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Impacts Of Yarn Characteristics On The Dimensional Stability Of A Fabric

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Abstract— This article illustrates the impact of the constituent filament characteristics of a fabric on the fabric's dimensional stability. Among these characteristics there is the tensile strength of the yarns, the elongation, the kilometric resistance, the actual metric number of the yarn and the hairiness index. To do this, evaluations of the dimensional stability of the fabrics as a function of these various parameters were experimented and then modeled in the form of an equation in order to have a better appreciation of the variation in shrinkage or elongation of the fabric in relation to the parameters mentioned previously. The experimental study was carried out with four (04) different fabric samples in order to better understanding the behavior of fabrics depending on these constituent yarns. Each model is presented with the respective relative and absolute errors.

Keywords— Dimensional Stability, Yarns, Modeling, Fabric, Shrinkage.

I. Introduction

The dimensional stability of a fabric is one of the parameters guaranteeing the quality of fabrics, this parameter can be improved or degraded by several parameters and conditions. Among these conditions there are the fabric treatment processes, the washing and drying methods but one of the fundamental points is above all the yarns constituting the fabric.

The yarns constituted of various fibers, of multiple nature and origin, in which the yarn characteristics are essentially based on the trials and tests to which they are subjected. Among these tests we can determine its kilometric resistance, its elongation, its tensile resistance, its hairiness index as well as its real metric number.

Therefore, the objective of this article is to determine the impact of these yarn characteristics on the dimensional stability of a fabric. To do this, two experiments were carried out separately, the first consisted to determine the characteristics of the constituent yarns of the fabric and the second aim is to determine the dimensional stability of the fabric.

II. Dimensional Stability Methodology

2.1. Principle of sampling and measurement

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

- The fabric sample should have a dimension of 500 mm * 500 mm
- The marking for measuring shrinkage or elongation represents a dimension of 350 mm * 350mm 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 for 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 1.

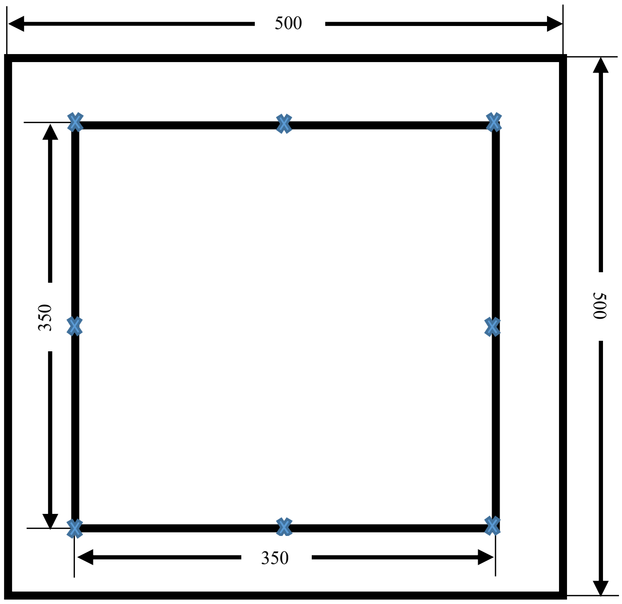

Fig. 1. tissue sampling

2.2. 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, it 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.

2.3. 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 aim of this work is to determine the effects of the characteristics of the yarns constituting the fabrics on its dimensional stability. During our experiments, we took a cotton-based fabric which is composed of 55% cotton and 45% linen. The yarns are similar in terms of warps and wefts. The weight of the fabric is 125 g/m^2.

Several factors impact the dimensional stability of a fabric, but during this work we are mainly interested in the influences of specific yarn characteristics (such as kilometric resistance, elongation, tensile strength, index of hairiness and the actual metric number) on the dimensional stability of a fabric.

TABLE I. . OVERALL CHARACTERISTIC OF THE CONSTITUTING YARNS OF FABRICS

Settings	***Chain yarns***	***Weft yarns***
Metric number	***34***	***34***
Coefficient of variation	***2,06***	***2,06***
Yarn density [/cm]	***22,5***	***19***
Imperfection	***2308***	***2308***
Spinning system	***Card***	***Card***

IV. PRESENTATION OF THE RESULTS

In this work, the aim is to understand the correlation between the technical characteristics of the constituent yarns of the fabrics and the dimensional stability of the fabric. In that case, we tested batches of yarn for making a fabric and then after making, we measured the dimensional stability. The results presented in this work show the general relationships between dimensional stability and yarnline characteristics.

4.1. Impact of yarn resistance on dimensional stability

Yarn strength refers to the tensile strength of the yarn, it is defined by the maximum force that can be applied to the yarn until it breaks. Generally, its unit is centimeter Newton but in our case, the values obtained are in gram-force [gF].

4.1.1. Relationship between resistance and dimensional stability on the warp part of the fabric:

Figure 2 illustrates the relationship between the useful width of the fabric, the strength of the yarn and the stability in the warp part of the fabric:

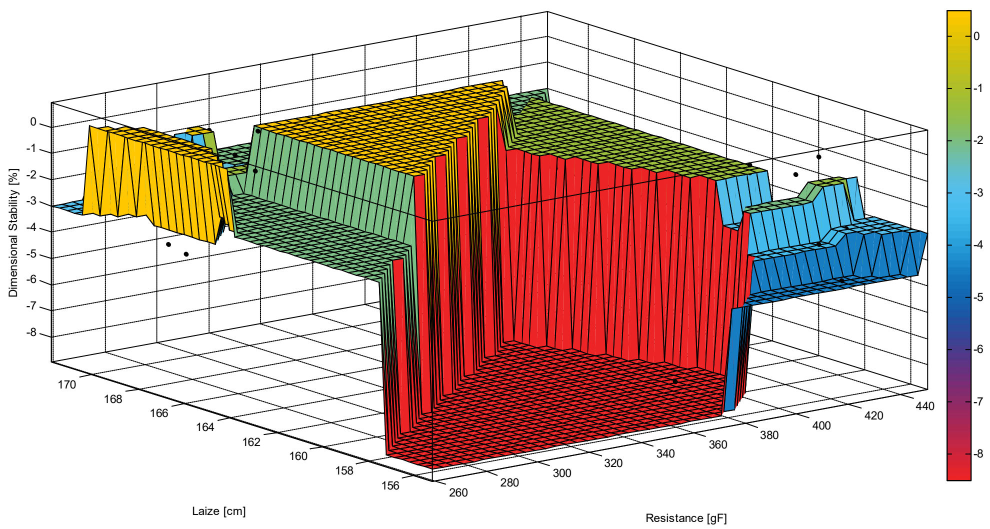

Fig. 2. Dimensional stability in warp depending on width and resistance

We notice that the fabric tends to shrink since the dimensional stability values are generally negative. The more the resistance increases, the more the fabric tends to shrink.

By removing the variable which corresponds to the useful width of the fabric, we obtain the relationship between the resistance and the dimensional stability of the fabric which is given by equation 2:

$$DS(x) = -2{,}54 + 0{,}55 \sin\left(\frac{\pi}{4}x^2\right) + 0{,}97e^{-(0{,}6x)^2} \qquad (2)$$

x: represents the resistance in [gF]

DS(x) : warp dimensional stability of the fabric [%]

The characteristic curve of this equation is given by the Figure 3 below:

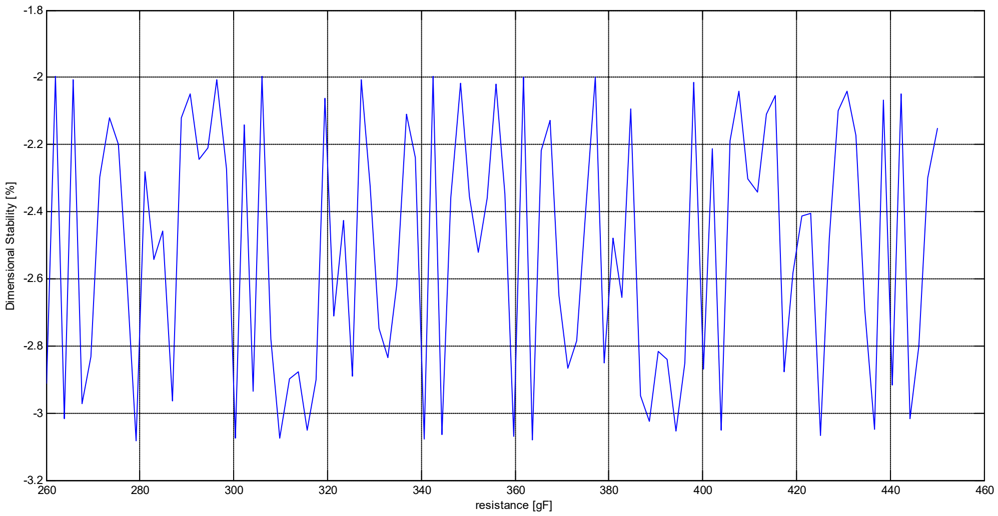

Fig. 3. Warp dimensional stability as a function of resistance

The precision of equation (2) which illustrates the dimensional stability of the fabric as a function of the resistance of the yarns is illustrated by the errors in which values are:

- Absolute error : $\Delta DS = 0{,}31\ [\%]$
- Relative error : $\frac{\Delta DS}{DS} = 11{,}77\%$

4.1.2. Relationship between resistance and dimensional stability on the weft part of the fabric:

The relationship between the effective width of the fabric, the strength of the yarn and the stability in the weft part of the fabric is presented in Figure 3:

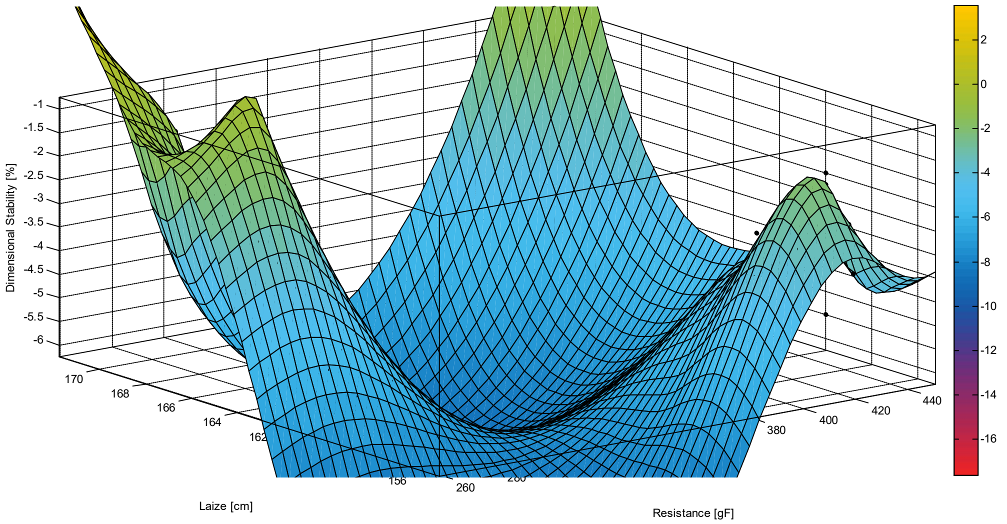

Fig. 4. Dimensional stability in weft depending on width and resistance

In this figure we notice that the fabric tends to shrink since the dimensional stability values are generally negative. Increasing the tensile strength of yarns has a considerable impact on the dimensional stability value.

Equation 3 illustrates the relationship between fabric strength and dimensional stability:

$$DS(x) = -3 + 0{,}26\sin(2{,}1x^2) + 0{,}72e^{-(0{,}8x)^2} \qquad (3)$$

x: represents the resistance in [gF]

DS(x) : dimensional stability in weft of the fabric [%]

Figure 5 illustrates the characteristic curve of this equation:

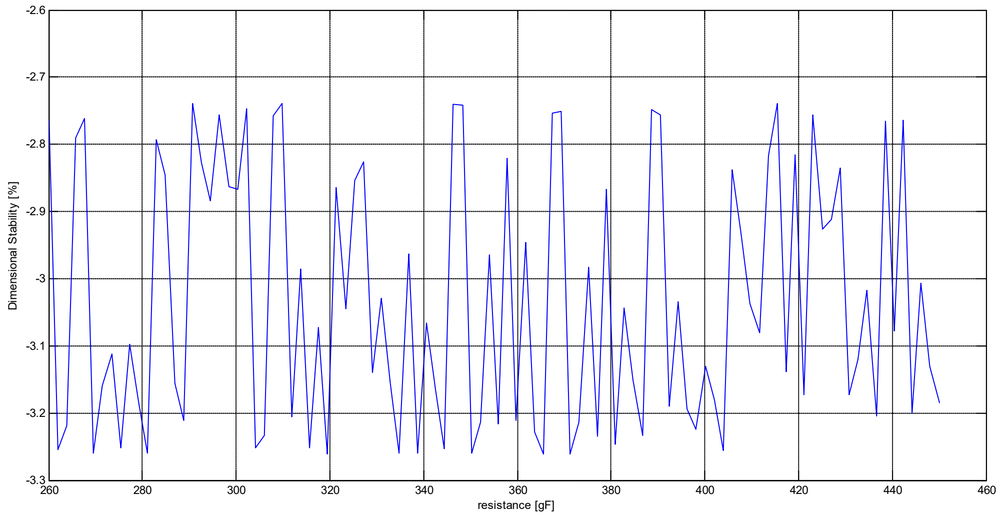

Fig. 5. Weft dimensional stability as a function of resistance

Equation (3) which illustrates the dimensional stability of the fabric as a function of the resistance of the yarns has the precision illustrated by the errors in which values are:

- Absolute error : $\Delta DS = 0{,}09\ [\%]$
- Relative error: $\frac{\Delta DS}{DS} = 3{,}37\%$

4.2. Relationship between yarn elongation and fabric dimensional stability

Yarn elongation represents the increase in yarn length which is caused by breaking strength. It is dimensioned in [%] because it is the ratio between the final length and the initial length.

4.2.1. Effect on warp dimensional stability

The relationship between the useful width of the fabric, the elongation of the yarn and the stability in the warp part of the fabric is shown in Figure 6:

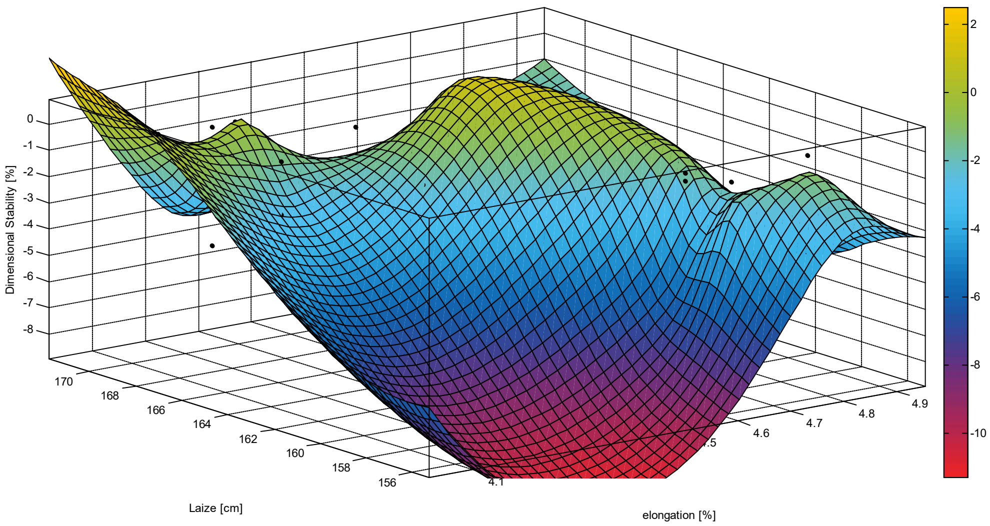

Fig. 6. Dimensional stability in chain depending on the width of the yarn elongation

We notice that the increase in the value of the elongation of the yarns does not influence the dimensional stability too much. Apart from a spike in the middle, the two extremes remain stable and the dimensional stability value oscillates around -3.

Equation 4 illustrates the relationship between yarn elongation and fabric dimensional stability:

$$DS(x) = -2{,}98 - 1{,}08\sin(1{,}33x^2) + 0{,}33e^{-(0{,}81x)^2} \quad (4)$$

x: represents the elongation in [%]

DS(x) : warp dimensional stability of the fabric [%]

The representative curve of equation 4 is given by Figure 7:

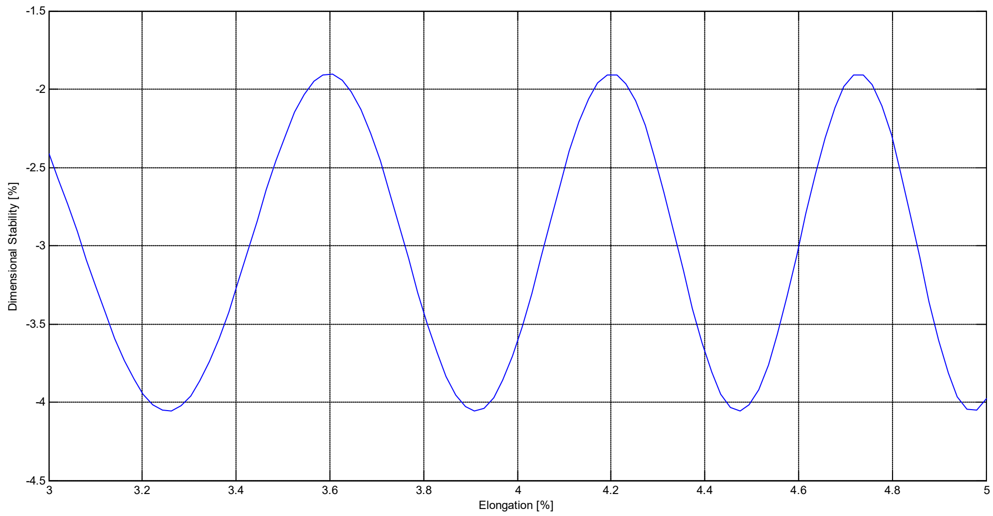

Fig. 7. Dimensional stability in chain depending on the elongation of the yarns

The relationship between the dimensional stability of the fabric and the elongation of the yarns represented in equation (4) has precision in which values are given by the errors, namely:

- Absolute error: $\Delta DS = 0,76\ [\%]$
- Relative error: $\frac{\Delta DS}{DS} = 27,8\%$

4.2.2. Effect on weft dimensional stability

Figure 8 reflects the relationship between the effective width of the fabric, the elongation of the yarn and the dimensional stability in the weft part of the fabric:

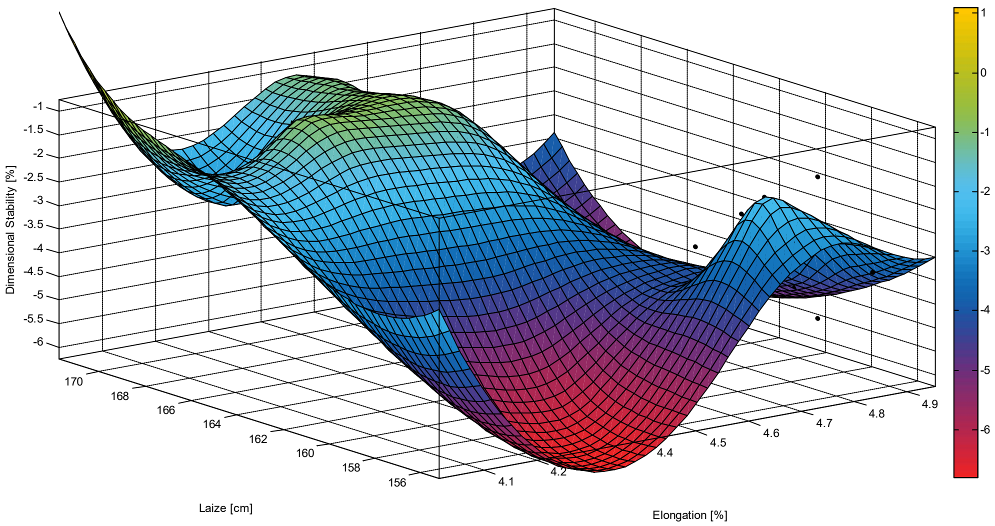

Fig. 8. Dimensional stability in weft depending on the width and elongation of the yarns

We notice a slight increase in the fabric shrinkage value compared to the increase in the yarn elongation value. Relationship 5 then gives us the impact of the elongation of the yarns on the dimensional stability of the fabric:

$$DS(x) = -3 - 0{,}05\sin(1{,}4x^2) + 0{,}17e^{-(0{,}71\ \ )^2} \quad (5)$$

x: represents the elongation in [%]

DS(x) : dimensional stability in weft of the fabric [%]

The curve which illustrates equation 5 is given by figure 9:

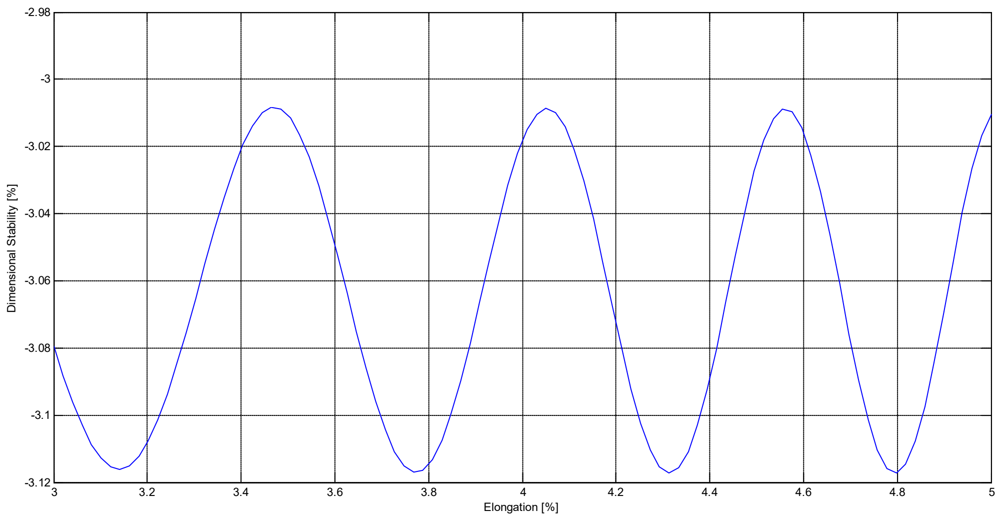

Fig. 9. Dimensional stability in weft depending on the elongation of the yarns

The precision of equation (5) which corresponds to the relationship between the dimensional stability of the fabric and the elongation of the yarns is given by the errors in which values are:

- Absolute error: $\Delta DS = 0{,}82\ [\%]$
- Relative error : $\frac{\Delta DS}{DS} = 27{,}3\%$

4.3. Relationship between the kilometric resistance of the yarns (RKM) and the dimensional stability of the fabric

In this section, the aim is to report, according to the experiments, the relationship between the RKM of the yarn and the dimensional stability of the fabric. Knowing that the kilometric resistance corresponds to the number of kilometers of yarn necessary to hang from a yarn so that it breaks under its own weight.

4.3.1. Influence of RKM on the dimensional stability of the fabric (warp side)

Figure 10 represents the relationship between the RKM and the dimensional stability on the warp part of the fabric:

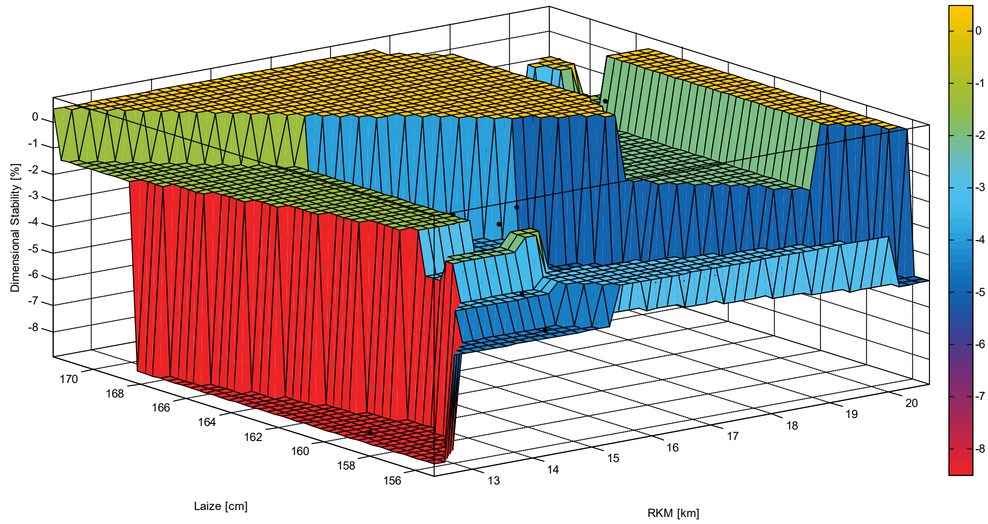

Fig. 10. Warp dimensional stability depending on the width and RKM of the yarns

So, we see in Figure 10 that the higher the kilometer resistance value, the more stable the fabrics. The relationship which illustrates the impact of RKM on the dimensional stability of the fabric is given by equation 6:

$$DS(x) = -2{,}61 + 0{,}02\sin(1{,}44x^2) + 0{,}49e^{-(0{,}65\ \ )^2} \quad (6)$$

x: represents the kilometric resistance [km]

DS(x) : warp dimensional stability of the fabric [%]

Figure 11 reflects the representative curve of equation 6:

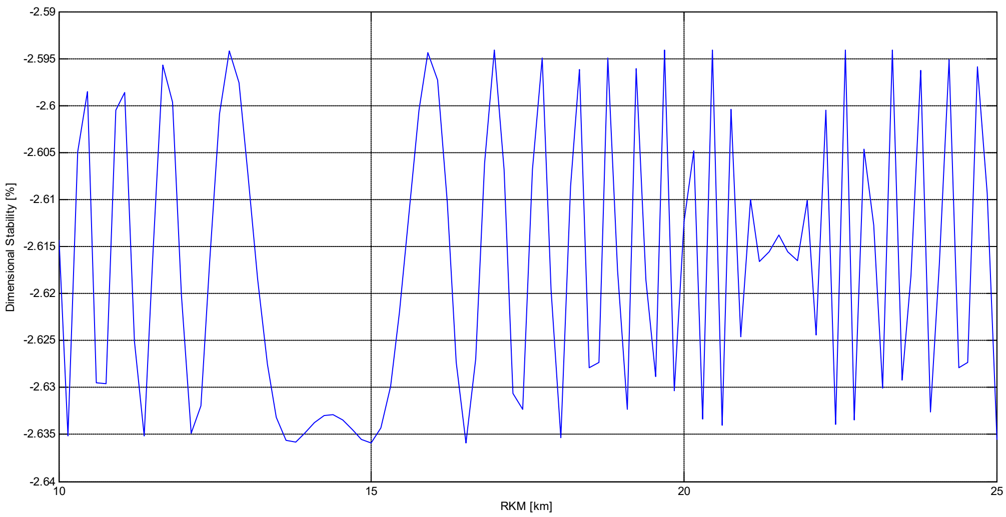

Fig. 11. Chain dimensional stability as a function of the RKM of the yarns

The respective absolute and relative errors linked to equation (6) are:

– Absolute error: $\Delta DS = 0{,}03\ [\%]$

– Relative error: $\frac{\Delta DS}{DS} = 1,1\%$

4.3.2. Effect on weft dimensional stability

On the weft part of the fabric, the dimensional stability as a function of the useful width of the fabric and the kilometric resistance of the yarns is illustrated in Figure 12:

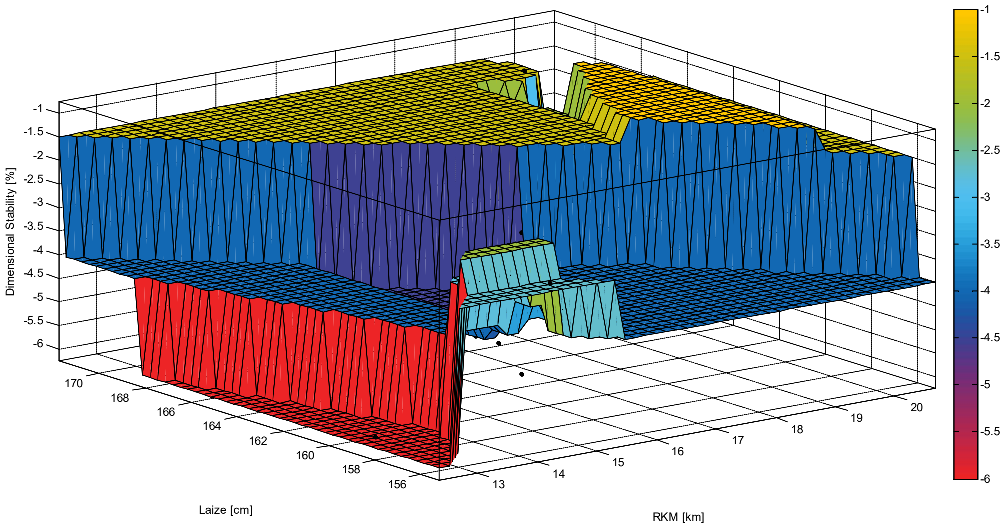

Fig. 12. Dimensional stability in weft depending on the width and RKM of the yarns

We see in Figure 12 the same behavior as on the chain side but less accentuated. Equation 7 reflects the relationship between the RKM of yarns and the dimensional stability of the weft side of the fabric:

$$DS(x) = -3,1 + 0,39\sin(1,97x^2) + 0,05e^{-(0,28x)^2} \quad (7)$$

x: represents the kilometric resistance [km]

DS(x) : dimensional stability in weft of the fabric [%]

The representative curve of equation 7 is given by figure 13:

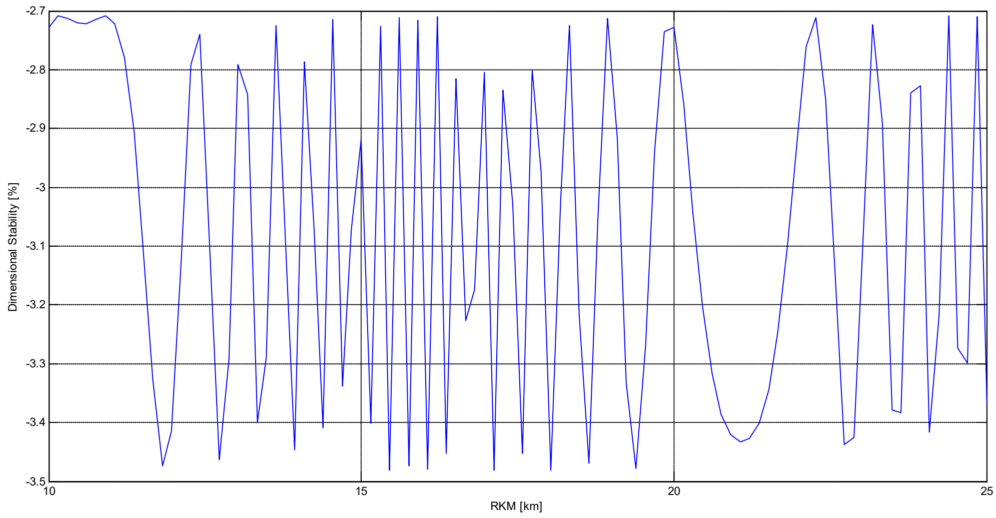

Fig. 13. Weft dimensional stability as a function of yarn RKM

The respective absolute and relative errors linked to equation (6) are:

- Absolute error: $\Delta DS = 0{,}23\ [\%]$
- Relative error : $\frac{\Delta DS}{DS} = 7{,}3\%$

4.4. Relationship between the actual metric number of the yarns (TITLE) and the dimensional stability of the fabric

This aspect reflects the relationship between the metric number, also known as the count of a yarn and the dimensional stability of the fabric. Knowing that the metric number corresponds to the length of one gram of yarn. During our experiment we considered the ratio on 100m of yarn.

4.4.1. Influence on the warp stability of the fabric

Figure 14 illustrates the relationship between the title, the useful width and the warp dimensional stability of the fabric:

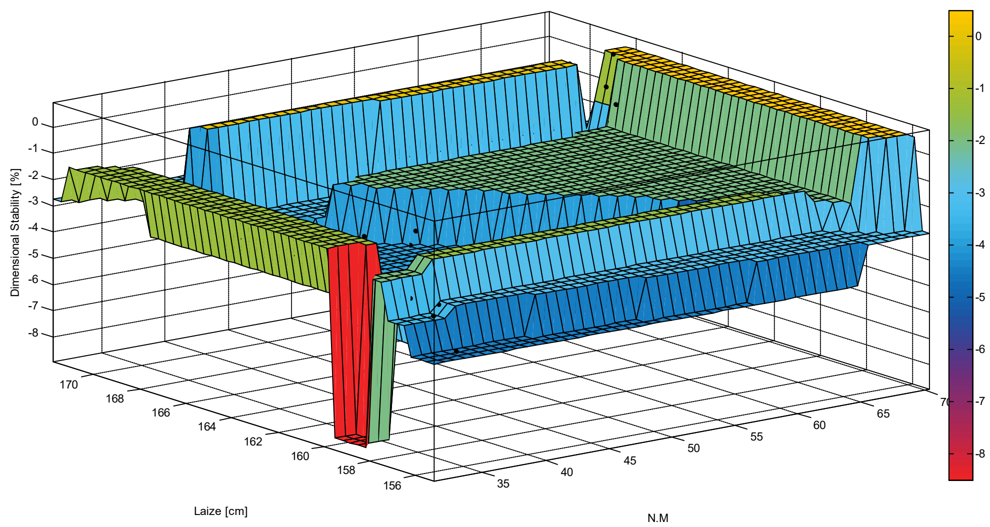

Fig. 14. Dimensional stability in warp depending on the width and the title of the yarns

It is noted that fabrics with low metric numbers are less stable than fabrics with high metric numbers. The equivalence relationship between the metric number and dimensional stability is given by equation 8:

$$DS(x) = -2{,}62 - 0{,}3\sin(x^2) + \frac{e^{-(0{,}53\ \ )^2}}{2} \qquad (8)$$

x: represents the actual metric number of the yarn [S.I]

DS(x) : warp dimensional stability of the fabric [%]

The representative curve of equation 8 is given by figure 15 :

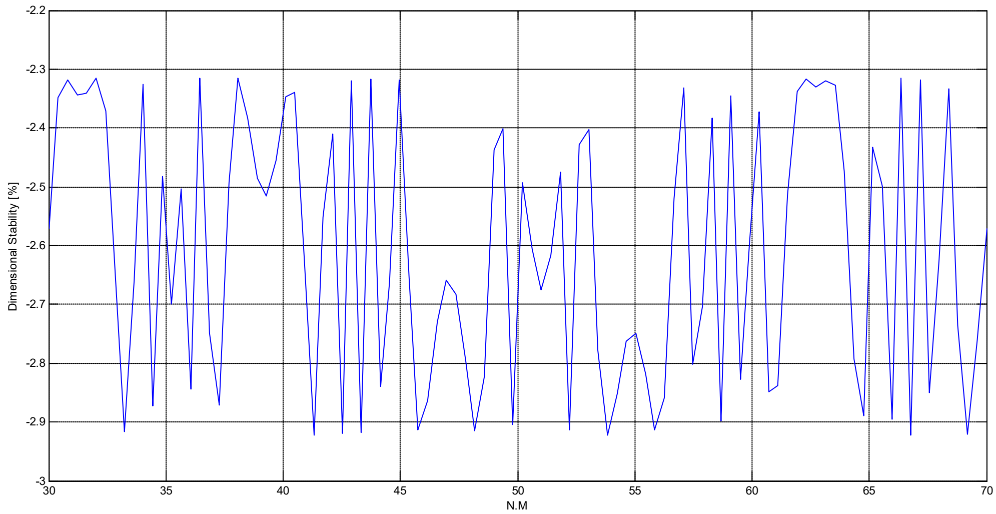

Fig. 15. Warp dimensional stability depending on the metric number of the yarns

The respective absolute and relative errors linked to equation (8) are:

– Absolute error: $\Delta DS = 0{,}29\ [\%]$

– Relative error: $\frac{\Delta DS}{DS} = 9{,}5\%$

4.4.2. Influence on the weft stability of the fabric

Figure 16 reflects the relationship between the title, the useful width and the weft dimensional stability of the fabric:

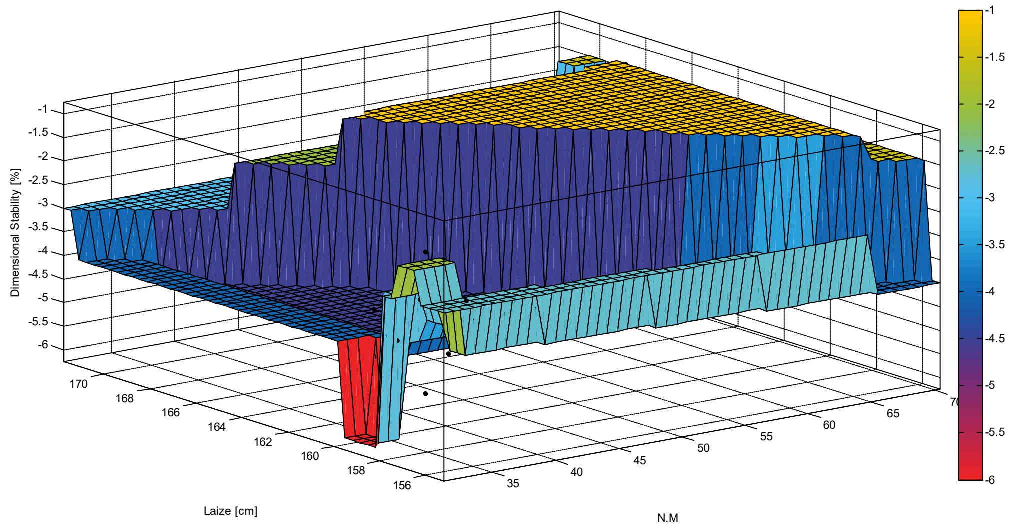

Fig. 16. Dimensional stability in weft depending on the width and yarn count

We notice in Figure 16 the same behavior as that of the chain side but less accentuated. Equation 9 reflects the relationship between the metric number of yarns and the dimensional stability of the weft side of the fabric:

$$DS(x) = -3{,}05 - 0{,}68\sin(1{,}9x^2) + 0{,}56e^{-(0{,}67x)^2} \quad (9)$$

x: represents the actual metric number of the yarn [S.I]

DS(x) : dimensional stability in weft of the fabric [%]

SO, Figure 17 shows the representative curve of equation 9:

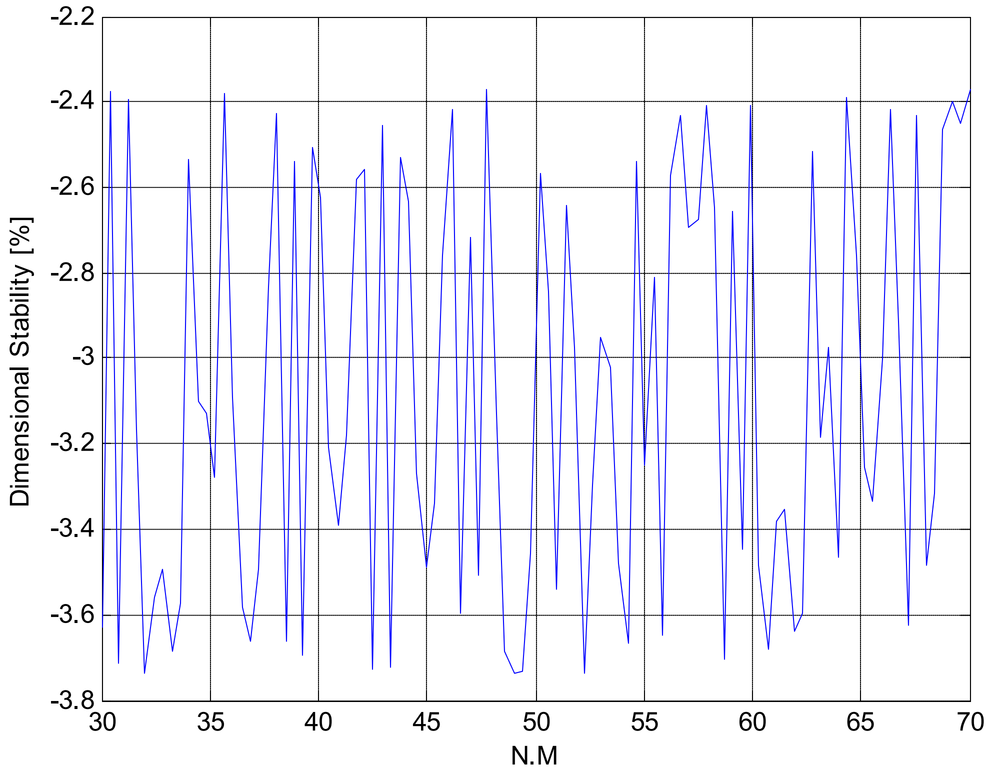

Fig. 17. Weft dimensional stability depending on the metric number of the yarns

Equation (9) which illustrates the dimensional stability of the fabric as a function of the metric number of the yarns has the precision illustrated by the errors in which values are:

- Absolute error: $\Delta DS = 0{,}32\ [\%]$
- Relative error : $\frac{\Delta DS}{DS} = 9{,}82\%$

4.5. Influence of the hairiness index of the yarns on the dimensional stability of the fabric

In this paragraph, the aim is to dissect the relationship between the hairiness index of the yarn and the dimensional stability of the fabric. Knowing that the hairiness index corresponds to the total length of fibers released from 1 cm of yarn.

4.5.1. Influence on the stability of the warp fabric

Figure 18 represents the relationship between the warp dimensional stability of the fabric with the hairiness index of the yarn and the useful width of the fabric:

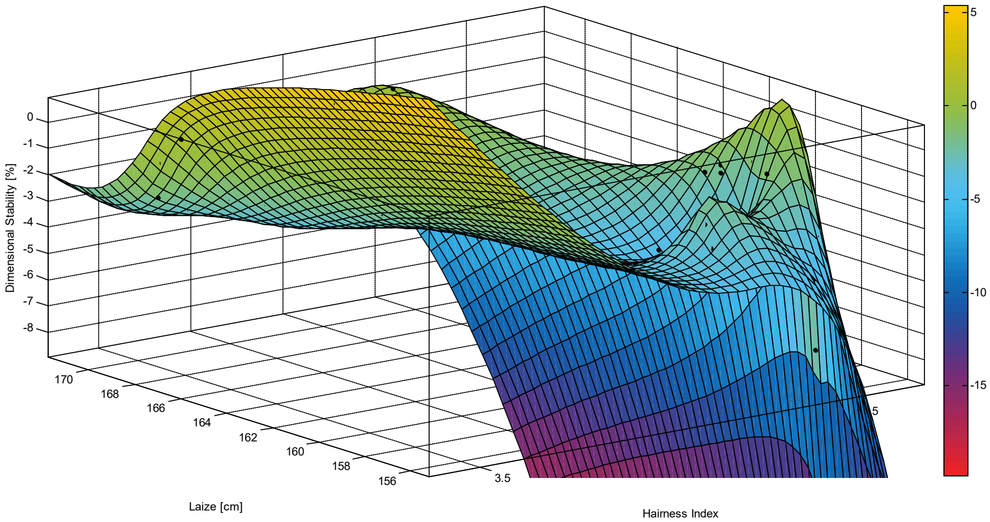

Fig. 18. Warp dimensional stability depending on the width and hairiness index of the yarns

Based on Figure 18 we see that the higher the hair index, the less stable the fabric. Equation 10 reflects the relationship between dimensional stability and hairiness index of a yarn for the warp side of the fabric:

$$DS(x) = -2{,}6 + 0{,}47\sin(0{,}74x^2) + 0{,}69e^{-(0{,}36x)^2} \qquad (10)$$

x: represents the hairiness index of the yarn [S.I]

DS(x) : warp dimensional stability of the fabric [%]

Figure 19 reflects the representative curve of equation 10:

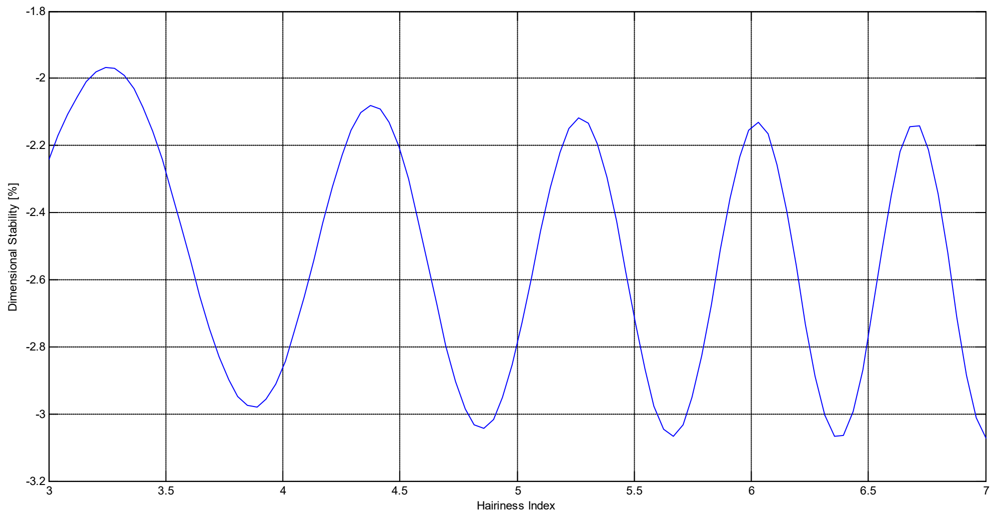

Fig. 19. Chain dimensional stability depending on the hairiness index of the yarns

The respective absolute and relative errors linked to equation (10) are:

- Absolute error: $\Delta DS = 0{,}16$ [%]

– Relative error : $\frac{\Delta DS}{DS} = 6{,}65\%$

4.5.2. Influence on the stability of the weft fabric

Figure 20 represents the relationship between the dimensional stability in weft of the fabric and the hairiness index of the yarn as well as the useful width of the fabric:

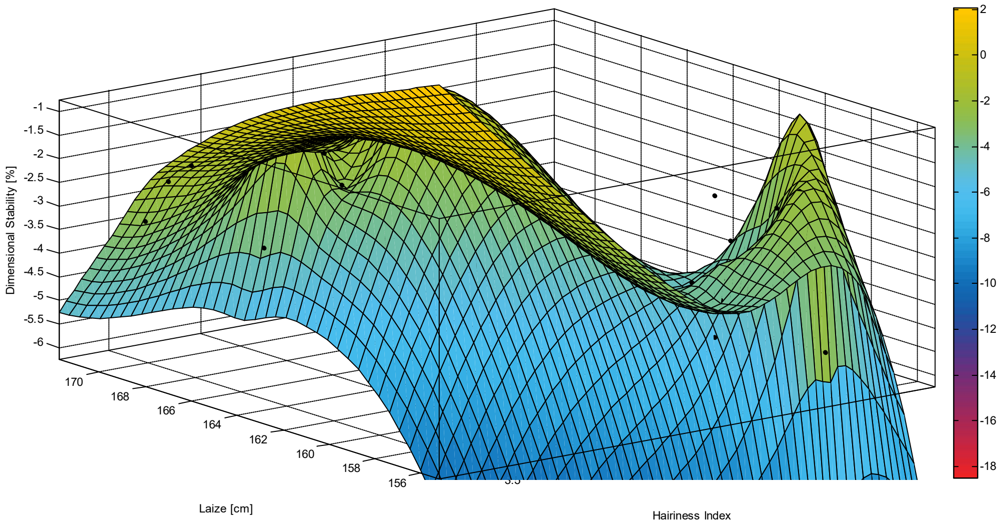

Fig. 20. Dimensional stability in weft depending on the width and hairiness index of the yarns

We notice in Figure 20 the same behavior as that of the chain side, although module is less important. Equation 11 reflects the relationship between the hairiness index of the yarns and the dimensional stability of the weft side of the fabric:

$$DS(x) = -3{,}03 + 0{,}44\sin(2{,}85x^2) + 0{,}14e^{-(0{,}42x)^2} \quad (11)$$

x: represents the hairiness index of the yarn [S.I]

DS(x) : dimensional stability in weft of the fabric [%]

Figure 21 gives the representative curve of equation 11:

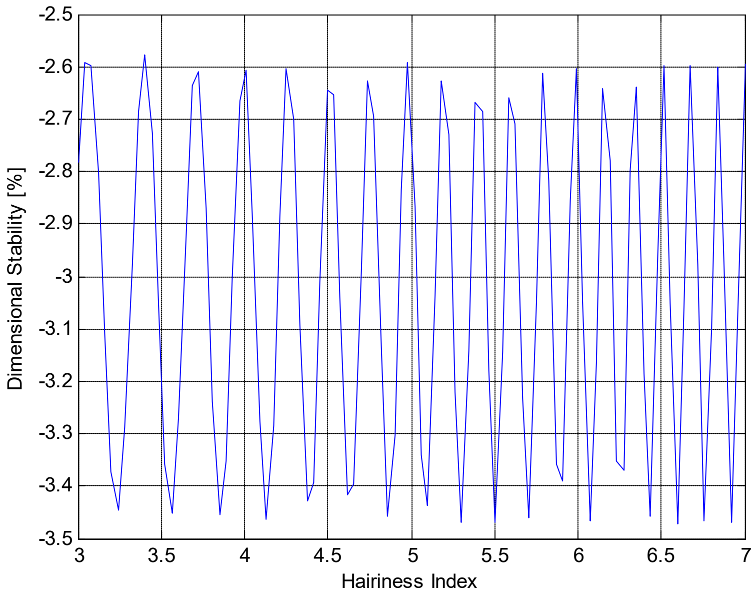

Fig. 21. Dimensional stability in weft depending on the hairiness index of the yarns

Equation (11) which illustrates the dimensional stability of the fabric as a function of the hairiness index of the yarns has the precision illustrated by the errors in which values are:

- Absolute error : $\Delta DS = 0{,}15\ [\%]$
- Relative error : $\frac{\Delta DS}{DS} = 5{,}24\%$

V. Conclusion and perspectives

This article demonstrates the relationships that can exist between the dimensional stability of the fabric and the yarn parameters such as resistance, hair index, real metric number and kilometric resistance of the yarns. To do this, the constituent yarns of the fabrics are analyzed according to the rules of the art then after making the fabrics we measured the dimensional stability in the direction of warp and weft of the fabric.

In each paragraph, models illustrating the relationship of dimensional stability with the technical parameters of the yarns are given with their precision which are represented by the absolute and relative errors.

As a perspective, it would be interesting to understand the phenomena of the initiated tear and also to see the cause and effect relationship with the parameters of the constituent yarns of the fabric.

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