International Journal of Progressive Sciences and Technologies (IJPSAT)
ISSN: 2509-0119.

Vol. 40 No. 2 September 2023, pp. 343-359

Evolution Of The Dimensional Stability Of Cotton/Lycras Fabric

Dr. RAVONISON Elie Rijatiana Hervé[1], RAOELISON Barimino[2], Pr. RAKOTOSAONA Rijalalaina[3]

[1]Institute of Higher Education Antsirabe Vakinakaratra (IESAV)
University of Antananarivo
Antsirabe, Madagascar
elie.ravonison@gmail.com

[2]SOCOTA quality laboratory
Antsirabe 110, Madagascar
barimino.qualite@ctn.socota.com

[3]Polytechnical High school of Antananarivo
IMMP Materials Laboratory
University of Antananarivo
Antananarivo, Madagascar
rijalalaina.rakoto@gmail.com

Abstract— In this article, we study the evolution of the dimensional stability of fabrics containing spandex fiber. Indeed, a good quality fabric depends on its dimensional stability after washing and drying. The fabric that constitutes it has to respect the standards imposed in terms of size in order to the garment does not shrink too much or stretching too much. The fabric containing spandex often encounters problems in respecting dimensional standards, hence the interest of this article. During the fabric manufacturing process, the evolution of the dimensional stability after each step will be presented to have a better appreciation of the fabric's regulator. A modeling of the dimensional stability which is a function of the total width of the fabric after each treatment was carried out.

Keywords— dimensional stability, spandex, shrinkage, elongation, width.

I. INTRODUCTION

Human beings have always sought to dress for well-being but also for comfort. The fabric manufacturing process is vast and ancestral, but with the evolution of technical and technologies, customers have specific and precise needs in terms of fabric quality.

One of the main parameters that warrant the quality of the fabrics delivered to customers is respecting for the dimensional stability of the fabrics. The fabric should not reweave too much or stretch too much after washing and drying. As for as parameters are respected, the fabric has a lifespan in accordance with the standards.

This article then focuses on the evolution of the dimensional stability of the fabric during the key manufacturing processes in order to see its behavior after each stage. In that case, we were interested in the manufacturing process of the fabric containing lycras, which is a fabric that is difficult to control.

II. DIMENSIONAL STABILITY ASSESSMENT METHOD

A. Fabric processing steps

To meet the needs of customers, the textile industries carry out fabric treatment technical, whether mechanical or chemical, so that the fabrics have touch and remain dimensionally stable.

Our study is focused on the behavior of fabrics in terms of dimensional stability upstream and downstream of the three treatments which are: washing, thermo-fixation, sanforizing.

• Sanforizing is a mechanical treatment process for fabrics whose purpose is to improve the chain shrinkage of the fabric and make it more compact. The process involves forcing the threads together so that the fabric becomes thicker and heavier. Figure 1 [1] illustrates the impact of sanforizing on a fabric.

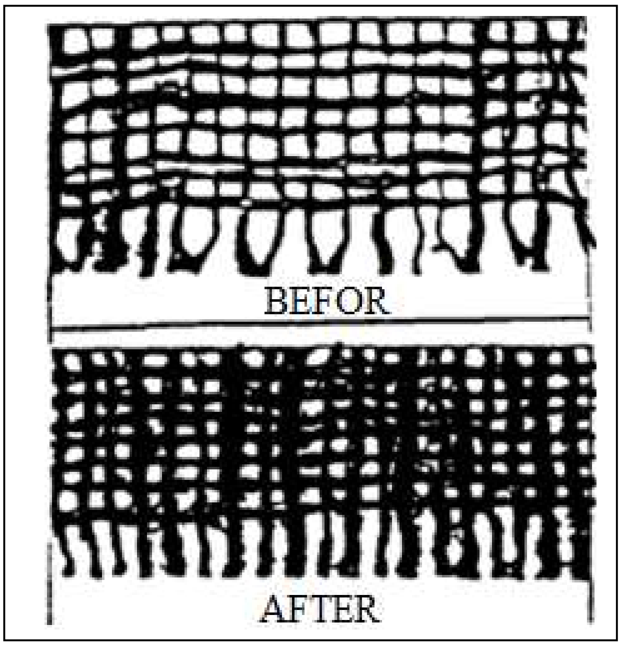

Fig. 1. Preview of a fabric after sanforizing

- Thermo-setting: this treatment also consists of improving the dimensional stability of fabrics, especially those containing thermoplastic fibres. The principle consists of passing the fabric through a heating zone for a determined time and temperature which resets the morphology memory of the thermoplastic fiber. This new state relieves the stresses and strains imparted to the fiber through the yarns and weaving. For synthetic fibres, heat setting has several objectives, namely:

➢ Optimization of primers for cleaning treatments

Reduced pilling

➢ Increases crease or crease retention

➢ Modifies the structure of synthetic fibers by the action of high heat

➢ Adoption of new cooling fiber structure.

- Washing which consists of cleaning additive residues and dirt caused by elements outside the operations..

*B. **Sampling and measurement***

To have a good appreciation of the measurement of dimensional stability, it is essential to follow the sampling standards. In fact, there are 3 steps:

- The sample of the fabric must have a dimension of 500 mm * 500 mm
- The marking for the measurement of shrinkage or elongation represents a dimension of 350 mm * 350 mm of the sample, i.e. an offset of 75 mm on each side of the sample.
- The edges of the fabric sample must be sewn to have a better result.

A test sample of dimensions 500mm *500mm should have three pairs of reference points which are made in each direction on the fabric at a distance of 350mm and placed 75mm from the edge as shown in Figure 2.

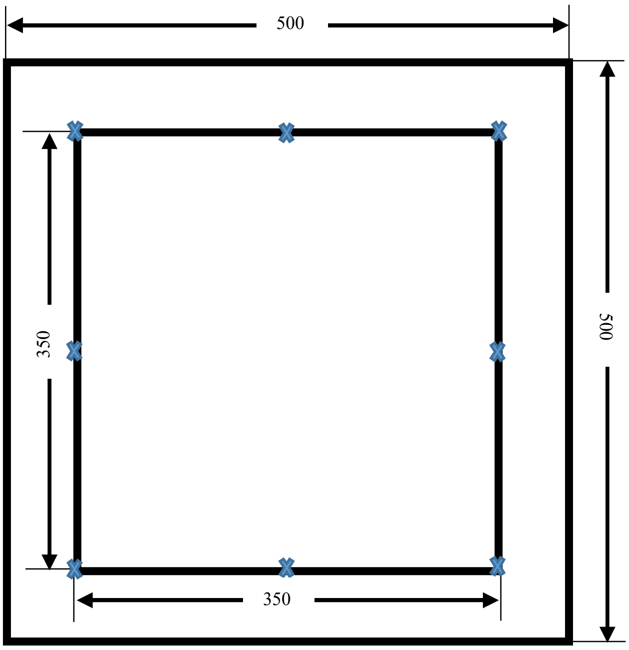

Fig. 2. Tissue sampling

C. **Washing and drying condition**

The washing condition adopted during the tests is set by the ISO 6330 standard. This standard sets the washing parameters such as: the rinsing and its number of repetitions; the washing time, if there is cooling after washing, the spin time, the washing temperature, the level of liquor used during washing and rinsing...

During our study, the washer that we used is the "Wascator" machine, which is an industrial washing machine commonly used for tests and which is programmable according to the needs and the desired parameters. In our case, the washing was done with the 4N program in which main parameters are illustrated in Table 1:

TABLE I. WASH PARAMETER – PROCEDURE 4N

Washing	**Temp a [°C]**	**40±3**
	Liquor level b c [mm]	***100***
	Wash time d [min]	***15***
	Cool down f	***No***
Rinse 1	***Liquor level b c [mm]***	***130***

	Rinse time d g [min]	***3***
Rinse 2	***Liquor level b c [mm]***	***130***
	Rinse time d g [min]	***3***
	Spin time d [min]	***-***
Rinse 3	***Liquor level b c [mm]***	***130***
	Rinse time d g [min]	***2***
	Spin time d [min]	***-***
Rinse 4	***Liquor level b c [mm]***	***130***
	Rinse time e g [min]	***2***
	Spin time d [min]	***5***

- N: Normal agitation: 12 s drum movement and 3 s static.
- a: Main wash temperature refers to the heating switch-off temperature.
- b: Liquor level is measured from the bottom of the cage after the machine has been run for 1 min and allowed to stand for 30 s.
- c: For type A1 machines use volume measurement for better accuracy
- d: The stated times may have a tolerance of 20 s
- e: No agitation during heating up to set temperature -5°C. From the set temperature of -5°C to the set temperature, agitate with gentle action.
- f: cool down: top up with cold water to 130 mm level and agitate for a further 2 min.
- g: Rinse time is measured when liquor level is reached.

Drying is carried out on a standard dryer machine with a nominal temperature of 60°C for a time of 70 minutes.

D. Calculation of dimensional stability

The dimensional stability of fabrics represents its ability to keep its dimensions which are likely to stretch or shrink after washing. There are two main methods to define dimensional stability:

- Using the formula:

$$Average\ \%\ DC = \frac{(B-A)}{A} * 100 \qquad (1)$$

- DC : Average dimensional change
- A : Average original dimension
- B: Average dimension after laundering

- Use of a template with markings called shrinkage rule which defines shrinkage or elongation according to ISO 3759.2008.

III. Presentation Of The Fabric

The fabric studied in this work is a cotton/lycra based fabric. Currently lycra is the best solution to have a combination between a chemically polyurethane fiber and natural fibers such as cotton, wool, silk. Lycra-based fabrics are generally used for making indoor and outdoor clothing, but also for sportswear. Lycra is always mixed with other natural or artificial fibers, it has the characteristic of being light compared to rubber thread and its advantage and that it does not break down when exposed to perspiration, oil, lotions or body washes. The most widely used blend for the textile and knitting industries is the cotton/Lycra blend.

The fabrics studied in this work are made of 97% cotton and 3% elastane, with a density of 245 g/m^2 and a useful width of 150 cm. The fabric is made with a TWILL 3-1 weave. The warp threads have the metric number 50p 100% cotton and the weft threads is 34E whose composition is 93% cotton and 7% lycra. The characteristics of the warp yarn is shown in Table 2 :

TABLE II. CHARACTERISTIC OF WARP YARN.

Metric number	***50P***
CV	***1,58***
finesse	***0***
size	***2***
NEPS	***40***
Imperfection	***42***
Irregularity	***9,32***
RKM	***17,19***
CV (RKM)	***7,71***
Elongation	***4,62***
CV (Elongation)	***7,93***
IP	***5,46***

Table 3 illustrates the technical characteristics of the weft yarn:

TABLE III. CHARACTERISTIC OF WARP YARN

Metric number	***34E***
CV	***1,7***
finesse	***0***
size	***7***
NEPS	***7***
Imperfection	***14***
Irregularity	***8,87***
RKM	***15,37***
CV (RKM)	***8,4***
Elongation	***7,87***
CV (Elongation)	***8,93***
IP	***6,69***

- CV : Coefficient of variation
- RKM : Mileage resistance
- IP : hairiness value

IV. Presentation of the results

During this work, 20 fabrics with the same basic characteristics are sampled upstream and downstream of the target treatments for the measurement of dimensional stability.

E. Dimensional stability before sanforizing

1) Chain dimensional stability :

Figure 3 represents the chain dimensional stability (D.S) of the fabrics before the sanforizing treatment:

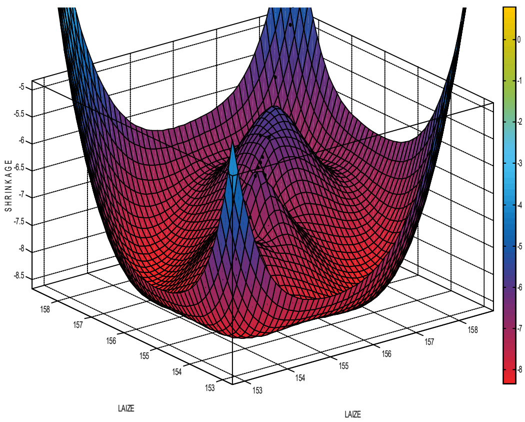

Fig. 3. Dimensional stability in chain before sanforizing

With this curve we obtain the dimensional stability equation according to the total width of the fabrics. This equation has for expression:

$$DS_C(x) = -2\sqrt{10} + \frac{1}{2}\sin\left(\frac{\pi^2}{5}x^2\right) + \frac{9}{10}e^{-(0,3x)^2} \qquad (2)$$

Hence the simplified curve of the D.S is illustrated in Figure 4:

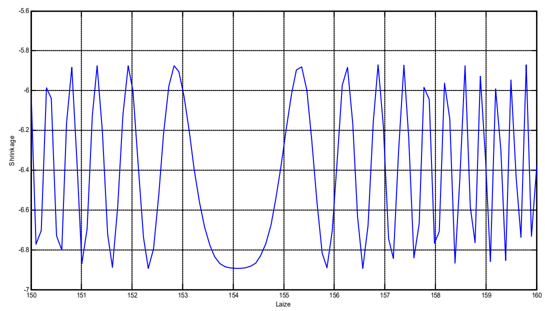

Fig. 4. Simplified curve of the D.S in chain before sanforizing

The dimensional stability equation (2) shown on the curve in figure 4 has an absolute uncertainty $\Delta DS = 1{,}4\ cm$ and a relative uncertainty $\frac{\Delta DS}{DS} = 17.8\%$

2) **Dimensional stability in Weft:**

Looking at the weft side of the fabric, Figure 5 depicts its dimensional stability:

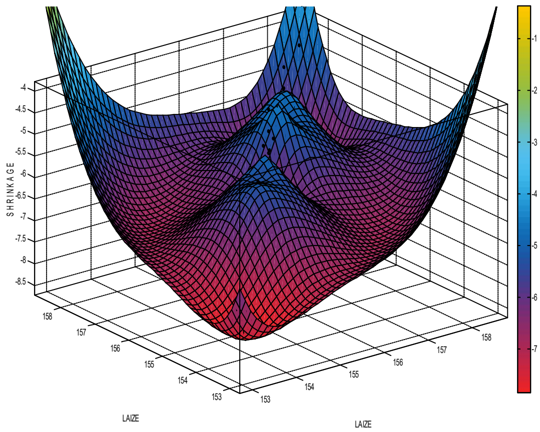

Fig. 5. Dimensional stability in weft before sanforizing

Based on this curve and considering the dimensions between the useful width and the total width, the weft dimensional stability equation before sanforizing has the expression:

$$DS_w(x) = -\frac{11}{2} + \frac{1}{4}\sin\left(\frac{2\pi^2}{11}x^2\right) + \frac{2}{11}e^{-\left(\frac{4x}{5}\right)^2} \quad (3)$$

Then, this equation gives us the shape of the curve representative of the dimensional stability in the weft before sanforizing:

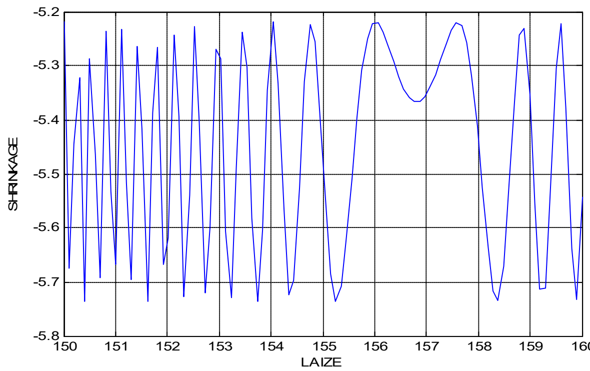

Fig. 6. Simplified curve of the D.S in weft before sanforizing

The dimensional stability equation (3) shown on the curve in figure 6 has an absolute uncertainty $\Delta DS = 1{,}35\ cm$ and a relative uncertainty $\frac{\Delta DS}{DS} = 19.4\%$.

F. **Dimensional stability after sanforizing**

1) **Chain dimensional stability**

After the sanforizing operation, the curve representative of the dimensional stability of the tissues is illustrated in figure 7:

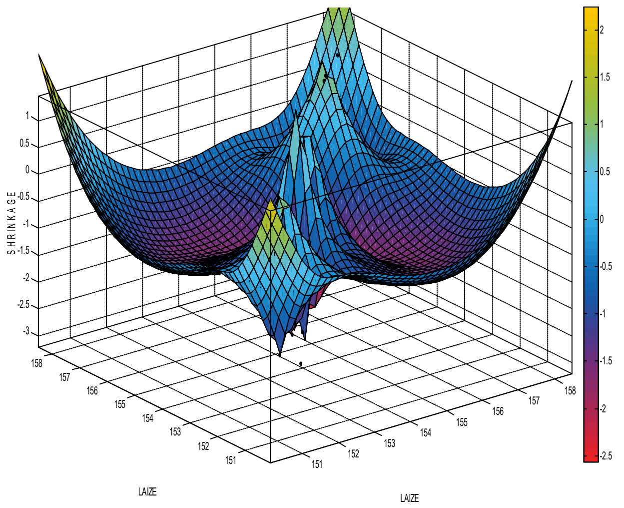

Fig. 7. Chain dimensional stability after sanforizing

The linear interpolation of figure 7 gives us the expression of the chain dimensional stability equation of the fabric as:

$$DS_C(x) = -\frac{2}{3} + \frac{1}{2}\sin\left(\frac{\pi}{2}x^2\right) + \frac{\sqrt{10}}{5}e^{-\left(\frac{3x}{5}\right)^2} \quad (4)$$

The representative curve of equation 4 is shown in figure 8:

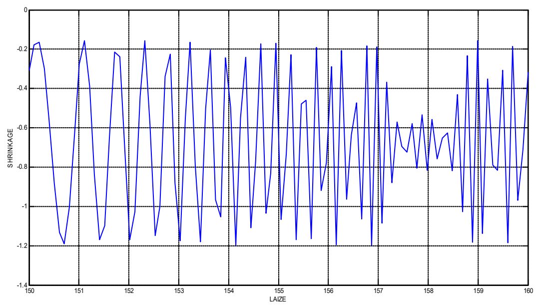

Fig. 8. Simplified curve of D.S in chain after sanforizing

The dimensional stability equation (4) shown on the curve in figure 8 has an absolute uncertainty $\Delta DS = 0{,}52\ cm$ and a relative uncertainty $\frac{\Delta DS}{DS} = 35.18\%$

2) **Dimensional stability in weft**

On the weft of the fabric, the dimensional stability after sanforizing is illustrated in figure 9:

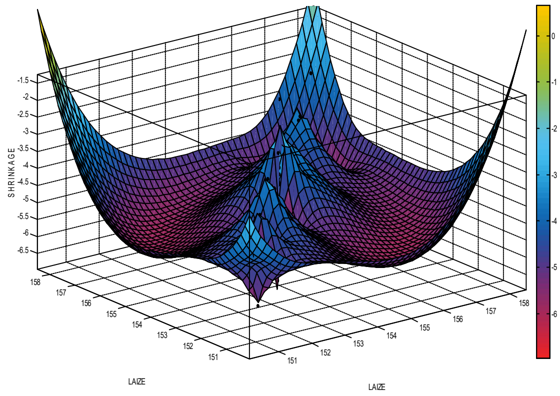

Fig. 9.Dimensional stability in weft after sanforizing

Equation 5 reflects the weft dimensional stability of the fabric after the sanforizing operation:

$$DS_w(x) = -\frac{43}{10} + \frac{3}{10}\sin\left(\frac{\pi^2}{4}x^2\right) + \frac{10\sqrt{3}}{23}e^{-\left(\frac{4x}{9}\right)^2} \tag{5}$$

Hence the curve representing the equation which is given by curve 19:

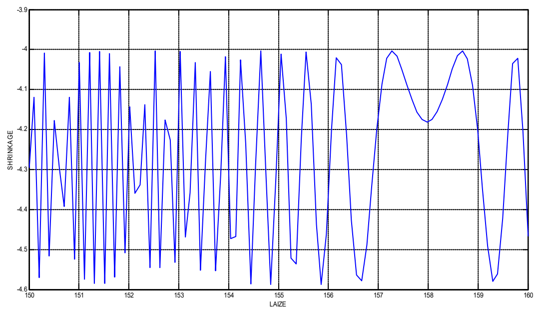

Fig. 10. Simplified curve of the D.S in weft after sanforizing

The dimensional stability equation (5) shown on the curve in figure 10 has an absolute uncertainty $\Delta DS = 0{,}55\ cm$ and a relative uncertainty $\frac{\Delta DS}{DS} = 13.63\%$.

G. **Dimensional stability after heat setting**

1) **Chain dimensional stability**

After the heat fixing operation, the curve representation of the chain dimensional stability is illustrated in figure 11:

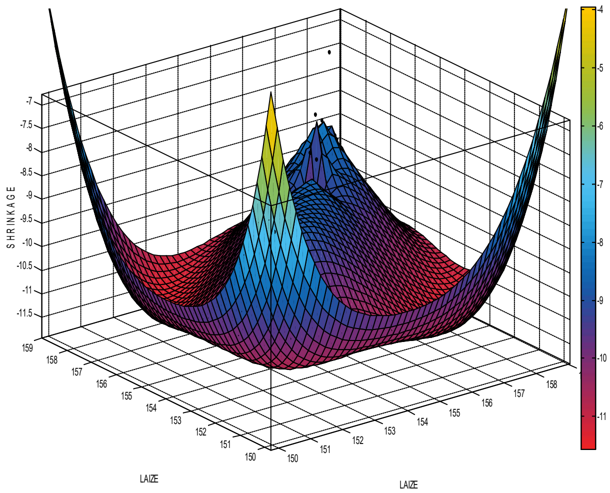

Fig. 11. Chain dimensional stability after heat setting

The interpolation of curve 11 gives us the chain dimensional stability equation after thermosetting which is given by equation 6:

$$DS_C(x) = -9 + \frac{11}{20}\sin\left(\frac{6\pi^2}{19}x^2\right) + \frac{1}{6}e^{-\left(\frac{31x}{42}\right)^2} \quad (6)$$

From where we obtain the curve representative of equation 6:

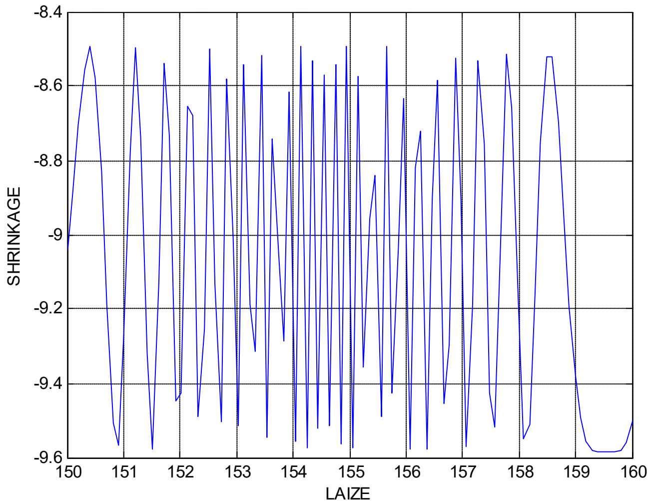

Fig. 12. Simplified curve of the D.S in chain after thermo fixing

The dimensional stability equation (6) shown on the curve in figure 12 has an absolute uncertainty $\Delta DS = 0{,}27\ cm$ and a relative uncertainty $\frac{\Delta DS}{DS} = 4.53\%$.

2) **Dimensional stability in weft**

On the weft part of the fabric, the dimensional stability is shown in Figure 13:

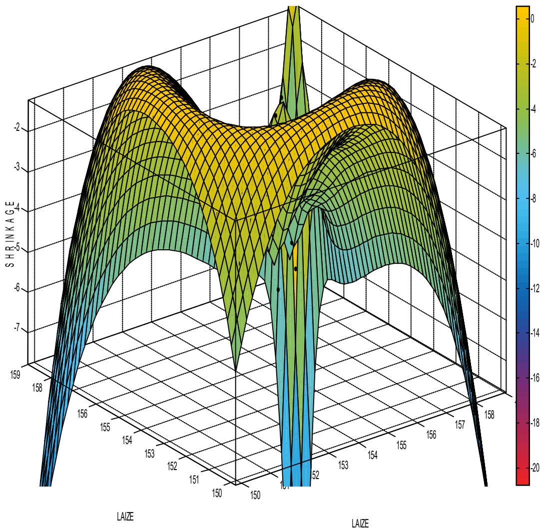

Fig. 13. Dimensional stability in weft after heat setting

Based on Figure 13, the equation that defines the weft dimensional stability of the fabric after heat setting is given by Equation 7:

$$DS_w(x) = -\frac{43}{11} + \frac{7}{8}\sin\left(\frac{4\pi^2}{13}x^2\right) + \frac{4}{25}e^{-\left(\frac{24x}{25}\right)^2} \quad (7)$$

From which we obtain figure 14 which represents the weft dimensional stability of the fabric after heat fixing:

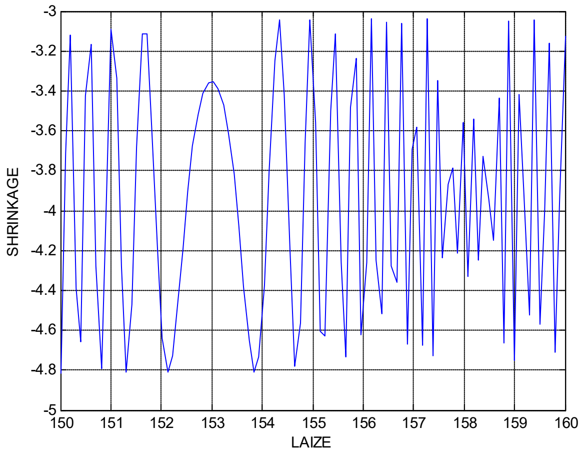

Fig. 14. Simplified curve of the D.S in weft after thermo fixing

The dimensional stability equation (7) shown on the curve in figure 14 has an absolute uncertainty $\Delta DS = 0{,}75\ cm$ and a relative uncertainty $\frac{\Delta DS}{DS} = 14.97\%$.

H. **Dimensional stability after washing 7**

1) **Chain dimensional stability**

During our study, we considered a washing operation which is performed on washer 7. The figure below illustrates the dimensional stability after this operation:

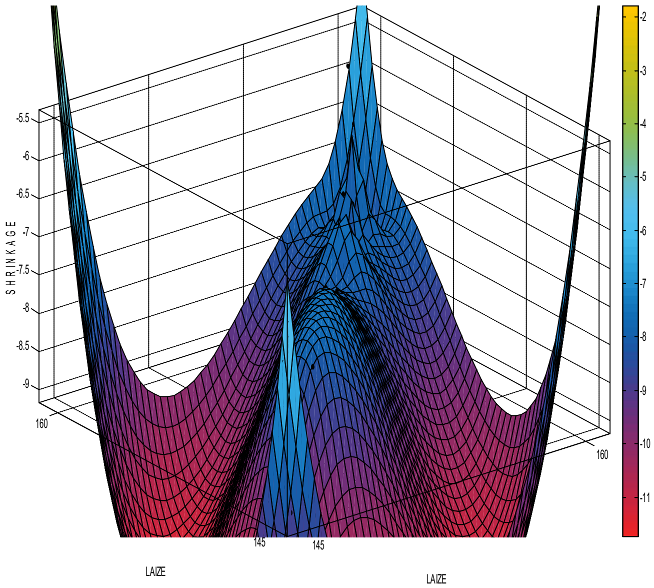

Fig. 15. Dimensional stability in chain after washer 7

By interpolation of Figure 15, equation 8 represents the chain dimensional stability of the fabric as a function of the width:

$$DS_C(x) = -\frac{39}{5} + \frac{\sqrt{3}}{7}\sin\left(\frac{4\pi^2}{13}x^2\right) + \frac{11}{25}e^{-\left(\frac{9x}{11}\right)^2} \qquad (8)$$

Figure 16 then illustrates the curve representative of equation 8:

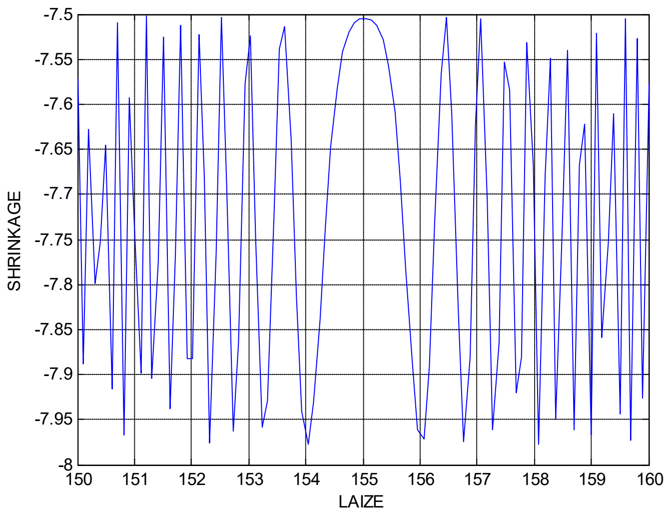

Fig. 16. Simplified curve of the D.S in chain after washer 7

The dimensional stability equation (8) shown on the curve in figure 16 has an absolute uncertainty $\Delta DS = 1{,}15\ cm$ and a relative uncertainty $\frac{\Delta DS}{DS} = 12.78\%$.

2) Dimensional stability in weft

Figure 17 gives us the weft dimensional stability after washer:

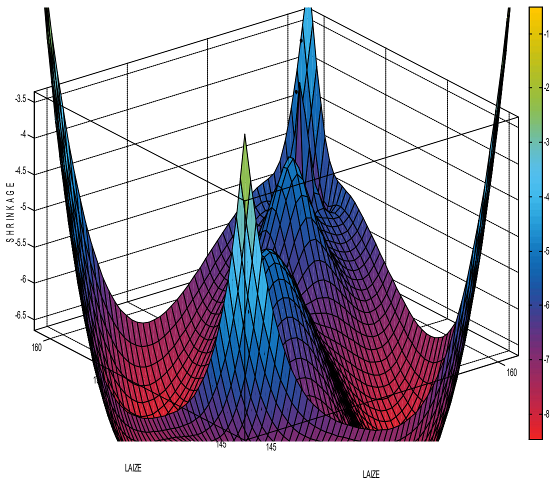

Fig. 17. Dimensional stability in weft after washing 7

Equation 9 represents the dimensional stability of weft fabrics after the washing operation:

$$DS_w(x) = -\frac{17\sqrt{5}}{7} + \frac{8}{21}\sin\left(\frac{7\pi}{10}x^2\right) + \frac{2\sqrt{10}}{7}e^{-\left(\frac{6x}{7}\right)^2} \tag{9}$$

So, we obtain the curve representative of equation 9 which is illustrated in figure 18:

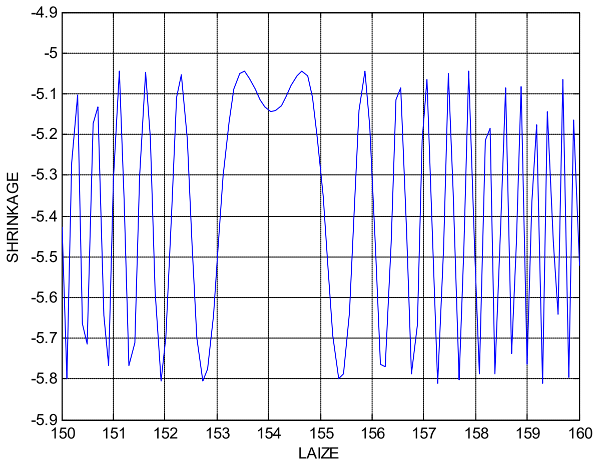

Fig. 18. Simplified curve of the D.S in weft after washer 7

The dimensional stability equation (9) shown on the curve in figure 18 has an absolute uncertainty $\Delta DS = 0{,}96\ cm$ and a relative uncertainty $\frac{\Delta DS}{DS} = 15.92\%$

I. Dimensional stability after sorting

1) Chain dimensional stability

Before being delivered to the customer, the fabrics are checked, and sorted. Therefore, Figure 19 gives us the chain dimensional stability of the tissues after sorting:

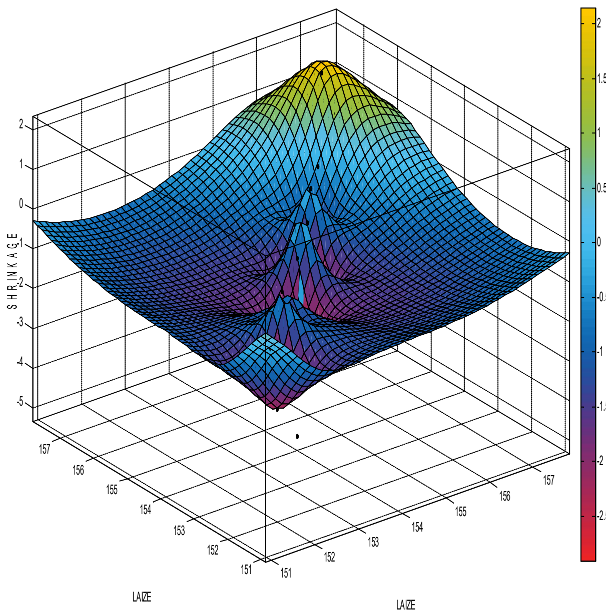

Fig. 19. Dimensional stability in chain after sorting

Considering the total width of the fabrics, equation 10 represents the dimensional stability which is a function of this width:

$$DS_C(x) = -\frac{\sqrt{6}}{2} + \frac{3}{4}\sin\left(\frac{\pi^2}{4}x^2\right) + \frac{7}{8}e^{-\left(\frac{\sqrt{7}x}{5}\right)^2} \tag{10}$$

From where we obtain the curve representative of equation 10:

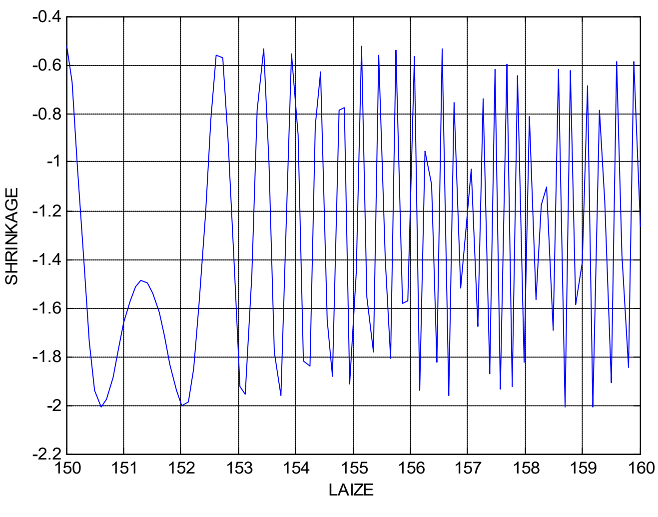

Fig. 20. Simplified curve of the D.S in chain after sorting

The dimensional stability equation (10) shown on the curve in figure 20 has an absolute uncertainty $\Delta DS = 0{,}59\ cm$ and a relative uncertainty $\frac{\Delta DS}{DS} = 34.37\%$

2) **Dimensional stability in weft**

Weft dimensional stability of fabrics after sorting is shown in Figure 21 :

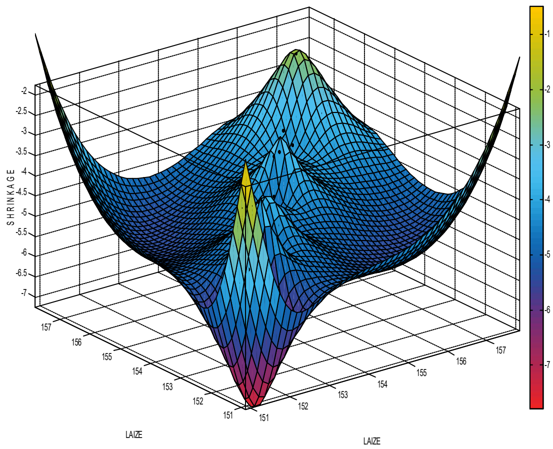

Fig. 21. Dimensional stability in weft after sorting

The weft dimensional stability after sorting as a function of the total width of the fabric is given by equation 11:

$$DS_w(x) = -3\sqrt{2} + \frac{4}{25}\sin\left(\frac{\pi^2}{17}x^2\right) + \frac{\sqrt{10}}{4}e^{-\left(\frac{\sqrt{6}x}{5}\right)^2} \tag{11}$$

From this equation, the characteristic curve of weft dimensional stability after sorting results:

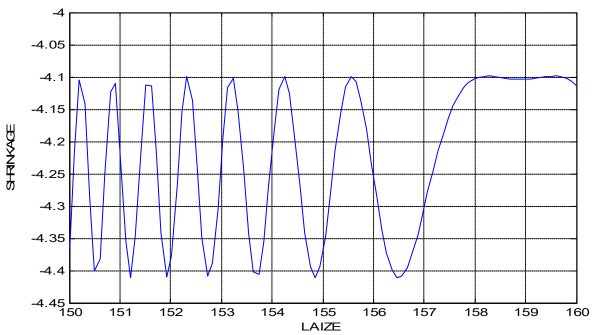

Fig. 22. Simplified curve of the D.S in weft after soting

The dimensional stability equation (11) shown on the curve in figure 22 has an absolute uncertainty $\Delta DS = 0.90\ cm$ and a relative uncertainty $\frac{\Delta DS}{DS} = 17.9\%$.

J. **Evolution of the dimensional stability of tissues**

1) **Evolution of chain dimensional stability**

Figure 23 shows the evolution of the chain dimensional stability of the fabrics during the treatment processes studied:

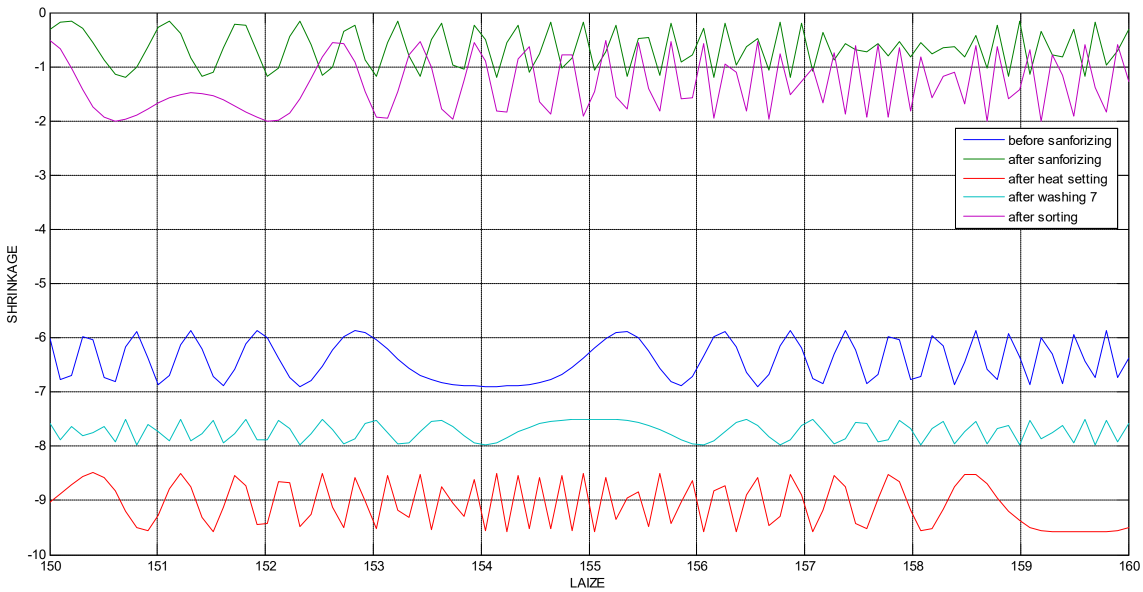

Fig. 23. Evolution of chain dimensional stability

According to the evolution shown in Figure 23, we can see that the dimensional stability of the warp side of the fabrics is negative after sorting, with an average value DS=-1.17 cm so the fabrics tend to shrink which is acceptable and responds to the standard imposed by the market

2) Evolution of weft dimensional stability

The evolution of weft dimensional stability during fabric processing processes is shown in Figure 24:

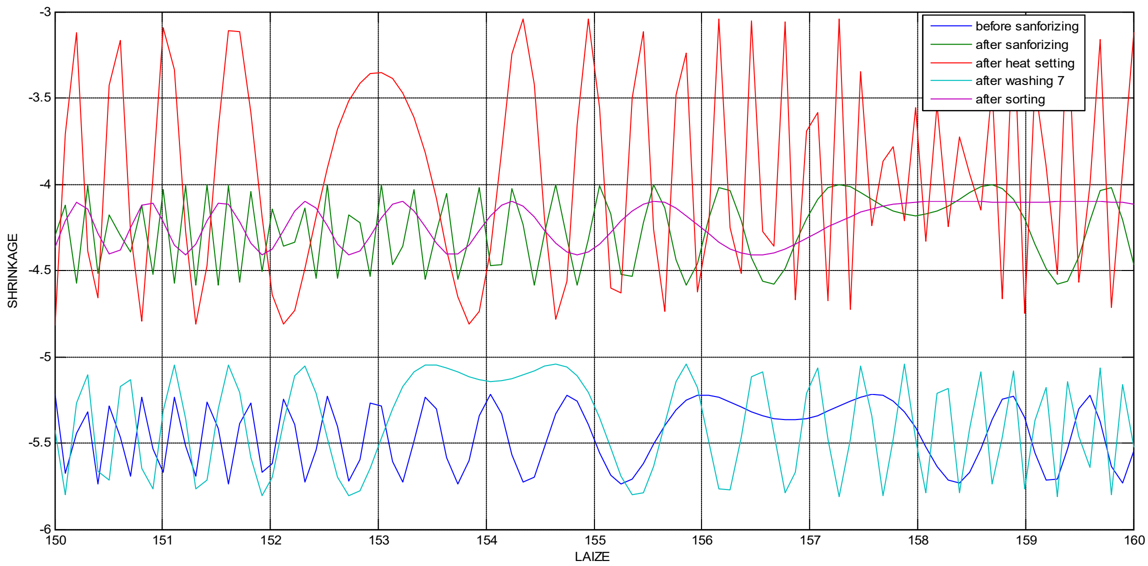

Fig. 24. Evolution of dimensional stability in weft

Based on Figure 24, which illustrates the evolution of dimensional stability on the weft side of the fabrics, we can see that the fabrics are progressing in quality in spite of the treatments carried out. Before sanforizing it has an average value which is -5.5

and after sorting its value is -4. Therefore, the fabrics delivered to the customer and placed on the market meet the standard and shrink after washing.

V. Conclusion and perspectives

This article presents the evolution of the dimensional stability of Lycra-based fabrics for certain treatment and operation during the manufacturing of the fabrics. The results obtained by this work is beneficial for industries as well as customers because it brings a new vision and a better appreciation of the quality of fabrics in terms of dimensional stability.

The modeling carried out in this work offers a general view of the dimensional stability upstream and downstream of each treatment, and provides a reference on the subject. Generally, fabrics delivered to customers have negative dimensional stability.

In perspective, a better appreciation of the relationship between the technical parameters of the yarns constituting the fabrics and its impacts on the dimensional stability will be interesting.

References

[1] Pietro Bellini, Ferruccio Bonetti, Ester Franzetti, Guiseppe Rosace, Sergio Vago, Textile Reference book of finishing

[2] Physical testing of textiles,B P Saville, The Textile Institute, CRC Press, Boca Raton Boston New York Washington, DC, Cambridge England

[3] Tests results registration book, lab-Rb, 002-14, SOCOTA.