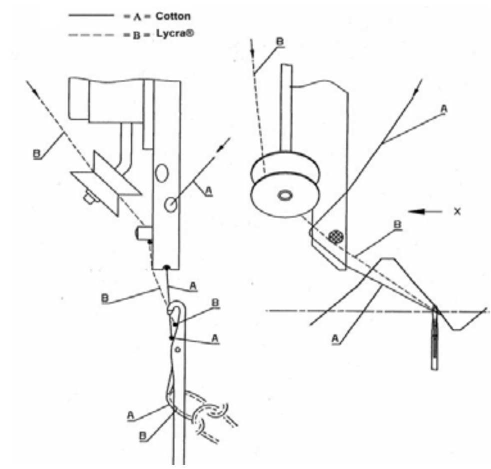


FIGURE 1. Ground and Lycra® yarns laying position in a roll plating yarn guide.

This kind of laying position should ensure the Lycra® yarn enters the hook first and keeps steady. Then, the cotton yarn enters the hook along with the closure of the needle latch. This guarantees that the yarn position remains steady, and decreases the misplating problems. Lycra® yarn appears therefore in the backside and cotton yarn in the front side of the plain knitted fabric as shown in *Figure 2*.

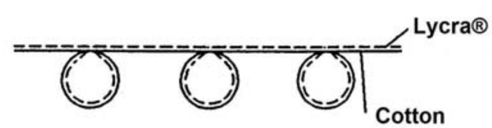


FIGURE 2. Lycra® plated plain knitted fabric pattern.

Lycra® yarn consumption was varied by varying elastane feeder speed. Lycra® consumption and tension were measured by using a yarn meter (MLT WESCO - MEMMINGER-IRO GmbH). Ground yarn consumption was kept constant at 31 cm/100 needles. Fabric width and weight were measured at different sites of the tubular fabric. All measurements were performed 24 hours after fabric knitting, in order to enable fabric to relax, under standard textile testing conditions of 21°C ± 1°C, and 65% ± 2% relative humidity. Seven specimens of each sample were tested and the mean values of width and weight were calculated.

The evaluation of elastic properties was performed 24 hours after knitting with a cyclic loading test by using a constant speed gradient dynamometer LRX

2.5 K (LLOYD, England) (300 $mm.min^{-1}$). The fabric sample (50x300 mm) is grabbed with two roll clamps that manufactured especially for knitted fabrics according to the French standard NF G 07-140 [13]. Theses clamps permit a soft grabbing of knitted fabric and avoid any sample rupture or weakness near the clamping area. Specimen loading starts by gradually increasing the load to 15N and then decreasing the load until load zero (*Figure 3*).

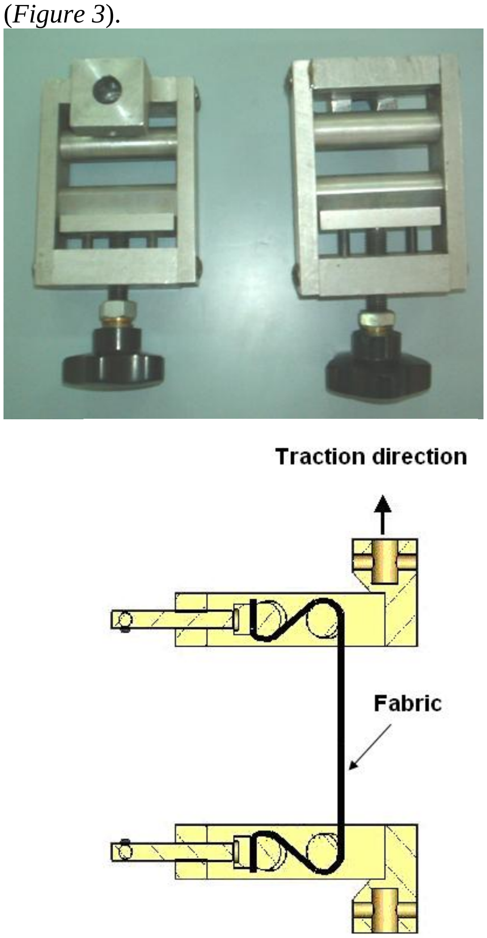


FIGURE 3. Cyclic loading roll clamps.

Loading was performed till the inelastic zone in order to examine fabric recovery. Preliminary load-elongation tests showed that 15 N is situated outside the elastic zone of all samples. Samples are testes in longitudinal (wale) and transversal (course) directions and cyclic loading curves are obtained (*Figure 4*).

Maximum elongation *ME* (at 15 N) and permanent elongation *PE* (at 0 N) are registered. Recovery ratio *RR* is then calculated as following:

$$RR(\%) = \frac{(ME - PE)}{PE}.100 \qquad (1)$$

**RESULTS AND DISCUSSION**

Fabric width, fabric weight and recovery ratios obtained with different Lycra® consumption levels are summarized in *Table I*.

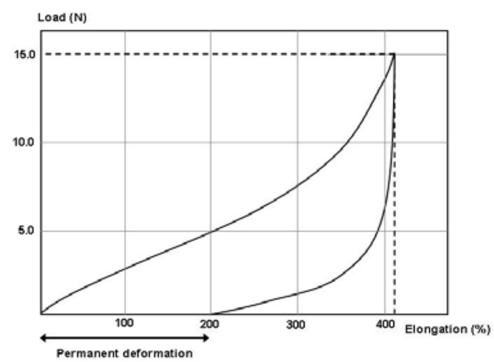


FIGURE 4. Fabric cyclic loading diagram.

TABLE I. Evolution of fabric characteristics with Lycra® consumption.

| Lycra® consumption (cm/100 needles) | Lycra® proportion (%) | Lycra® tension (cN) | Fabric width (cm) | Fabric weight ($gr/m^2$) | Longitudinal RR (%) | Transversal RR (%) |
|---|---|---|---|---|---|---|
| 10,1 | 4,12 | 6,3 | 157 | 182 | 45 | 50 |
| 10,4 | 4,24 | 4,4 | 161 | 178 | 52 | 60 |
| 10,45 | 4,26 | 4,3 | 162 | 177 | 55 | 62 |
| 10,6 | 4,32 | 3,1 | 166 | 175 | 58 | 65 |
| 10,7 | 4,36 | 2.1 | 168 | 172 | 62 | 70 |

*Figure 5* shows the evolution of fabric width with Lycra® consumption. It appears that fabric width increases almost linearly with Lycra® proportion in the fabric.

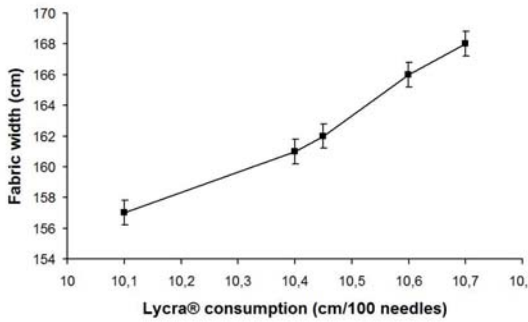


FIGURE 5. Evolution of fabric width with Lycra® consumption.

*Figure 6* shows that fabric weight decreases with the increase of Lycra® consumption. This can be explained by the fact that the decrease of Lycra® consumption involves an increase of Lycra® tension as can be seen in table 1.

Tension inside the elastomeric yarn makes stitch wales closer to each other and, consequently, fabric width is reduced and stitch density which is expressed by fabric weight increases.

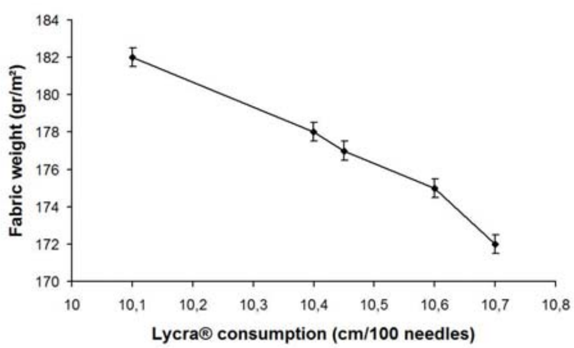


FIGURE 6. Evolution of fabric weight with Lycra® consumption.

Ground stitch dimensions (length and width) is widely liked to Lycra® tension of a yarn running into a large-diameter circular knitting machine because positive Lycra® yarn delivery takes place in such a way that exactly as much yarn is supplied as is consumed in the region of the knitting point. Ground yarn consumption is constant but stitch geometric configuration is modulated by the tension applied by the Lycra® plating yarn. Cuden *et al.* [10] observed stitch deformation of Lycra® plated plain knitted fabric during relaxation process. They concluded that the increase of fabric weight during relaxation is due to an increase of fabric wales and courses densities. Pusch *et al.* [14] proposed theoretical model showing the relationship between stitch length and yarn tension during knitting process. This model show that stitch length depend on delivered yarn length, yarn tension applied by needles and yarn elasticity module. Munden [15] led an experimental study showing that plain knitted fabric dimensions changes are due to loop's dimensions changes. Experimental observations by Doyle [16] confirmed the dependence of fabric dimensions on the loop's dimensions of plain knitted fabrics.

The knowledge of fabric width and weight dependence is of great interest for fine gauge fabric manufacturers. Fabric width has to be rigorously taken into account especially for edge seamless articles in which width tolerance is extremely limited. Fabric weight is one of the main fabric characteristics that determine fabric use. Area density is a basic parameter defining knitted fabric offer. Its specification is inseparably attached to the purchaser's order. Knitted fabric area density is determined by both yarn and knitted fabric parameters. To keep the area density in accordance with the order specification, knitting process parameters such as elastane yarn consumption and tension have to be adjusted.

*Figure 7* shows the evolution of longitudinal and transversal fabric recovery with Lycra® consumption. It appears clearly that fabric recovery increases in a linear manner in both directions when Lycra® consumption increases.

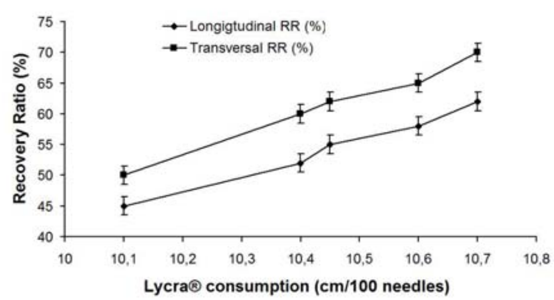


FIGURE 7. Evolution of recovery ratio with Lycra® consumption

The cyclic loading tests involved lengthening in the wale and course direction expressed by the permanent deformation depending on Lycra® proportion inside fabric. The final use of the knitted fabric is usually determined by its elastic properties. The residual extension depends on yarn composition and structure, knitted fabric structure and properties and tension. Elastic properties of knitwear, namely recovery have a noticeable impact on comfort, adding flexibility and freedom of movement. Gymnastics knitwear requires important recovery rates while for everyday garments, reasonable recovery levels are enough to add comfort.

Cyclic loading test is a dynamic test that simulates deformation applied on fabric during wearing. After elongation, spun yarns do not recover initial dimension. The partial recovery of the knitted fabric dimensions after cyclic loading can be explained by the hysteresis phenomenon of spun yarns. This recovery is incomplete depending on Lycra® proportion inside fabric. Recovery ratio is between 45 and 70% in longitudinal direction and between 45 and 62% in transversal direction. It is as important as Lycra® consumption is high. This can be explained by the fact that Lycra® yarn is knitted in the weft direction and consequently weft plated fabrics are naturally more elastic in the transversal direction. The increase of fabric recovery with Lycra® consumption is due to the increase of potential energy inside fabric that permits better recovery levels of fabric dimensions.

The permanent deformation obtained after loading test can be explained by plastic deformation due to spun yarn fibre slippage and/or fibre permanent extension because elastane yarn is purely elastic. Spun yarn Fibre slippage phenomenon depends on bending and torsion of the yarn, while fibre permanent extension depends on the fibre viscoelasticity. It would be very interesting to simulate spun yarn fibres slippage in the knitted yarns in order to predict without experiments permanent deformations due to fabric fatigue, but there is no suitable yarn bending model in the literature. One major reason is that the complicated movement of fibres in the spun yarn during bending deformation can not be simulated satisfactorily. Once this problem is solved, plated knitted fabric recovery could be predicted by starting with the fibre properties.

**CONCLUSION**

The results obtained in the present work indicated that the amount of elasthane has a significant effect on dimensional and elastic properties of cotton/Lycra® plated plain knitted fabric. Fabric width increases while fabric weight decreases with Lycra® consumption when using a large-diameter circular knitting machine with positive Lycra® yarn delivery. This phenomenon is linked to tension inside the elastomeric yarn and consequently to ground yarn stitch wales density. Cyclic loading test proved that fabric recovery increases with Lycra® proportion inside fabric. The partial recovery of the knitted fabric is due to hysteresis phenomenon of spun yarns having a plastic deformation behaviour linked to cotton fibre slippage and viscoelasticity.

Substantial theoretical study aiming to model the behaviour of fibre slippage and viscoelasticity in the yarn is necessary in order to understand hysteresis phenomena and to predict elastane plated knitted fabric behaviour from yarn and fibre properties.

**REFERENCES**

[1] Grunfeld, A. J., "Knit fabric with elastic combination yarn", US Patent 5198288, 1993.

[2] Bon M.,"Method for making patterned plated knit fabric", European Patent 1006822, 1998.

[3] Sangiacomo F., "Method for making patterned plated knit fabric", US Patent 6715325, 2004.

[4] Miller, R. A., Atkins, J. D., Rummel, D. R., " Cotton jersey fabric construction having improved stretch characteristics", US Patent 7040124, 2006.

[5] Pfangen, T., "Finishing of woven and knitted fabrics with elastane fibers", *Asian Textile Business*, 585, 2003, 46-51.

[6] Iyer, C., Mammel, B., Schach, W., "Circular Knitting", Meisenbach GmbH, Bamberg, Germany, ISBN 3-87525-066-4, 1995.

[7] "Dorlastan in circular knitting", Dorlastan product information technical report, Asahi Kasei Spandex Europe GmbH, Germany, 2008.

[8] Baozhu, K., Weiyuan, Z., "The optimal design of three-layer plated fabrics", *Fibres & Textiles in Eastern Europe*, 15, 2007, 59-61.

[9] Bruer, S. M., Powell, M., Smith, G., "Three-dimensionally knit spacer fabrics: a review of production techniques", *Journal of Textile and Apparel, Technology and Management*, 4, 2005, 1-31.

[10] Cuden, A. P., Srdjak, M., Pelko, H., "Optimization of the cotton/Lycra plain knitted

Fabric parameters", *International Journal of Polymeric Materials*, 47, 2000, 633 – 648.

[11] Özdil, N., "Stretch and Bagging Properties of Denim Fabrics Containing Different Rates of Elastane", *Fibres and Textiles in Eastern Europe*, 1, 2008, 63-67.

[12] Gorjanc, S., Bukosek V., "The behaviour of fabric with elastane yarn during stretching" , *Fibres and Textiles in Eastern Europe*, 3, 2008, 63-68.

[13] Ben Abdessalem, S., Elmarzougui,S. Sakli, F., "Dynamic fatigue of plain knitted fabric", *Journal of Textile and Apparel, Technology and Management*, 5, 2006, 1-10.

[14] Pusch, T., Wünsch I., Offermann P., "Dynamics of yarn tension on knitting machines", *AUTEX Research Journal*, 1, 2000, 55-63.

[15] Munden, D.L.,"The geometry and dimensional properties of plain-Knit fabrics", *Journal of The Textile Institute*, 50, 1959, 448-471.

[16] Doyle, P.J., Fundamental aspects of the design of knitted fabrics, *Journal of The Textile Institute*, 44, 1953, 561-578.

## AUTHORS ADDRESSES

**Saber Ben Abdessalem, Sofiene Mokhtar, Ph.D., Saber Elmarzougui, Ph.D.**

Technology High School of Ksar Hellal, Textile Research Unit, Tunisia
Avenue Hadj Ali Soua
Ksar Hellal, Monastir 5070
TUNISIA

**Youssef Ben Abdelkader**

National Engineering School of Monastir,
TUNISIA