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# Study of Specific Conditions to Control the Mechanical Behaviour of Dorlastan® Core Spun Yarn

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## Abstract

The mechanical properties of yarns play a phenomenal role in the quality of the end product. Studying these properties requires a specific test following international standards. As for elastic core spun yarn, knowledge of the mechanical behaviour is not obvious due to the absence of the specific condition. The aim of this study was to determine appropriate conditions to control the tenacity, elongation at break and elastic recovery of Dorlastan® core spun yarns of different linear densities (counts) (100, 50, 33.33 & 25 tex) and various elastane drafts. The results obtained show that the initial tension necessary to straighten elastic core spun yarns and eliminate their curling increases while the Dorlastan draft increases and, respectively, the Dorlastan ratios decreases. Furthermore we noted a decrease in tenacity and breaking elongation with a decrease in the dorlastan draft and, respectively, with an increase in Dorlastan ratios. On the other hand, we observed the decreasing trend of elastic recovery while the Dorlastan draft increases.

**Key words:** Dorlastan, initial tension, draft, ratio, mechanical behaviour.

Besides, Huseyin investigated the effect of spandex and yarn linear densities on the properties of elastic core-spun yarns produced on a Murata vortex spinner [6].

Moreover Merati studied the effect of filament pre-tension on the structural parameters and the mechanical properties of the core yarn [7].

Furthermore Miao and Horng studied the mechanical properties of elastic core-spun yarn in various processing conditions [3, 8].

There are many difficulties in studying the mechanical behaviour of elastic core spun yarn due to the absence of specific method control. Obtaining reproducible results with weak errors is the most important difficulty that can be found. Thus the first part of this work details appropriate conditions needed to control the mechanical properties of Dorlastan core spun yarns. In the second part, a study of the mechanical properties of Dorlastan core spun yarns is carried out on the basis of the test conditions obtained.

## Experimental details

### Materials and method

Dorlastan® filaments used in this study were elastane filaments produced by Bayer Faser GmbH (Germany) and by Dorlastan Fibers LLC (Germany).

The Dorlastan® filament is characterised by very good extensibility that ranges between 400 and 550%. However, it presents poor tenacity, hence it is necessary

to cover elastane filaments with other staple fibers. In this study, we were interested in cotton covered Dorlastan core spun yarn. The cotton properties used in this work are presented in **Table 1**.

In this work, composite yarn with elastane is produced by the core spinning method, allowing the automatic insertion of the elastane with different percentages.

The elastane draft is determined as follows [11]

$$D_{elastane} = \frac{t_{elastane}}{T_{yarn}} \times R \quad (1)$$

where  $T_{yarn}$ ,  $t_{elastane}$ , are, respectively, the yarn linear density, in tex and elastane linear density, in dtex, and  $R$  is the fixed ratio of elastane filament in the yarn, %.

In this study, elastane core spun yarns with different linear densities of 100, 50, 33.33 and 25 tex and the same twist factor, equal to 138, were produced. These yarns were employed as weft yarns in denim fabrics.

In this study, we used Dorlastan of 156, 78 and 44 dtex linear densities, respectively, for yarn linear densities 100, 50, 33.33 and 25 tex, designated as 100/156, 50/78, 33/44, 33/78 & 25/44.

**Table 1.** Cotton fibre properties.

Characteristic	Mean value
Micronaire, µg/inch	4.06
Maturity	0.90
UHML, mm	29.67
Tenacity, cN/tex	29.26
Elongation, %	8.36

## Introduction

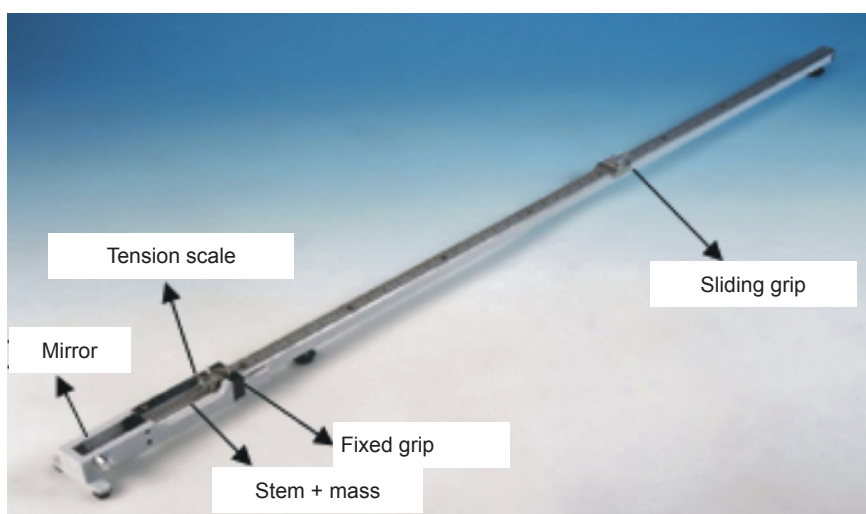
Elastic core spun yarns are widely used in manufacturing textile products, and such textiles have been well received by the market as they present good moisture absorption when natural fibers cover the outer layer and are very comfortable to wear. Moreover, elastane filaments used as the core improve the yarn's elasticity to fit different end-products.

Schwarz, Schneider, Horng Lin and Motte have presented various methods of producing elastic core spun yarn [1 - 4].

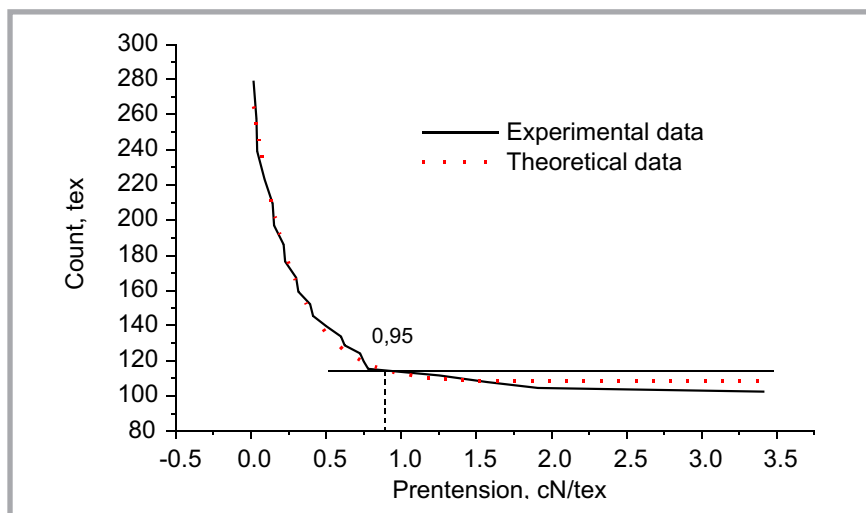
Studies of the mechanical properties of elastic core spun yarn are limited; however, we would like to note the study of the impact of the elastane ratio on the mechanical properties of cotton wrapped elastane core spun yarns carried out by Babay [5].

**Table 2.** Different ratio and draft values used.

Yarn linear density, tex	100									
Dorlastan® linear density, dtex	156									
Ratio, %	4.0	4.5	5.0	5.5	6.0	6.5	7.0	7.5	8.0	8.8
Draft	3.90	3.47	3.12	2.84	2.60	2.40	2.23	2.08	1.95	
Yarn linear density, tex	50									
Dorlastan® linear density, dtex	78									
Ratio, %	4.0	4.5	5.0	5.5	6.0	6.5	7.0	7.5	8.0	
Draft	3.90	3.47	3.12	2.84	2.60	2.40	2.23	2.08	1.95	
Yarn linear density, tex	33.33									
Dorlastan® linear density, dtex	44					78				
Ratio, %	4.0	4.5	5.0	5.5	6.0	6.5	7.0	7.5	8.0	
Draft	3.30	2.93	2.64	2.40	3.90	3.60	3.34	3.12	2.93	
Yarn linear density, tex	25									
Dorlastan® linear density, dtex	44									
Ratio, %	4.0	4.5	5.0	5.5	6.0	6.5	7.0	7.5	8.0	
Draft	4.40	3.91	3.52	3.20	2.93	2.71	2.51	2.35	2.20	



**Figure 1.** Device of determination of the pre-tension.



**Figure 2.** Determination of the pretension value for a length yarn equal to 5 cm.

The elastane draft and ratio values for the different yarns are given in **Table 2**.

In this study, tensile tests were conducted with a dynamometer of the type LLOYD,

controlled by software NEXYGEN version 5.0. Tests were performed in a conditioned atmosphere of  $20 \pm 2$  °C and  $65 \pm 2\%$  RH according to French Standard NF G00 003 [9]. Considering the

great dispersion of results, for each test we used a sample size of 50 specimens. We chose a sample gauge length of 500 mm, as specified in French Standard NFG 07-002 for the control of yarns [10]. The extension rates used in this work were  $20 \pm 3$  seconds of breakage time, as recommended by French Standard NFG 07-002 [10].

### Initial tension determination

Many standards have been established to control the properties of conventional yarn, open-end yarn, and textured yarn etc. But there is no standard for testing the mechanical behaviour of elastic core spun yarn. That is why we intended, in this work, to define a general procedure that can be used for Elastane® core spun yarns to control their mechanical properties correctly.

Moreover we sought abacuses giving the variation in the initial tension value in relation to the yarn linear density and Elastane® draft or ratios, which would make it easy to search for the initial tension values for given Elastane® core spun yarns.

In order to determine the initial tension values, we used a CRIMP TESTER device (**Figure 1**).

During the conditioning, we created a specimen of different lengths for different yarn linear density and for different Dorlastan® ratios. The test-piece was fixed between the two grips without any load.

Afterwards it was extended by moving the sliding grip with a step equal to 1 cm until reaching the maximum elongation allowed by the crimp tester (120 cm). For each elongation, we noted the load value given by the tension scale in gf (re-calculated in cN). In this way we got the range of elongation and tension. Then we plotted a curve giving the variation in the linear density in tex as a function of the initial tension values in cN/tex, as shown in **Figure 2**.

The function obtained can be approximated to the exponential one:

$$Y(x) = y_0 + A_1 \exp(-x/t_1) \quad (2)$$

where  $y_0$  and  $t_1$  are constants.

For all the yarns and all lengths studied, we have chosen to draw the equation straight:

$$Y(x) = y_0 (1 + 5\%) \quad (3)$$

The intersection between the equation straight  $Y(x) = y_0 (1 + 5\%)$  and the curve corresponds to the initial tension value.

This method is applied to the different lengths and for each yarn type. In this way, the initial tension range is reached.

Then the average of the initial tension values obtained for the different lengths is calculated. The mean value corresponds to the initial tension value necessary to eliminate the curl of the corresponding Dorlastan® core spun yarn.

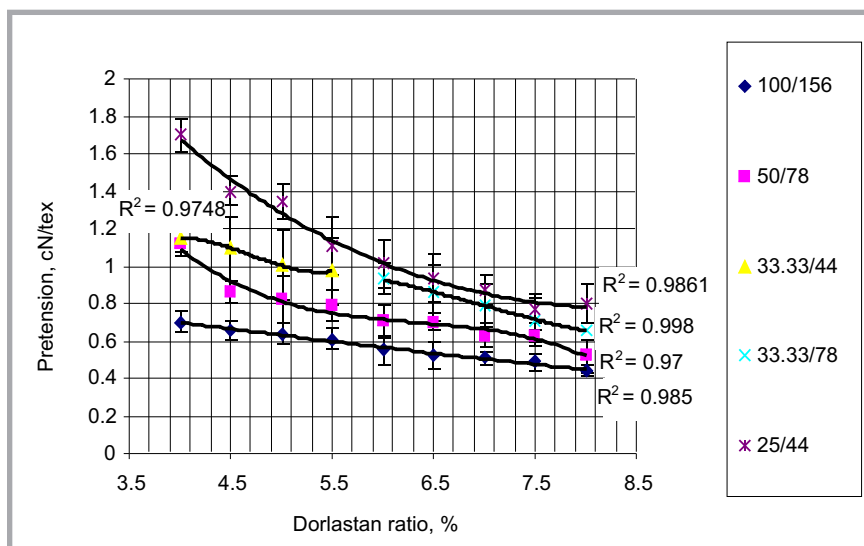
This test was conducted for different yarns and for their various Dorlastan® ratios. **Figure 2** shows the way to determine the pre-tension value in cN/tex for the yarn 100/156 with 5% of Dorlastan®.

### ■ Results and discussion

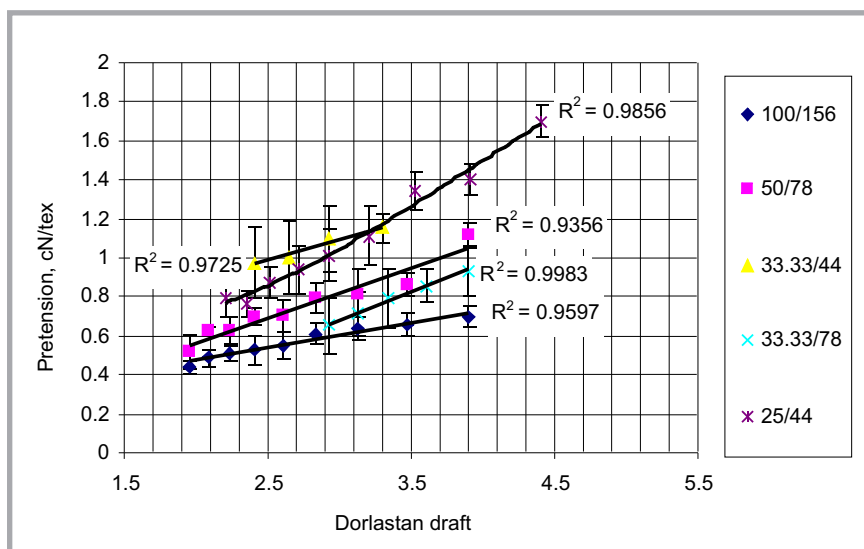
Experimental tests were carried out to determine the range of initial tension values necessary to deploy the elastic core spun yarn. Representations of the initial tension according to the Dorlastan ratio and Dorlastan draft for each yarn are given in **Figures 3** and **4**.

In this research, we noted, starting from **Figures 3** and **4**, the decreasing trend of the core-yarn's initial tension while the Dorlastan ratio increases and, respectively, the Dorlastan draft decreases for different yarns: 100/156, 50/78, 33/44, 33/78 and 25/44.

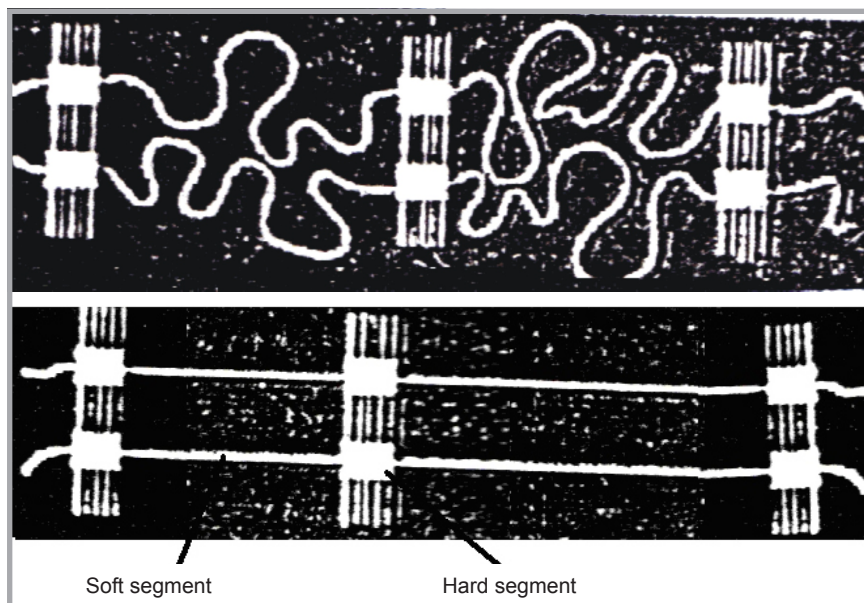
This may be explained by the fact that the more Dorlastan draft there is, the less the wrapping fiber compactness is, as explained in an earlier paper [5] and, consequently, the easiness of the curling of the core spun yarn. Furthermore the soft segment presented in the structure of the Dorlastan filament (cf. **Figure 5**) participates in the curling of the core spun yarn; in fact, Dorlastan filament composed of hard and soft segments. Under tension, the filament is much extended, and if we eliminate the tension, the soft segments curl; this phenomenon becomes more accentuated when the tension becomes more significant. Thus the core contributes much to elastic core spun yarn curling.



**Figure 3.** Pretension values of the four yarns versus the Dorlastan® ratio.



**Figure 4.** Pretension values of the four yarns versus the Dorlastan® draft.



**Figure 5.** Soft and hard segments of elastane structure (a) relaxed, (b) extended [11].

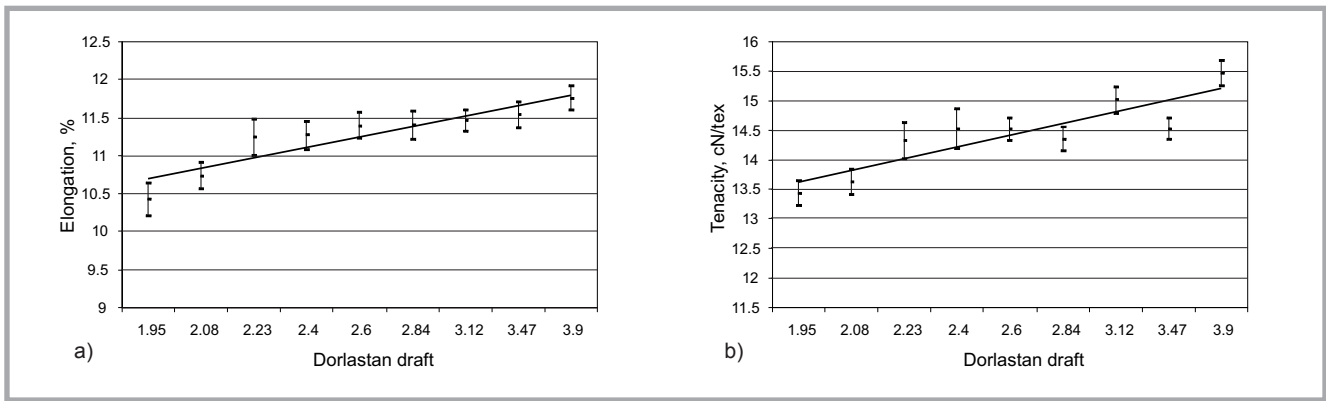


Figure 6. Variation in elongation at break (a) and tenacity (b) versus Dorlastan draft for 100/156 yarn.

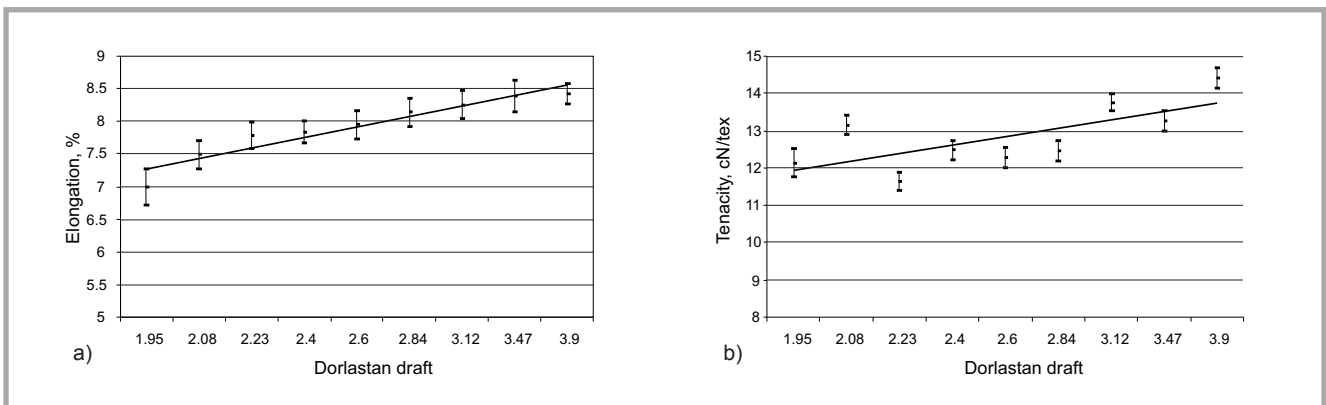


Figure 7. Variation in elongation at break (a) and tenacity (b) versus Dorlastan draft for 50/78 yarn.

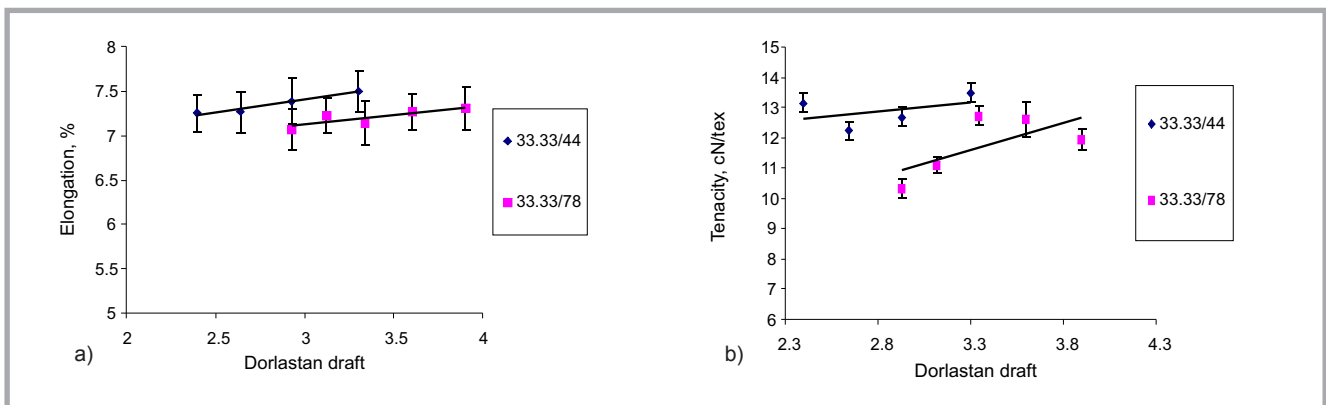


Figure 8. Variation in elongation at break (a) and tenacity (b) versus Dorlastan draft for yarns 33.33 tex/44 dtex and 33.33 tex/78 dtex.

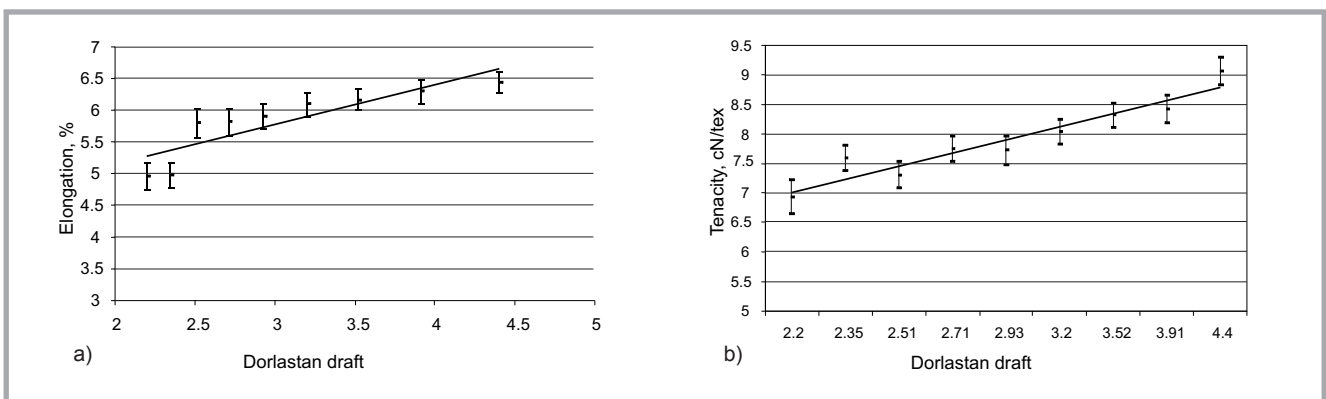


Figure 9. Variation in elongation at break (a) and tenacity (b) versus Dorlastan draft for 25 tex/44 dtex yarn.



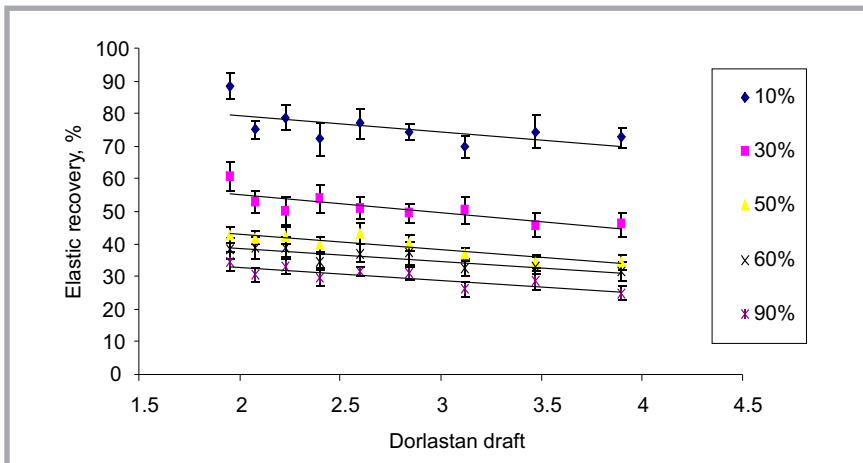


Figure 10. Elastic recovery versus Dorlastan draft for different extension ratios for yarn 50 tex/156 dtex.

Table 3. *p* value of variance analyses; \* Statistically significant at  $\alpha = 0.05$ .

Parameters	Initial tension	Tenacity	Extension	Elastic recovery
Yarn linear density, tex	0.000*	0.000*	0.000*	-
Dorlastan draft	0.000*	0.041*	0.000*	0.000*
Dorlastan linear density, dtex	0.000*	0.132	0.534	-
Extension ratio, %	-	-	-	0.011*

In addition, we noted, starting from these figures and according to the high determination coefficients  $R^2$ , that the decreasing trend of the initial tension versus the Dorlastan ratio and consequently the increasing trend of the initial tension versus the Dorlastan draft are clearly established.

Moreover, Figures 3 and 4 show that initial tension curves are located in a descending order according to the decrease in the elastic core spun yarn linear density, except for yarn linear density 33.33 tex. Indeed, Figure 4 shows that for the same Dorlastan® linear density (ie. 78 dtex or 44 dtex), the initial tension curves of yarn 33.33 tex/44 dtex and yarn 33.33 tex/78 dtex are located at the top of the initial tension curves, respectively, of yarns 25 tex/44 dtex and 50 tex/78 dtex. This phenomenon can be explained by the fact that finer yarns (ie. 25 tex/44 dtex) have a more significant tendency to be curled than coarser ones (ie. 100 tex/156 dtex) and for a higher Dorlastan draft. This needed a more significant initial tension value to eliminate the curling, which can be due to the less important quantity of fibres which wraps the Dorlastan filament in the fine yarn, and consequently the Dorlastan filament does not find much difficulty to retract and curl. On the other hand, as well as for coarser yarn, the quantity of fibres which wraps the core of Dorlastan is greater, and consequently the curling

will be a little blocked by these fibres, except for yarn linear density 33.33 tex, for which we noted a higher initial tension value for the yarn with a lower Dorlastan linear density (44 dtex). Thus the insertion of the Dorlastan with greater drawing in fine yarn generates more accentuated curling of these yarns.

As regards the confidence interval of the results found, we can state that the tests were carried out under good conditions resulting in few errors. Also the values of coefficient  $R^2 \approx 0.9$  imply that the tendency of the curves is well established.

#### Mechanical behaviour in tensile test

The tensile test is one of the more important tests used to study the mechanical behaviour of materials. Thus the tenacity and elongation at break are the very important properties to control. These properties also influence the mechanical behaviour of the fabrics.

Figures 6 - 9 present the variation in tenacity and elongation at break versus the Dorlastan draft for different yarns. These results are the average of 50 tests, presented with their confidence intervals.

As seen in Figures 6 - 9, the elastic core-spun yarns with a lower Dorlastan draft had lower tenacities and elongations at break than elastic core spun yarns with a higher Dorlastan draft.

This can be attributed to the fact that most of the loading stress in the core-spun yarns is taken up by the more extensible part. Furthermore when a lower Dorlastan draft is used, there must be fewer interfibers and less cotton Dorlastan cohesion. Supporting this assumption, we found that the tenacity and breaking elongation of the elastic core-spun yarns increased with an increased Dorlastan draft, and the elastic part of the Dorlastan core-spun yarns contributed much to the yarn stretch and strength.

#### Effect of the Dorlastan draft on elastic recovery

In this experiment, extension-cycle tests of Dorlastan core spun yarns were conducted. We applied an imposed extension equal to 10, 30, 50, 60 and 90% of the elongation at break to Dorlastan core spun yarn 50/156 for five tensile cycles, then we calculated the elastic recovery, defined as the following equation:

$$ER = EE/TE \times 100 \text{ in } \% \quad (4)$$

where:  $ER$  - elastic recovery,  $EE$  - elastic extension,  $TE$  - total extension.

Figure 10 shows the evolution of the elastic recovery values as a function of the Dorlastan draft for different extension percentages for 50 tex/156 dtex.

As shown, we can notice the growing trend of the elastic recovery when the deformation imposed decreases. This is because high values of deformation were chosen from the viscoelastic and plastic zone of the tensile curves. For these two zones the permanent extension is very high, and consequently the elastic recovery is very weak. Also when the extension ratio increases, the plastic extension increases, the elastic extension decreases, and consequently the elastic recovery decreases.

Moreover we notice a decreasing trend in the elastic recovery when the Dorlastan draft increases; consequently, the Dorlastan ratio decreases. This can be explained by the fact that after repeated application of stress, core spun yarn with a higher Dorlastan draft loses elasticity more than core spun yarn with a more important Dorlastan draft.

#### Variance analysis

In order to determine whether the effects of the Dorlastan draft, yarn linear density and Dorlastan linear density on the ini-

tial tension, tenacity, extension and elastic recovery are statistically important or not, univariate variance analysis was carried out, related p values of which are given in **Table 3**.

As can be seen from **Table 3**, the effect of the Dorlastan draft, yarn and Dorlastan linear density on the initial tension values are statistically significant at a 95% significant level. Moreover we note that the effect of the Dorlastan draft and yarn linear density on the tenacity and extension values are significant, but that of the Dorlastan linear density is not significant for tenacity and extension values.

In addition, we note the effect of the Dorlastan draft and extension ratio on the elastic recovery of elastic core spun yarns.

## ■ Conclusions

It is difficult to conduct a tensile test and cyclic test correctly and to study the mechanical behaviour of elastic core spun yarn accurately due to the absence of specific conditions of control.

For this reason, we determined abacuses of determination of the initial tension necessary to deploy yarns of different linear density (100, 50, 33.33 and 25 tex) and for various Dorlastan drawings and to eliminate their curling. We note that the more the Dorlastan draft increases, the more the preload is important. Moreover finer yarns require more important initial tension values, except for yarn lin-

ear density 33.33 tex with a lower Dorlastan linear density.

The growing trend in mechanical properties such as tenacity and elongation at break when the Dorlastan draft increases confirm that the Dorlastan draft and, consequently, the Dorlastan ratio had a significant effect on the mechanical behaviour of the elastic core spun yarns.

The experimental results revealed that elastic core spun yarns produced with a higher Dorlastan draft showed higher tenacity and breaking elongation values than that produced with a lower Dorlastan draft. Furthermore we note that the mechanical properties were conducted under good conditions.

Moreover this study indicates that the Dorlastan draft has an appreciable effect on the elastic recovery of elastic core spun yarn. In fact, the elastic recovery decreases when the Dorlastan draft increases.

In conclusion, the Dorlastan draft is one of the most important parameters that can influence the tenacity, elongation at break and elastic recovery of elastic core spun yarns.

The study of the influence of the elastane draft on elastic core spun yarn will be pursued to determine an optimal Dorlastan draft leading to the best elastic recovery of the yarn.

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